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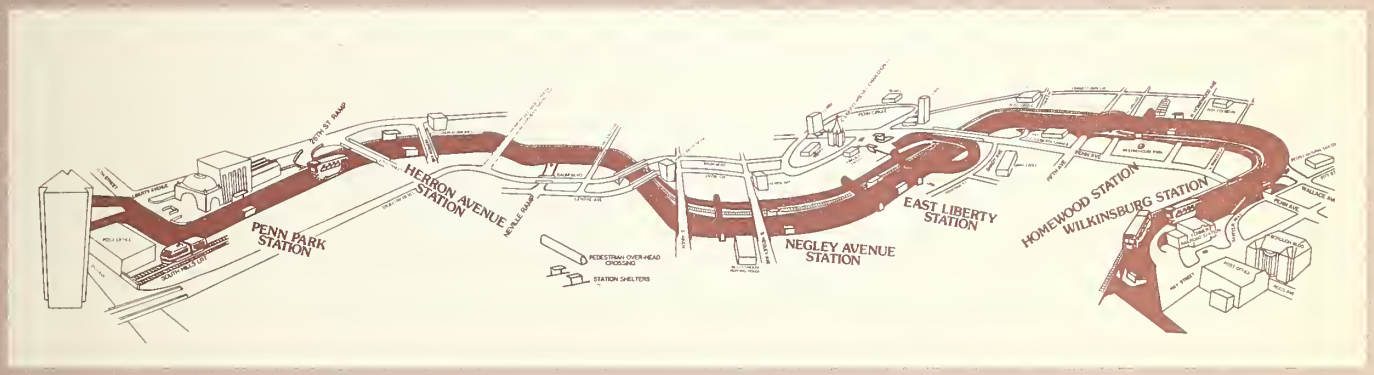
Administration

The Martin Luther King, Jr. East Busway in Pittsburgh, PA

UMTA/TSC Evaluation Series

Final Report
October 1987



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16. Abstract

The Port Authority of Allegheny County (PAT), the primary public transit operator in Pittsburgh, PA, built an exclusive roadway for buses which opened for service in February 1983. The two-lane, 6.8-mile facility serves the eastern suburbs via a right-of-way shared with Conrail tracks. The busway includes six stations and seven bus ramps. New routes which provide frequent service catering to walk-ons and transfers at the stations have proved popular. These routes, and pre-existing express service which has been rerouted to take advantage of the busway, offer significant travel time savings compared to conditions before the busway. The busway was as expensive to build as a light rail line built in an alignment requiring similar (cut and fill) construction techniques. Operating costs on the busway are less than for comparable light rail service. The report includes documentation of planning and implementation, operations, safety and reliability, ridership, and community impacts.

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PREFACE

This report was prepared by Crain and Associates, Inc., under contract to the Transportation Systems Center (TSC) of the U.S. Department of Transportation, under sponsorship of the Service and Methods Demonstration (SMD) Program of the Urban Mass Transportation Administration. The TSC project evaluation manager was Robert Casey. The UMTA program manager was Joseph Goodman.

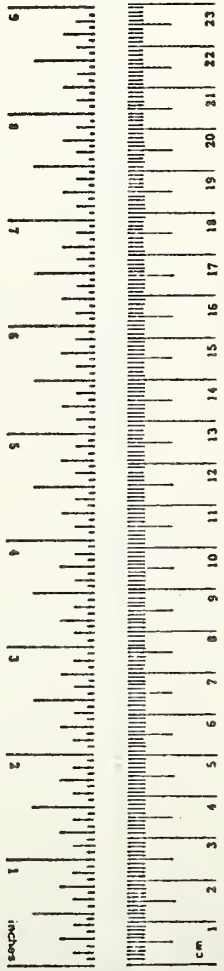
The Port Authority of Allegheny County (PAT) provided most of the data needed for the report. Peter Menniti, Transit Planner and PAT's manager for the project, and Cathy Williams and Laurie Anderson, associate transit planners at PAT, were especially helpful in providing information. Other PAT staff members who were also very helpful include Norman Voigt, engineer, and Henry Cusack.

The report was written at Crain & Associates, Inc., by Susan Pultz, under the direction of David Koffman. Section 5.1, Ridership Increases, was prepared by David Koffman and George Rhyner. Computer programming was done by Charles Cutten. The report was typed by Tracy Cox and Pam Holtz.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hecteres (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

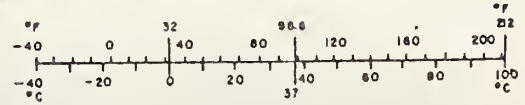


TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF ILLUSTRATIONS

LIST OF TABLES

EXECUTIVE SUMMARY

INTRODUCTION

The Martin Luther King, Jr. East Busway is a 6.8-mile, grade-separated facility running between downtown Pittsburgh, PA, and the eastern suburb of Wilkinsburg. The Port Authority of Allegheny County (PAT), which provides transit service in the Pittsburgh metropolitan area, was awarded a Service and Methods Demonstration (SMD) grant in the amount of $120,000 to evaluate the busway.

The East Busway is different from most other busways in that it shares the Conrail railroad right-of-way rather than a highway right-of-way. Busway service began in February 1983 and is provided by five new routes and 21 suburban routes, mostly expresses, which were diverted to the busway for the last part of their trips to the downtown. One of the new routes, the EBA, (East Busway All-stops) operates only from the suburban end of the busway to downtown, boarding passengers at six busway stations, plus a downtown circulator loop.

Busways are seen as a method of improving bus service and as a potential alternative to light rail facilities. This evaluation examines: 1) the suburban routes which were diverted to the busway, before and after these routes began using the busway, thereby comparing busway service with regular bus route service; 2) the new route service which is largely restricted to operation on the busway and therefore imitates the operation of a rail facility; and 3) the cost-effectiveness of busway service compared to light rail service.

PLANNING AND IMPLEMENTATION

The plan for a busway in the east corridor grew out of concern about increasing commuter congestion on the Penn Lincoln Parkway. Studies conducted during the 1960's concluded that a busway which shared the Conrail Railroad right-of-way would be

feasible and provide the desired transit improvement. As a result of negotiations with Conrail, PAT agreed to build the busway in such a way that the railroad service could continue during construction and to upgrade the train signaling and communication systems. Some elements of the busway design were determined by citizen's groups representing east corridor residents; citizen vote decided the configurations of the East Libery Station, Oakland off-ramp, and Wilkinsburg interchange. The major marketing effort for the busway was free service offered the weekend prior to the opening. The busway opening met with very high ridership, so that headways on the EBA route had to be shortened immediately.

OPERATIONS

Approximately 90 buses per peak period use the busway in the peak direction. Speeds on the busway are about 34 m.p.h. during the a.m. peak in-bound and 31 m.p.h. during the p.m. peak outbound. Buses using the busway appear to break down less than they did before the busway. While about 30 percent fewer accidents of all types have occurred on diverted routes after they began using the busway, this result is not statistically significant. Almost all busway drivers state that driving on the busway is easier than parkway or local street driving under all kinds of road and weather conditions.

LEVEL OF SERVICE

Both new and diverted route passengers have decreased their travel times after they began using busway routes. On diverted routes, during the a.m. peak, travel time has decreased by an average of eight minutes mainly because of decreases in line-haul, in-vehicle time. During the p.m. peak, average time savings of about 3.5 minutes have occurred because of decreases in downtown in-vehicle and walk time. Passengers on the EBA, the major new route, have reduced their travel times by about 21 to 24 minutes, a reduction of 40 to 45 percent. The time savings

are due mainly to decreases in in-vehicle travel time, though savings in wait time and bus stop access time were estimated, as well. On trips involving a transfer to the EBA route, passengers have reduced their travel time by 15 to 23 percent. An on-board survey showed that both new and diverted route passengers perceive large travel time savings since they began using the busway. They also perceive that transferring has gotten easier. Diverted route service reliability improved after using the busway, based on an analysis of line-haul travel times on these routes. Most new route passengers and a moderate percentage of diverted route passengers perceive that service reliability and chances of getting a seat have improved.

RIDERSHIP

The new routes operating on the busway, primarily the EBA, have attracted an average weekday patronage (including transfers) of about 13,000, or about 11 percent of total east corridor ridership. The routes diverted to use the busway, mostly suburban expresses, carry about 7,000 average weekday riders, or about 6 percent of total east corridor ridership. Much of this patronage consists of people who formerly used the same or other routes (79 percent of new route riders and 83 percent of diverted route riders). However, 11 percent of new route riders and 7 percent of diverted route riders used to travel by car.

The introduction of the Busway increased total east corridor ridership by 800 to 1,900 riders per average weekday, or by one to two percent, based on two different estimation methods, compared to levels expected without the Busway. The increase contrasts with generally declining ridership in the corridor, and follows a major fare increase, so that actual ridership levels have remained nearly flat over the period studied. The riders attracted by the new routes are similar in most respects to riders of other, nonbusway routes.

The busway experience shows that routes operating on a busway, in a manner similar to a light rail line, can attract

high levels of patronage. The success of the EBA (and a similar route, called the EBO, for "East Busway Oakland") may be highly dependent on the development patterns around the busway stations and the existence of good transfer opportunities from local routes. At least in Pittsburgh, it has not been necessary to provide major new parking facilities, although that result may be due to the extensive existing parking opportunities near the Wilkinsburg terminal.

For all route types, most passengers report walking to the bus stop. However, higher percentages of new route passengers transfer and higher percentages of diverted route passengers park and ride or are dropped off than passengers on other routes in the PAT system. Parking space occupancy rates are about the same in the vicinity of all busway stations. They are high, 60 to 74 percent, but still well below capacity at both the a.m. peak and midday. Most diverted route passengers park in free lots. While most new route passengers park on the street, a high percentage also park in pay lots. More than passengers of the other route types, new route passengers reported using parking areas a few blocks away from their bus stops.

Many passengers on new and diverted routes report starting their trips later than they used to before the busway. On average, new route passengers leave for their trips 9.5 minutes later and diverted route passengers leave 2.8 minutes later.

COST ANALYSIS

Busway capital costs totalled $156 million in 1983 dollars. About 58 percent of this cost was for busway construction contracts, another 16 percent was for purchasing land, and about 14 percent was for relocating the Conrail track. The remaining 12 percent was for engineering services, PAT planning and administration, and utility relocation. Weekday operating costs are lower for new routes than for diverted routes and all other routes per passenger trip and per passenger mile. Operating costs per seat mile are estimated to be about the same for

busway routes and other routes. New busway route operating costs per service unit are lower than those for light rail systems for selected service unit measures. Busway capital costs per facility mile are similar to those for light rail systems with cut and fill construction, that is techniques similar to those required for the busway.

COMMUNITY IMPACTS

Local officials feel that parking has gotten slightly tighter near Negley and Wilkinsburg Stations as a result of the busway, but parking impacts are imperceptible at the other stations. Peak hour traffic volumes are low near Wilkinsburg station, but cause congestion near East Libery probably in part because of busway commuter traffic. Some officials feel that some new commercial and high rise residential development took place near Wilkinsburg and East Liberty Stations because of the busway. Others feel that developers have expressed a lot of interest, but that development has not yet taken place.

CONCLUSIONS AND TRANSFERABILITY

- The planning and design process for the East Busway was more involved than would be expected for other busways because of the complication of construction in the Conrail right-of-way.

- The line-haul, busway speeds for express routes average 34 m.p.h. in the a.m. peak and 31 m.p.h. in the p.m. peak.

- The EBA route operates much like a light rail or other fixed guideway service. The diverted routes, however, combine the service flexibility of regular bus routes with the efficiency of fixed guideway service and eliminate the need for a transfer.

- Vehicle speeds have increased due to the busway. Passenger travel time has decreased for this reason and because of changes in routing that accompanied the busway. Changes due to rerouting are not necessarily transferrable to other sites.

- Buses operating on the busway may have fewer accidents and break down less often than other buses although the evidence is statistically inconclusive. In addition, drivers surveyed report that busway driving is easier and safer under all road and weather conditions than driving on local streets and highways.

- According to point check measurements and passenger perceptions, the busway has improved service reliability.

- Busway routes operated in a manner similar to light rail have attracted high levels of patronage. This result may depend on the presence of substantial retail and residential development near some busway stations. However, few new transit uses were attracted by the busway.

- For the new routes (primarily the EBA), costs per passenger trip and per passenger mile, but not per vehicle mile, are lower than for other PAT bus routes. All unit operating costs examined were lower than for selected light rail systems. For suburban routes diverted to the busway, costs per vehicle mile are lower than for other PAT bus routes, but costs per passenger trip and passenger mile are higher.

- Capital costs per facility mile ($21.6 million) are similar to those of light rail systems with a cut and fill construction, similar to that needed for the busway right of way ($22.8 million).

- The busway has been a factor in attracting developers' interest in neighborhoods near busway stations.

1. INTRODUCTION

1.1 BACKGROUND

The Martin Luther King, Jr., East Busway is a 6.8-mile, grade-separated, exclusive bus facility running between downtown Pittsburgh and the eastern suburb of Wilkinsburg. The busway began operation in February 1983. The Port Authority of Allegheny County (PAT), which provides transit service in the Pittsburgh metropolitan area and operates the busway, was awarded a Service and Methods Demonstration (SMD) grant in the amount of $120,000 to evaluate the busway, of which $100,000 was budgeted for data collection.

1.2 BUSWAY DESCRIPTION

The East Busway is different from most other busways in several respects. Unlike other busways, it was not built next to a highway--it shares the Conrail right-of-way for its full length. Because it does not share an automobile facility right-of-way, buses using the busway have routes very different from their old ones. Also, the volume of service planned for the East Busway is much greater than for other busway facilities. The amount of busway-only service, catering to walk-ons at stations, is also an innovative feature of the East Busway.

The most comparable existing facilities are the Shirley Highway reversible lanes in the Virginia suburbs of Washington, D.C. and the El Monte Busway, running to the east of downtown Los Angeles. Both of these busways have been the subject of extensive evaluation studies.

The East Busway has one lane in each direction and pullouts at six stations. Buses can enter and leave the facility at six locations, including the two ends. Busway service is provided by five new routes and a number of pre-existing suburban routes, mostly expresses, which have been rerouted to the busway for the last part of their trips to the downtown. The major new route is

the East Busway All-stops (EBA), which operates on three-minute headways at peak, runs the length of the busway, plus a downtown loop, and serves patrons who either start their trip at a busway station or transfer to the busway from another route. The EBO (East Busway Oakland) is a similar new route, but it exits the busway early in order to run through the Oakland area, which includes two major universities, before terminating at Duquesne University, just short of the Pittsburgh CBD. Other new routes are the 73B between Highland Park and downtown, 78C between Shadyside and downtown, and 88A between Wilkinsburg and downtown. Figure 1-1 provides an overview of the busway and the routes that use it.

The busway began operation on February 21, 1983. Service offered by the new routes and the suburban express routes (diverted routes) has changed considerably since then. EBA's scheduled peak headways were six minutes initially, were soon adjusted to four minutes, and then to three minutes to accommodate the surge of demand for service. The surburban routes were diverted to the busway in stages. Some routes switched in February 1983, and others changed over in April, June, and November 1983, and in February 1984.

1.3 ISSUES AND APPROACH

Busways, as well as reserved lanes on highways, are seen as a method of improving bus service and as a potential alternative to light rail facilities. This evaluation compares the East Busway service with other bus services operated by PAT, compares the busway's cost effectiveness with several light rail systems, and provides information on busway service that can be used in evaluating a busway's potential in other locations.

Comparisons between busway service and other bus route service are made by comparing the new busway routes and the suburban routes which were diverted to the busway, with other routes in PAT's system that were selected as controls. The examination of suburban diverted route service, before and after

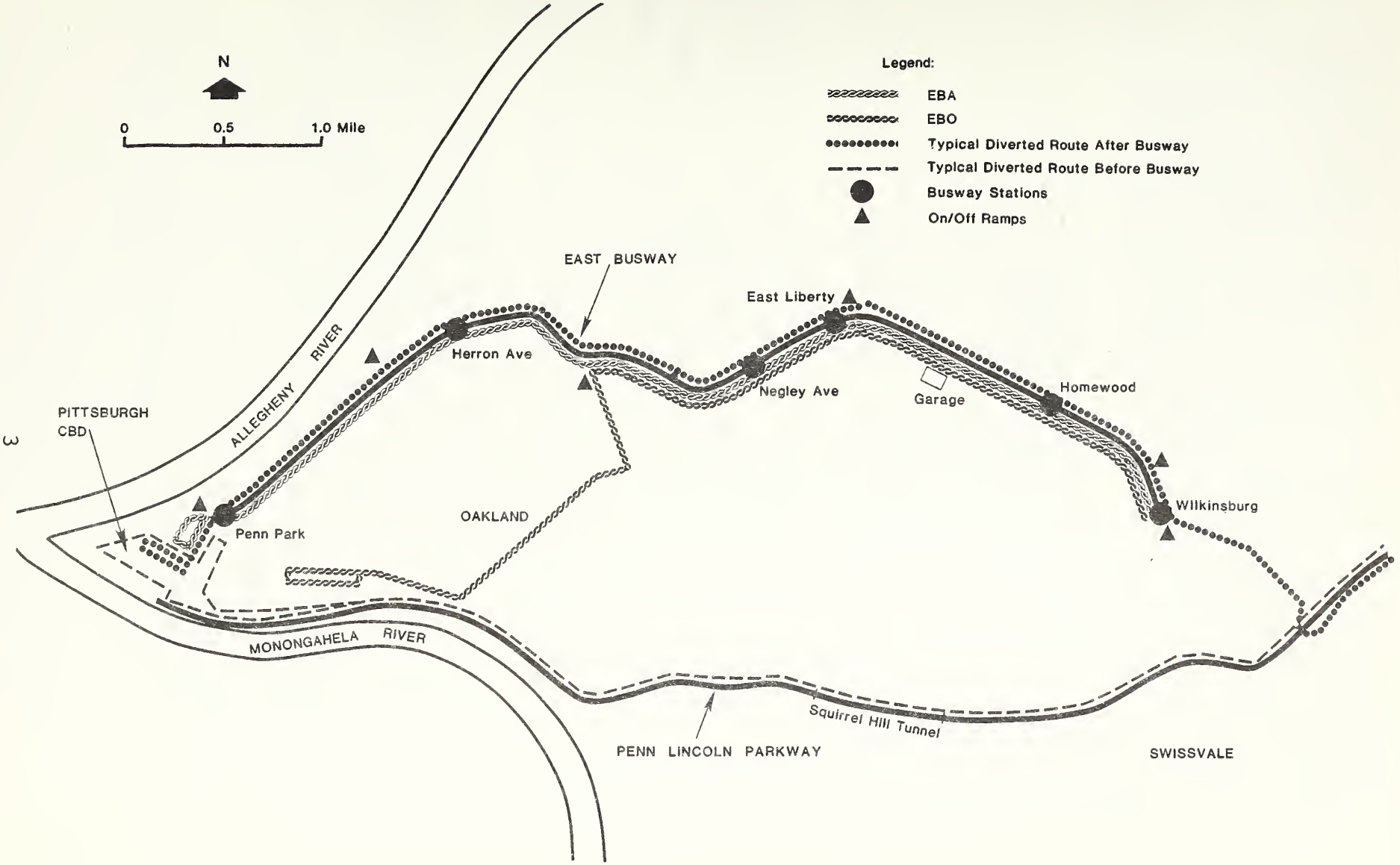


FIGURE 1-1. OVERVIEW OF BUSWAY LOCATION AND ROUTES

these routes began using the busway, also provides information on the busway's effect and on how busway routes compare with others.

PAT conducted several data collections in support of the evaluation, including end-point checks, ride checks, station checks, surveys of passengers and drivers, and a parking survey. PAT also provided extensive records of operations and ridership and an earlier on-board survey. The data collections are described in Appendix B.

Chapter II, Planning and Implementation, is a narrative of the planning, design, and construction process which relies mainly on interviews with PAT officials. Chapter III, Operations, is a detailed documentation of the amount and type of service offered. It is based primarily on information from schedules, route maps, point check data, driver survey results, accident records, and road service call records. Chapter IV, Level of Service, documents the travel time, service reliability, and chances of getting a seat on diverted routes before and after these routes began using the busway. Comparisons of travel times of new route passengers are also included. The data for this section comes mainly from point checks, station checks, and the on-board survey. Chapter V, Ridership, describes passenger attitudes and characteristics and the busway parking situation. The on-board survey was the main data source. This chapter also presents models that were used to explain the busway's effect on ridership in the East Corridor. Chapter VI, Cost Analysis, relies on PAT financial records to determine the capital costs of the busway facility and busway route operating costs. It also compares busway route costs per service unit with those of regular routes and light rail systems. Chapter VII, Community Impacts, based mainly on interviews with local officials, describes the busway's impacts on traffic, parking, and new development near busway stations.

1.4 SETTING

The Pittsburgh SMSA is the thirteenth largest in the United States with a 1980 population of 2,264,000. To help the reader put the Pittsburgh statistics into context, Table 1-1 gives population data for Pittsburgh and four other SMSA's of similar size: Boston, Atlanta, Newark, and St. Louis.

TABLE 1-1. POPULATION FIGURES FOR PITTSBURGH AND FOUR OTHER SMSAs

City	1980 Population	Percentage Change 1970-80	Density of City Proper
Pittsburgh	2,264,000	- 5.7%	7,700/sq. mi.
Atlanta	2,030,000	+16.0%	3,246
Newark	1,966,000	- 4.4%	14,027
St. Louis	2,356,000	- 2.3%	7,401
Boston	2,763,000	- 4.7%	12,335

Source: 1982-83 Statistical Abstract of the United States

Pittsburgh is located in western Pennsylvania, about 35 miles from the Ohio border, where the Allegheny and Monongahela rivers join to form the Ohio. Downtown Pittsburgh is built on the point of land formed by the confluence, so that it is separated from the remainder of the city by water on two sides. The terrain is very hilly.

The climate in Pittsburgh is classified as "humid continental," with cold winters, hot summers, and precipitation distributed throughout the year. Between December and February, the temperature does not rise above freezing one day out of

three; there are 10 days when an inch or more of snow falls, and total snowfall averages about 31 inches.

Water barriers, hills, and cold, snowy winters combine to create difficulties for all forms of travel in Pittsburgh. The road network is very irregular and not always in good repair. Icy conditions often make it impossible to negotiate some hills. Of the 80-100 bridges used by the bus system, it is not unusual for one or more to be closed, at least to heavy vehicles such as buses, and sometimes to all traffic.

Transit service is provided by the Port Authority of Allegheny County (PAT), which began consolidating 33 companies in 1964 and now operates in Allegheny County, including the City of Pittsburgh, and portions of the adjacent counties of Washington, Westmoreland, Armstrong, and Beaver. As of 1985, PAT operates an active fleet of about 950 buses and trolleys driven by 1600 operators, out of six divisions.

Since PAT's creation in 1964, annual total ridership has been fairly constant, staying within 10 percent of 100 million passengers. In 1981, average weekday ridership was 335,000, Saturday ridership averaged 188,000, and Sunday and holiday ridership 85,000. In the last few years ridership has been declining from a record high of 110 million passengers carried in 1979. High unemployment and a fare increase produced further decline in 1983.

PAT operates one commuter rail line, the PATrain, between Pittsburgh and Versailles, and two inclines. PAT also sponsors ACCESS, an advance reservation, door-to-door, shared-ride transportation system for the elderly and handicapped in Allegheny County, using service provided by private taxi companies and nonprofit private agencies.

1.5 ORGANIZATIONAL ROLES

UMTA Office of Service and Methods Demonstrations (SMD). Defined overall project goals, funded demonstration grant to PAT, sponsored evaluation by TSC.

Transportation System Center (TSC). Responsible for project evaluation under SMD sponsorship. Contracted with Crain & Associates, Inc., to carry out the Pittsburgh evaluation. Defines evaluation scope, issues, and general methodology. Reviews and publishes evaluation reports.

Port Authority of Allegheny County (PAT). The transit operator for the Pittsburgh area that built and operates the busway. Applied for and received SMD grant to evaluate the busway. Carried out data collections for the evaluation.

Crain & Associates, Inc. Under contract to TSC, designed and carried out an evaluation of the busway. Monitored developments; specified, designed, and analyzed data collections; prepared final evaluation report.

2. PLANNING AND IMPLEMENTATION

This section describes how the idea to construct a busway came about. It presents information gathered from interviews with PAT staff about the implementation of the busway project's planning, design, and construction phases.

2.1 PRELIMINARY PLANNING

During the 1950's, Pittsburgh's eastern corridor became highly congested. The major bottleneck was the Penn Lincoln Parkway tunnel, where during commute hours, traffic backed up for several miles. City streets parallel to the tunnel did not have sufficient capacity to alleviate the congestion. Consequently, commuters faced sizable delays daily, on the order of 15 to 20 minutes.

Concern about congestion in the eastern corridor grew still greater in the early 1960's when the Pennsylvania Highways Department developed plans to rebuild and repair the parkway. This construction project was expected to disrupt traffic severely for several years and cause even greater delays for commuters.

At about the same time, Pittsburgh's transportation officials decided to conduct a comprehensive analysis of travel patterns in the metropolitan area. This analysis was to help identify transportation system improvements that would be needed to accommodate travel in the foreseeable future. Officials were especially interested in determining what improvements should be made to the city's public transportation services, which had just been taken over by the Port Authority of Allegheny County (PAT).

It became apparent that a detailed study of Pittsburgh's transit needs was in order. An ad hoc committee, composed of PAT, Pittsburgh City Planning, Southwestern Pennsylvania Regional Planning Commission, Allegheny County Planning Commission, and Carnegie Mellon University officials was formed to conduct the

studies. PAT and the state highway department conducted the engineering studies. As a result of the studies, PAT developed a multiphased program to both modernize the current transit system and to add new facilities. This program, known as the Early Action Program, included plans for an 8-mile busway in eastern Pittsburgh to extend from the downtown along the Pennsylvania Central Railroad right-of-way to the Lincoln Parkway. This busway would bypass the Lincoln Parkway and its Squirrel Hill Tunnel bottleneck.

The idea of a busway came about because an all-transit facility was wanted, but concensus could not be reached as to the best type of transit system for that corridor; heavy rail, Skybus, and light rail systems were all considered. Decision-makers finally selected a busway as an interim solution which would provide high capacity mass transit to the eastern corridor. By constructing a busway, PAT could begin operating mass transit vehicles through the corridor, while preserving the right-of-way for a fixed-rail system that could be built at a later date. With a busway, PAT would have the advantage of being able to reroute buses from their conventional routes onto the busway.

Busway plans included use of the Penn Central Railroad right-of-way because the railroad had decided to abandon it, and it could be acquired at a low cost. The Penn Central Railroad went bankrupt, however, before PAT could acquire the property. After the bankruptcy, the federal government took over Penn Central and other northeastern railways and created Conrail, so Penn Central's plans to abandon the right-of-way were no longer valid. Because Conrail then chose not to abandon the railway, the original busway design was no longer feasible.

Faced with this problem, in February 1975, PAT directed its consulting engineer to determine whether or not a joint rail and bus system would be feasible. The study concluded that it would be feasible if a 5-mile section of the railway were redesigned. The busway could fit into the space that was then occupied by two tracks, leaving two other tracks for the railway.

In January 1977, PAT opened the South Busway, a 4-mile facility that occupied property originally purchased for the Skybus (an automated system which was stopped by public opposition in the planning stage). Because this busway was so successful at reducing congestion, interest in the East Busway remained high.

2.2 NEGOTIATIONS WITH CONRAIL TO ACQUIRE RIGHT-OF-WAY

In 1975, PAT began negotiating with Conrail to acquire shared use of the right-of-way. Conrail had purchased four tracks and was only using two of them. Appraising the value of the track bed, bridges, and structures was difficult because the use of "comparable values" was not possible--generally, no two segments of heavy mainline track are alike (because of the requirements of building on different types of terrain).

In the final agreement, PAT acquired about 73 acres of land from Conrail and had to pay to rebuild the tracks along the full length of the alignment. PAT also had to upgrade the train signaling and communication systems. Arriving at a construction agreement for relocating the track was an especially difficult part of the negotiations because it involved defining acceptable roles for various railroad unions. Part of the agreement was that the railroad service would not be forced to shut down during construction.*

2.3 COMMUNITY INVOLVEMENT IN BUSWAY DESIGN

Throughout the planning and design phase, PAT was very responsive to the community's needs. Certain elements of the busway design were determined by citizen's groups representing east corridor residents. Citizen input affected the design of the East Liberty station. Citizen votes struck down plans to build a Shadyside West Station and a busway extension to

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*Interview with Robert McKenzie, PAT.

Swissvale. PAT started meeting with citizen's groups to get support for the busway as early as 1976, but meetings on busway design did not become frequent until 1978 when the track relocation effort began.

The issues in the East Liberty Station design were the station site location and the positioning of the access ramps. The design was complex because East Liberty was planned as a major transfer point and place where diverted routes would access the busway. The citizens were concerned about the amount of traffic congestion that would be generated on local streets near the station. Also, the sites considered were not at the railroad station site; thus, the construction required taking some private land. Finally, the local business community wanted the facility to provide the most direct access possible to the shopping areas. The East Liberty citizens were presented with 25 alternative designs, and held about 70 meetings before they reached a final agreement on a design.

PAT could never get majority support for the planned station at Shadyside. The local community objected mainly because they expected high noise and air pollution levels. They also feared that security would be a problem. As designed, the station platform was well below street level on the railroad right-of-way and very secluded.

The public influenced the design of the busway in still other ways. Because of citizen opposition, the eastern terminal was moved west from Swissvale to Wilkinsburg, reducing the busway length from 8 to 6.8 miles. The Oakland off-ramp location was largely determined by the community. The Wilkinsburg interchange was designed originally with only one exit/entrance ramp, but because citizens expected too much bus traffic congestion at the ramp, PAT redesigned the interchange to include two ramps that would diffuse the traffic. Finally, the community groups requested improved lighting, landscaping, and safety features at all busway mainline passenger access points.

The extension to Swissvale is included in PAT's 10-year plans. However, it would not be constructed before 1988. The busway mainline alignment was positioned in such a way that the Shadyside Station could be added quickly and at low cost if the local community decides to support it.*

2.4 CONSTRUCTION

The major busway construction activities were relocating and reconstructing about 5.5 miles of Conrail mainline railroad track and building the busway. The construction activity involved widening the right-of-way in places, constructing a wall to separate the railroad and the busway, relocating utilities, and lowering the track bed in places. It also involved reconstructing auto and pedestrian bridges, constructing bus ramps, and putting in stairs and ramps for passenger access to stations. Thirty buildings had to be demolished in order to relocate the track.

The original design for the busway, as described in the Early Action Plan in 1970, was for an eight-mile long facility, in an abandoned railroad right-of-way, with the following ramps and stations:

BUS RAMPS	PASSENGER STATIONS
28th Street	28th Street
Shadyside	Shadyside
East Liberty	Negley Avenue
5th Avenue (Pt. Breeze)	East Liberty
Hill Avenue	Dahlem and Pt. Breeze
	Homewood
	Bushton
	Wilkinsburg and Edgewood

*Interviews with Henry Cusack, PAT.

The final design, which evolved from a great deal of community input was for a 6.8 mile facility, which shared the Conrail right-of-way, and had the following ramps and stops:

BUS RAMPS	PASSENGER STATIONS
Grant Street (downtown)	Penn Park
26th Street	Herron Avenue
Neville Avenue	Negley Avenue
Penn Mall at Penn Circle (East Liberty)	Penn Mall (East Liberty)
East Liberty Garage Ramp	Homewood Avenue (Homewood)
Wallace Avenue	Penn Avenue (Wilkinsburg)
South Avenue	

Most of the busway was completed about one year behind schedule. There were many reasons for the delay. Delays resulted from finalizing the agreement with Conrail and securing additional funds from UMTA in order to relocate the railroad and construct the busway in such a way that rail service could continue. Unanticipated problems in soil conditions and infrastructure relocation slowed the construction process. Reaching a consensus with citizens residing in the busway corridor on busway and station design was sometimes very time consuming and caused construction delays.*

2.5 MARKETING

Marketing of the East Busway was initiated long before it actually opened in February 1983. As busway segments were completed, tours were provided for the various community groups that had been active in the planning process. Brochures advertising the facility were distributed as early as 1981.

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*Interviews with Norman Voigt, PAT.

Figures 2-1 and 2-2 show one such brochure. In addition, PAT placed cards describing the facility on all the East Corridor buses.

One of the major marketing effort was the free busway service offered the weekend prior to the opening. A premiere of the EBA Route was planned with service every 30 minutes from 9 a.m. to 6 p.m., Saturday, and from 10 a.m. to 5 p.m., Sunday. PAT planned to schedule four buses for the marketing weekend.

However, the public turnout for the EBA opening was far larger than expected. By 9 a.m., Saturday, crowds were waiting to board the buses. By 1 p.m., 24 buses had to be scheduled to meet the demand, and the service was offered for four hours longer than planned. In all, 60,000 persons rode the EBA that weekend, when the EBA's usual weekend ridership was approximately 8,000 in 1983.

The great enthusiasm for the busway continued through to the first Monday of regular service. Headways had to be shortened immediately to accommodate demand.*

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*Interviews with Henry Cusack, PAT.

A COMMUNITY PROJECT

PAT's East Busway is coming to Allegheny County. By December 1982, some 90,000 daily transit riders will be able to travel between Downtown Pittsburgh and Wilkinsburg on a two-lane roadway exclusively for transit.

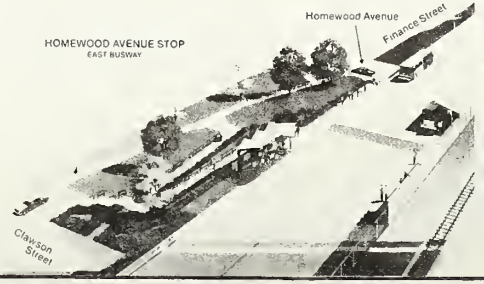
This vital transit improvement, like PAT's South Busway, will provide more reliable and faster public transportation to PAT riders by removing them from daily traffic jams on local streets. With buses operating on their own right-of-way, East Busway commuters can expect one-way time savings of up to 35 minutes, with greater savings during times of heavy street congestion.

The East Busway will have six stops and seven exit/entrance ramps, serving 16 neighborhoods in the City of Pittsburgh's East End and 27 suburban municipalities in the East Hills and Allegheny Valley.

Funding for this $110 million project is being provided by the Federal Urban Mass Transportation Administration (80%), Pennsylvania Department of Transportation (16⅔%) and Allegheny County (3⅓%).

Since a groundbreaking ceremony on August 28, 1978, construction of the facility has proceeded on schedule, thanks largely to the cooperation of elected and appointed officials of Allegheny County, the City of Pittsburgh and the Borough of Wilkinsburg, and to active community groups—the Shadyside Action Coalition, the East Liberty Chamber of Commerce, Bellefield-Area Citizen Association, the Pierce Street Block Club, and other civic clubs and organizations.

PAT's East and South Busways are currently the only busways in the country to be built entirely on their own right-of-way—further evidence of Allegheny County's commitment to providing reliable public transportation.



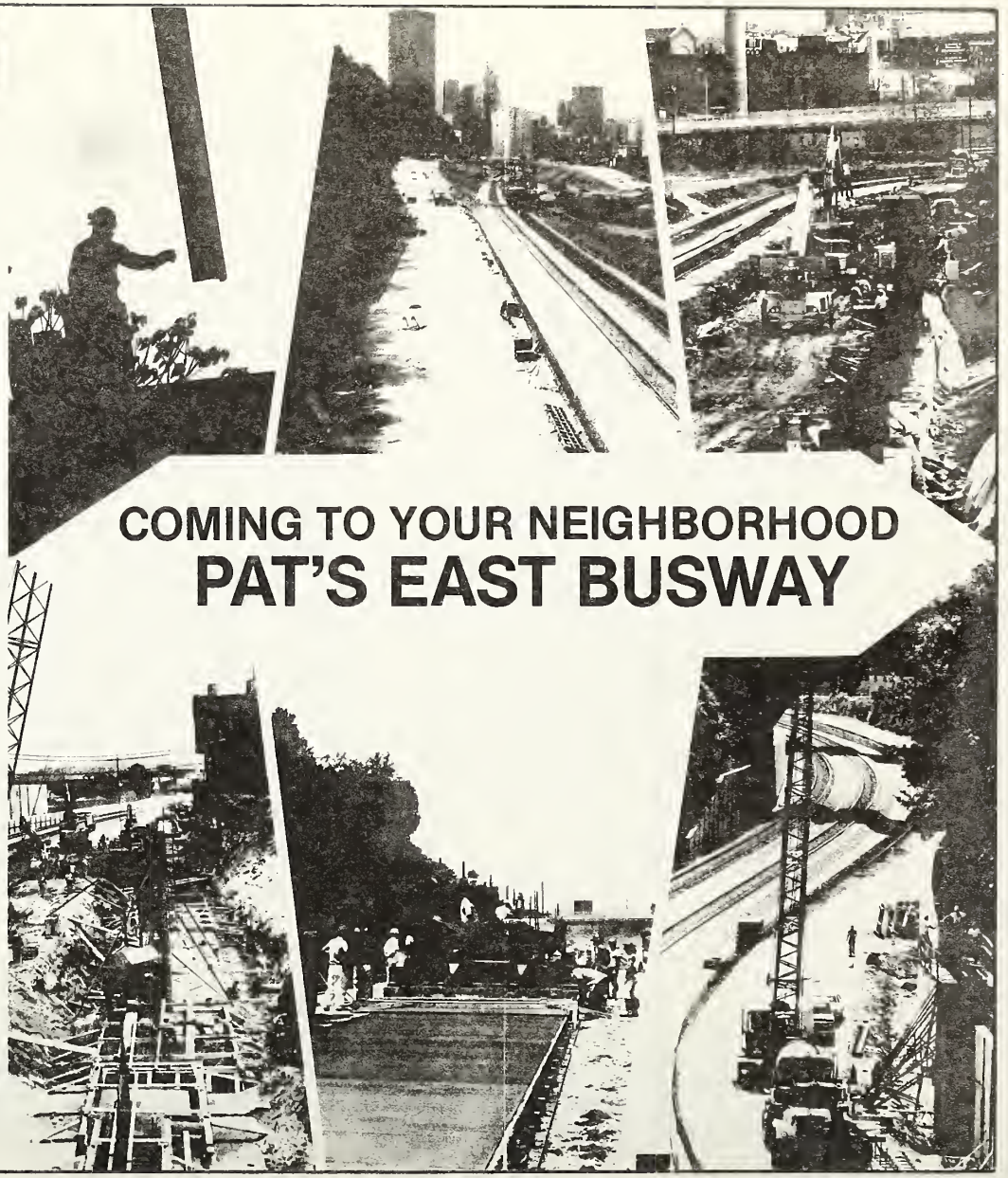


FIGURE 2-1. MARKETING BROCHURE

STOPS

PASSENGER STOPS WILL BE AT THE FOLLOWING LOCATIONS:

- GRANT STREET (Downtown)
- HERRON AVENUE (Polish Hill)
- NEGLEY AVENUE (Shadyside)
- PENN MALL (East Liberty)
- HOMEWOOD AVENUE (Homewood-Brushton)
- PENN AVENUE (Wilkinsburg)

ACCESS

BUS ACCESS WILL BE VIA THE FOLLOWING ENTRANCE/EXIT RAMPS:

- GRANT STREET AT LIBERTY AVENUE (Downtown)
- 26TH STREET AT LIBERTY AVENUE (Strip District)
- CENTRE AND NEVILLE AVENUES (Oakland-Shadyside)
- PENN MALL AT PENN CIRCLE, (East Liberty)
- FIFTH AVENUE AT PAT GARAGE (East Liberty)
- WALLACE AVENUE (Wilkinsburg)
- SOUTH AVENUE (Wilkinsburg)

COMING SOON

PAT'S EAST BUSWAY

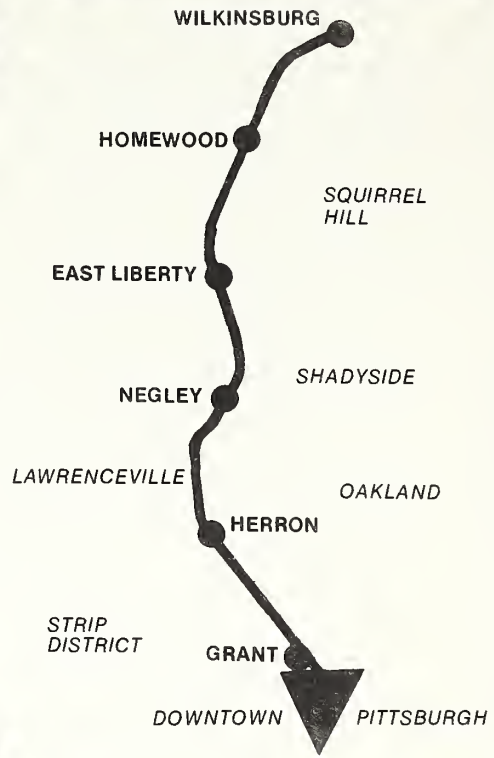
An Innovative Concept Providing:

- TRAFFIC-FREE TRANSIT FOR 90,000 DAILY RIDERS
- FASTER, MORE DEPENDABLE SERVICE TO 16 EAST END NEIGHBORHOODS AND 27 SUBURBAN MUNICIPALITIES IN EAST HILLS AND ALLEGHENY VALLEY
- A SAFE, ECONOMICAL AND ATTRACTIVE ALTERNATIVE TO THE PRIVATE AUTO

OPENING DECEMBER 1982

PATransit

PAT'S EAST BUSWAY



★ Another Allegheny County ★
Transit Improvement

FIGURE 2-2. MARKETING BROCHURE (CONTINUED)

3. OPERATIONS

3.1 PHYSICAL DESCRIPTION

The 6.8-mile long East Busway shown in Figure 3-1, is a roadway for buses only. It shares the Conrail right-of-way between downtown Pittsburgh and its eastern terminal at Wilkinsburg. With one lane in each direction, it is designed for a 50 m.p.h. operating speed for most of its length. Speed limits are 15 m.p.h. on ramps and 25 m.p.h. at stations and on one .1-mile segment west of the East Liberty Station, where the lane width changes from 12 to 11 feet. The shoulder widths vary, but they are generally 8 feet wide for the outbound lane, and 2 feet wide for the inbound lane.

Station platforms for bus boarding and deboarding are 120 feet long to accommodate two buses at all but the East Liberty and Penn Park Stations, where they are 240 feet long for four buses. All stations have pull-off lanes that allow express buses to bypass.

Two pedestrian bridges cross the busway at the East Liberty Station. Several stations have pedestrian crosswalks. The busway is crossed by several auto bridges. Busway photographs are provided in Figures 3-2 through 3-4.

Local street intersections near the Wilkinsburg and East Liberty Stations were redesigned to allow buses to merge with local traffic without delays. The improvements consisted of widened roadways and traffic signalization changes. The intersection at the downtown end of the busway, where buses merge with city traffic, was also improved.

Physical and service characteristics of the stations are described in the following paragraphs.

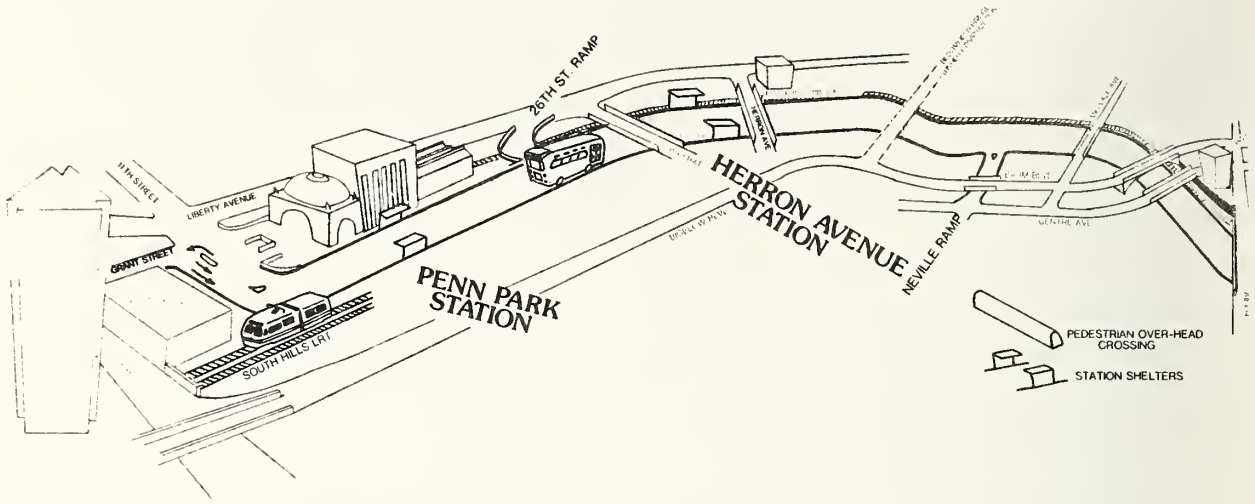


FIGURE 3-1. THE EAST BUSWAY
(Beginning)

Penn Park Station (downtown terminal) - no passenger facilities as yet. EBAs pick up passengers outbound, but not inbound due to conflict with reconstruction of the former Pennsylvania Railroad Station. In the future passengers will be able to transfer here between the EBA and the South Hills LRT.

Herron Station (1.9 miles from the downtown terminal) - stairs from Herron Avenue bridge to inbound platform shelter; outbound platform shelter; handicapped ramp from outbound platform to Herron Avenue. Service provided by East Busway All Stops Route (EBA).

Negley Station (3.8 miles from downtown) - inbound and outbound platform shelters; steps and handicapped passenger ramp from Negley Avenue to inbound platform; turnaround on Summerlea Street for paratransit and auto passenger drop-off. Service provided by EBA Route.

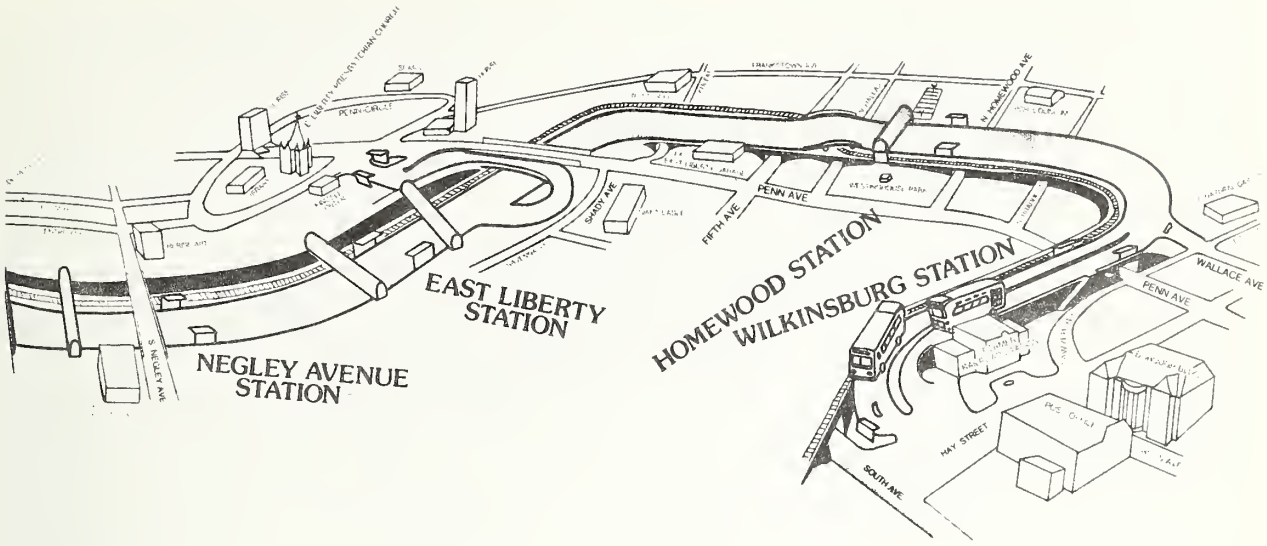


FIGURE 3-1. THE EAST BUSWAY
(Continued)

East Liberty Station (4.3 miles from downtown)- pedestrian bridges to Houston Street and Penn Mall Loop; inbound and outbound pedestrian shelters; ramp for handicapped access from pedestrian bridge to Penn Mall Loop; pull-off lane on Ravenna Street for auto passenger access. Service is provided by EBA, EBO, and diverted express routes. Nearby Penn Mall Loop has stops for transferring from city routes to busway routes.

Homewood Station (5.7 miles from downtown) - inbound and outbound platform shelters; ramp for handicapped access and stairs to inbound platform from Homewood Avenue and Clawson Street; stairs from outbound platform to Homewood Avenue Bridge; turnaround for paratransit on Clawson Street; no auto passenger drop-off lanes. EBA and EBO Route Service is provided.

Wilkinsburg Station (6.8 miles from downtown) - ramp for handicapped access and stairs from Sawyer Way to inbound platform; stairs from outbound platform to Penn Avenue; ramp from outbound platform to South Avenue; inbound and outbound platform shelters. The EBA, EBO, and diverted express routes provide service.

FIGURE 3-2. EAST LIBERTY STATION

FIGURE 3-3. HERRON AVENUE STATION

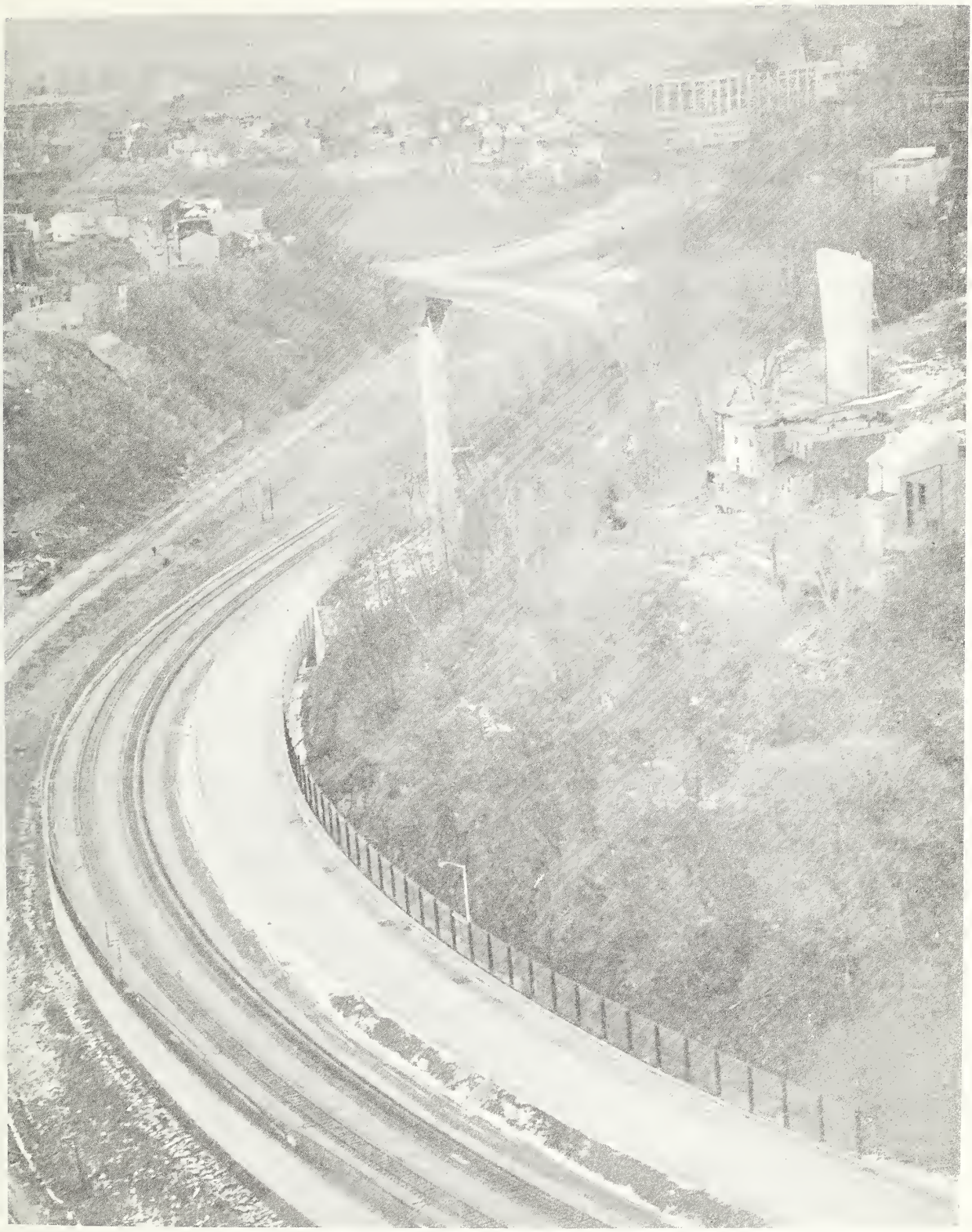


FIGURE 3-4. THE BUSWAY UNDER CONSTRUCTION (Near Herron Avenue, Neville Ramp in background)

3.2 NEW BUSWAY ROUTE OPERATIONS

Since the busway began operating in February 1983, five new routes have been added to the PAT system which use the busway for either all or most of their length. The major new route is the EBA (East Busway All Stops), which runs the length of the busway plus a downtown loop and, in November 1983, made about 130 roundtrips each weekday. During the peak, it provides service every 3 or 4 minutes between the busway stations and the downtown. The EBA serves a lot of walk-on passengers and transfers from other routes that stop at busway stations.

The other major new route is the EBO, which provides frequent service between East Busway stations and Duquesne University near the CBD via Oakland (an area about two miles east of the CBD where two major universities are located). There are also three new peak period express routes, the 73B, 78C, and 88A. The express routes access the busway at various intermediate points.

Average weekday vehicle miles of service in the East corridor increased by 3.5 percent, from 39,700 to 41,100 during the time period when the new busway routes were added between February 1983, and November 1983. Average weekday vehicle hours of service in the corridor increased by 2.1 percent, from 3,060 to 3,130, during this period. As of November, 1983, the new busway routes accounted for about 7 percent, or 2,840, of the average weekday vehicle miles and about 6 percent, or 180, of the average weekday vehicle hours. The number of vehicle miles added for new busway routes is greater than the increase in East Corridor vehicle miles, so nonbusway service was decreased slightly during this period.

A detailed description of the new busway routes is provided on the following page.

NEW BUSWAY ROUTES
(Effective November 1983)

EBA Operates between the eastern end of busway at Wilkinsburg and downtown between 6 a.m. and midnight weekdays and Saturday and between 10:30 a.m. and 7:30 p.m. Sundays. Peak period weekday service is every four minutes. Stops at all busway stations. Vehicle hours per weekday: 120. Vehicle miles per weekday: 2,131.

EBO Service to Oakland weekdays between 6 a.m. and 6 p.m. from busway stations at Wilkinsburg, Homewood, East Liberty, and Negley. Service every 20 minutes. Vehicle hours per weekday: 36. Vehicle miles per weekday: 534.

73B Weekday peak period express service to downtown. Three trips each during a.m. and p.m. peak about every 30 minutes. The route begins at Highland Park before accessing the busway at East Liberty.*

78C Weekday express service, one trip each during morning and evening peak between Shadyside and downtown. Accesses the busway via the Neville ramp.*

88A Weekday peak period express service between East Hills and downtown. Accesses busway at East Liberty Station. Makes five inbound trips during a.m. peak and five outbound trips during p.m. peak.*

3.3 DIVERTED ROUTE OPERATIONS

When the busway opened, many suburban routes were diverted from the Penn Lincoln Parkway and local streets onto the busway

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*PAT does not keep separate accounting of vehicle miles and vehicle hours on these routes.

for the last part of the trip to the downtown. Listed below are the diverted routes and the dates when they started operations on the busway.

February 1983	Suburban parkway express buses, 68A, 68B, 68F, and 68J. Red Flyer routes, G, LP, HP, M, MD, P, PG, T, U.
April 1983	S Flyer, 67C, and two suburban parkway express routes, the 68D and 68G.
June 1983	77E and most of the U Routes which serve Pittsburgh colleges and universities
November 1983	78A.
February 1984	AV and AVN Flyers.

Most of these routes enter the busway at Wilkinsburg and run express to downtown. The LP and the 78A run as expresses between East Liberty and downtown. Figure 3-5 shows park-n-ride routes that were diverted to connect with the busway, including most of those just listed.

In each peak period (6:45 to 9:00 a.m. and 3:30 to 5:45 p.m.) the busway carries about 90 vehicles in the peak direction, of which 50 to 60 are in the peak hour. Most of the volume consists of the diverted routes, as shown in Table 3-1.

TABLE 3-1. PEAK-PERIOD BUS VOLUMES
(Counted Buses)

	Peak Period		Peak Hour		Peak 15 Mins	
	AM	PM	AM	PM	AM	PM
EBA	34	29	18	13	5	5
Other New Routes	7	4	4	3	1	1
Diverted Routes	55	55	35	36	12	11
	96	88	57	52	18	17

Source: PAT Point Checks

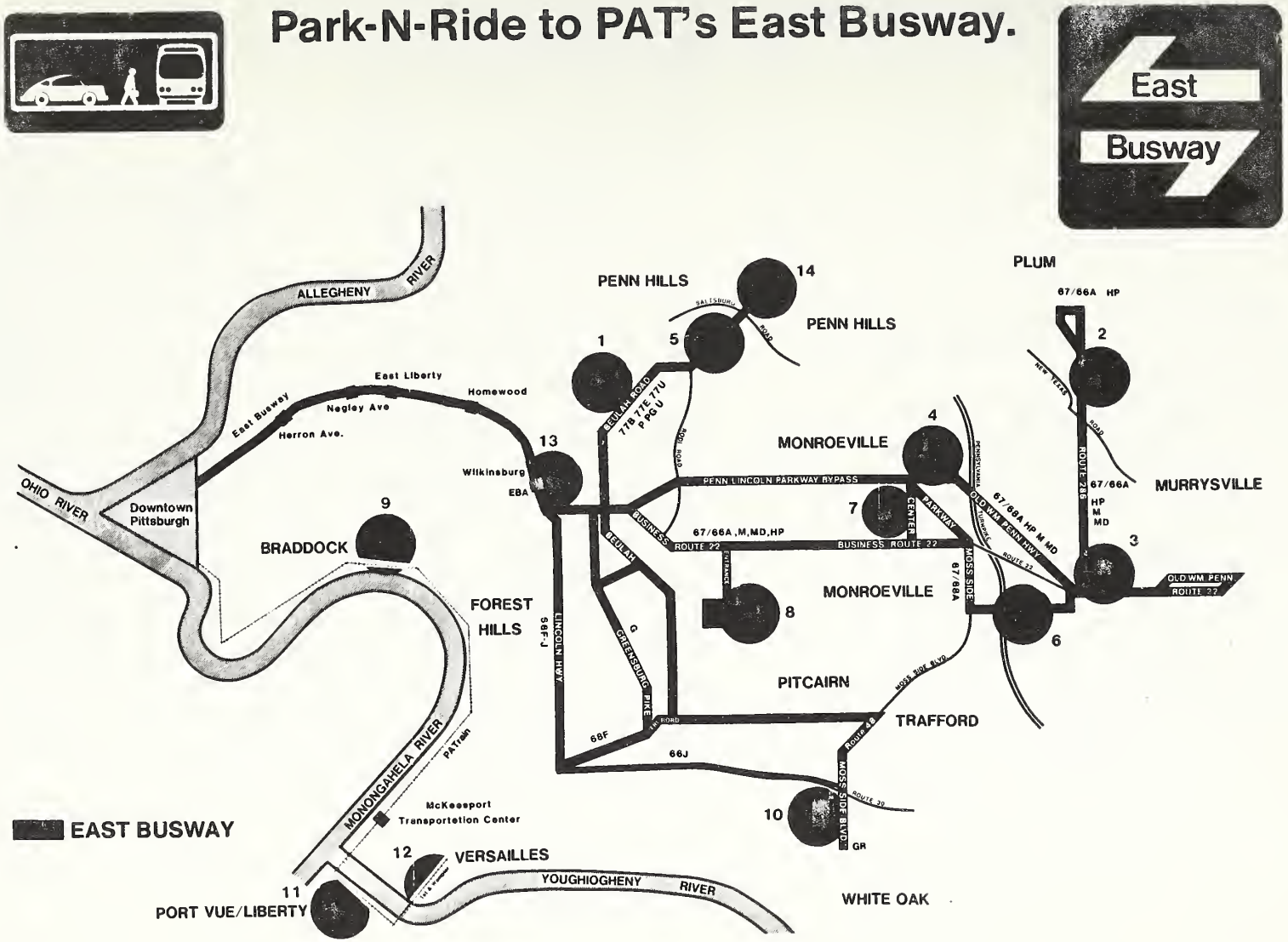


FIGURE 3-5. PARK-N-RIDE TO PAT'S EAST BUSWAY

3.4 BUSWAY CONNECTIONS WITH CITY ROUTES

A large number of city bus routes were revised so that they would stop at busway stations and allow riders the option of a $.25 transfer to an EBA Route bus. In February, 1983, about 1,900 trips on 27 routes in the eastern corridor were scheduled to stop at the Wilkinsburg, Homewood Avenue, and East Liberty stations. EBA Route connections can be made from the following routes at these four stations:

1. Wilkinsburg: 61A, 67A, 67C, 67E, 67F, 67J, 68B, 68F, 68J, 71C, 79A, 79B, and 86B
2. Homewood: 74A
3. East Liberty: 4B, 64A, 71C, 77A, 77B, 77C, 81B, 86A, 86B, 89A, 94A, and 94B
4. Negley: 77C

3.5 BUS SPEEDS

A major objective for this study was to provide information that can be generalized to other city transit systems on how busway route performance compares with routes used before the busway. Therefore, speed has been used as the performance measure, rather than travel time, because it controls for any differences in route length between busway routes and the former routes. However, in a latter section, this study examines the effects of the busway on passenger travel times, in order to evaluate how well the busway functions as compared to other routes within Pittsburgh alone.

Speeds on the segments of routes that use the busway were expected to be higher than speeds on the segments of routes that used to traverse the same area in Pittsburgh. Bus speeds were examined on comparable segments of diverted routes before and after using the busway. These segments are called "line-haul" segments; they run between a suburban point near the eastern end of the busway and end just short of the downtown, at the western end of the busway. The results are shown in Table 3-2.

TABLE 3-2. DIFFERENCE IN AVERAGE LINE-HAUL SPEEDS ON DIVERTED ROUTES BEFORE AND AFTER USING THE BUSWAY (m.p.h.)

A.M. PEAK INBOUND

ROUTE	SPEED BEFORE BUSWAY	N	SPEED AFTER BUSWAY	N	PERCENT CHANGE	STATISTICAL SIGNIFICANCE*
78A	20.0	16	39.3	13	97	Yes
68A	25.9	18	31.2	24	20	Yes
68F	23.1	28	30.3	40	31	Yes
68J	23.1	24	31.6	23	37	Yes
P	21.5	17	31.9	30	48	Yes
T	25.1	6	33.4	6	33	Yes
PG	29.7	22	35.6	17	20	Yes
M	31.0	15	34.0	18	10	No
MD	27.9	5	35.1	6	26	Yes
Average	25.3		33.6		33	

P.M. PEAK OUTBOUND

68A	36.2	23	30.8	24	-15	Yes
68F	32.4	23	31.7	22	-2	No
68J	29.7	23	29.8	23	--	No
P	33.5	12	29.3	12	-13	No
T	33.7	4	31.9	6	-5	No
PG	33.0	41	29.4	41	-11	Yes
M	38.8	22	33.1	23	-15	Yes
MD	33.9	6	33.7	6	--	No
Average	33.9		31.2		-8	

P.M. BASE PERIOD OUTBOUND

68J	36.4	5	32.3	6	-11	No
PG	35.7	5	29.8	5	-17	No
Average	36.1		31.1		-14	

*Statistical significance was based on a two-tailed t-test, .05 confidence interval.

Source: PAT point checks.

During the a.m. peak for inbound trips on diverted routes, speeds were uniformly higher after the routes began using the busway. As shown in Table 3-2, the increase in speed was statistically significant for 8 out of 9 routes. Speeds generally increased from between 20 and 30 m.p.h. before the busway to between 30 and 35 m.p.h. after the busway. However, speeds on diverted routes decreased slightly after using the busway during the p.m. peak and p.m. base periods. The decrease was statistically significant for only 3 out of the 8 routes considered.

A possible explanation for these results is that while speeds are very similar for the a.m. inbound and p.m. outbound in the after case, the p.m. outbound speeds are much faster than the a.m. inbound speeds in the before case. Before the busway, outbound and inbound trips took different routes for the line-haul segment. Most outbound trips on the diverted routes took the Boulevard of the Allies for about one mile after exiting from the downtown and then connected with the parkway. Inbound trips took the parkway all the way into the downtown. Speeds on the Boulevard of the Allies and on the downtown streets used to access the boulevard may have been much faster than speeds on the parkway and its downtown access streets.

3.6 FARE COLLECTION POLICY

The same fare collection procedures are used on all PAT bus routes. Fares are collected when passengers board on inbound trips and during deboarding on outbound trips. This fare collection policy means processing just a few passengers at a time, which is easier for the drivers. Fares are not collected in the downtown, where considerable delays would result from large numbers of passengers boarding and deboarding simultaneously. After 7 p.m., fares are collected at boarding on both inbound and outbound trips.

PAT has attempted to increase the efficiency of fare collection by encouraging the use of prepayment options, such as the weekly permit and the monthly pass. In July 1984, PAT reduced the prices for all passes and permits.

While PAT uses electronic fareboxes that read dollar bills, several seconds are lost each time a person feeds the farebox. Busway running time would be reduced if this delay could be eliminated. PAT experimented with selling Susan B. Anthony dollar coins, which can be processed more quickly. However, coin sales stabilized at only about 1,000 a day.

At present, transfers and U-Tickets are punched by the bus driver, while passes and permits are just displayed. The farebox is for cash fares only. Figures 3-6 and 3-7 display PAT's current fare information brochure.

3.7 TRANSFER POLICY

The transfer policy has changed a few times during the past several years. In October 1982, transfers were marked as to date and time of day, but designations were not made for trip direction, zone, and route. Patrons requesting transfers had to deposit $.25 in the farebox, in addition to paying their regular zone fare. Transfers were free for students at certain times and cost $.10 for handicapped persons. Holders of monthly passes and weekly permits use their passes and permits as transfers. Weekly permits require 10¢ cash drop with each use in the central fare zone. Monthly passes need no additional cash in the central fare zone.

Transfers also functioned as three-hour passes. They allowed passengers, upon presentation of the transfer, to ride any route during the three hours following the time of transfer issuance. Because transfers were presented to drivers, but not handed over, it was possible to present quickly an outdated transfer without the driver noticing. This made it easy to abuse the transfer system.

PAT FARE STRUCTURE

EFFECTIVE JULY 1, 1984

ONE-WAY CASH FARES

Central Zone (Zone 1)	**$1.00**
Zone 2 (Combines Zones 2 & 3)	**1.25**
Zone 3 (Replaces Zones 4 & 5)	**1.50**
Zone 4 (Replaces Zones 6, 7 & 8)	**1.75**
Zone 5 (Replaces Zones 9 & 10)	**2.50**
Downtowner Zone	**60¢**
Monongahela & Duquesne Inclines	**60¢**
Transfers	**25¢**

PASSES-PERMITS-TICKETS

	New	Old
Monthly Pass*	**$ 35.00**	$ 40.00
Annual Pass * *(*No Cash drop for one-zone rides)*	**350.00**	440.00
Weekly Permit	**8.00**	8.00
Monthly School Permit	**30.00**	30.00
10-Trip Commuter Tickets (Extended to Zone 2)	**10% Off Regular Cash Fare**	
One-Day Visitor's Pass	**4.50**	—
Mon Valley Flash Pass	**70.00**	—
20-Trip U-Tickets	**15.00**	15.00
Weekend Family Fare	**3.25**	3.25

PATrain FARES

	New	Old
Pittsburgh-Braddock	**$1.75**	$1.85
Pittsburgh-McKeesport	**2.00**	2.30
Pittsburgh-Port Vue/Liberty	**2.00**	2.55
Pittsburgh-Versailles	**2.25**	2.70

ACCESS FARES

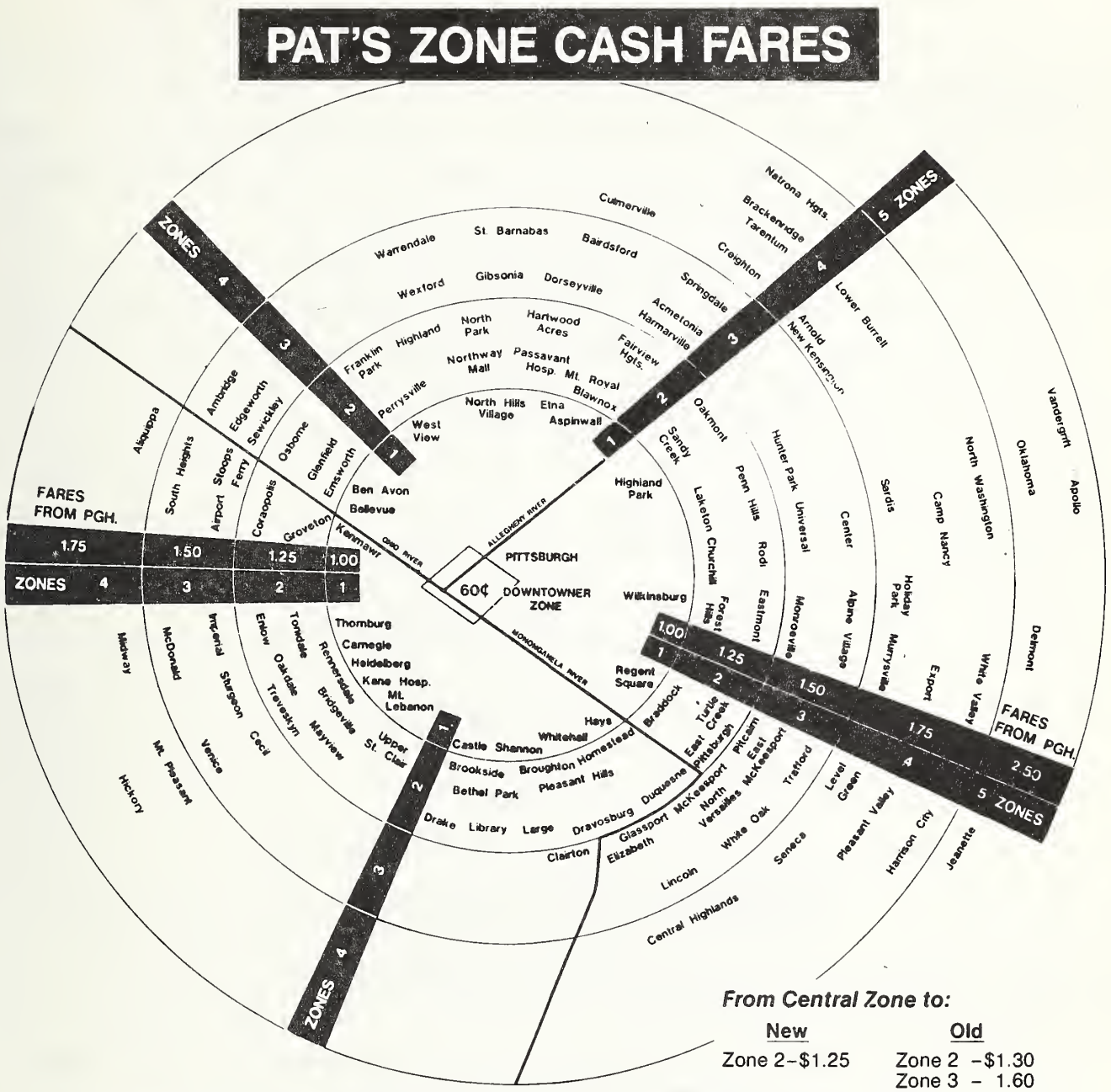
ACCESS Cardholder	**90% Discount**
ACCESS 65 Plus *(For Senior Citizens)*	**90% Discount†**
Minimum Cardholder Charge	**40 Cents**
Cash Zone Fares Per Airline Mile	**$3.00**

OTHER FARES

Senior Citizens *(Off-peak hours, weekends, major holidays)*	**Free†**
Handicapped Persons *(Off-peak hours, weekends, major holidays)*	**½ Fare**
Children Under 6	**Free**
Children 6 through 11	**½ Fare**

(†Funded through State Lottery Revenue)

FIGURE 3-6. PAT FARE STRUCTURE



Information: 231-5707

Transit

From Central Zone to:

New	Old
Zone 2-$1.25	Zone 2 -$1.30
	Zone 3 - 1.60
Zone 3- 1.50	Zone 4 - 1.90
	Zone 5 - 2.20
Zone 4- 1.75	Zone 6 - 2.50
	Zone 7 - 2.80
	Zone 8 - 3.10
Zone 5- 2.50	Zone 9 - 3.50
	Zone 10- 3.90

FIGURE 3-7. PAT'S ZONE CASH FARES

In an effort to improve control of transfer use, the transfer policy was changed in July 1984. Under the new policy, transfers had to be surrendered to the driver and if an additional transfer ride was desired, the passenger could buy the transfer for an added $.25 charge. PAT's current transfer policy brochure is shown in Figure 3-8.

During the 90 days between April 1 and June 30, 1983, a special free transfer policy was put into effect for transferring at busway stations. It was instituted to appease communities that felt that since very few of the routes serving their neighborhoods had been diverted to the busway, they should be able to transfer free onto busway routes. It was also intended to test neighborhood responses to shuttle buses to the busway stations. While the policy was in effect, a number of routes serving the "free transfer neighborhoods" were diverted to the busway. Thus, transferring became unnecessary and the free transfer policy was revoked.

3.8 ROAD SERVICE CALLS

3.8.1 Road Service Calls Per Million Vehicle Miles

Because of the lack of stop-and-go traffic, and excellent road surface conditions, it was expected that buses using the busway would require fewer road service calls for emergency repairs than they had before the busway. The failure codes expected to occur less frequently were for front axle, rear axle, brakes, clutch, air suspension, springs, and transmission. The failure codes not expected to be affected by the busway included body, electrical, engine, frame, steering, fuel and exhaust, and out of fuel.

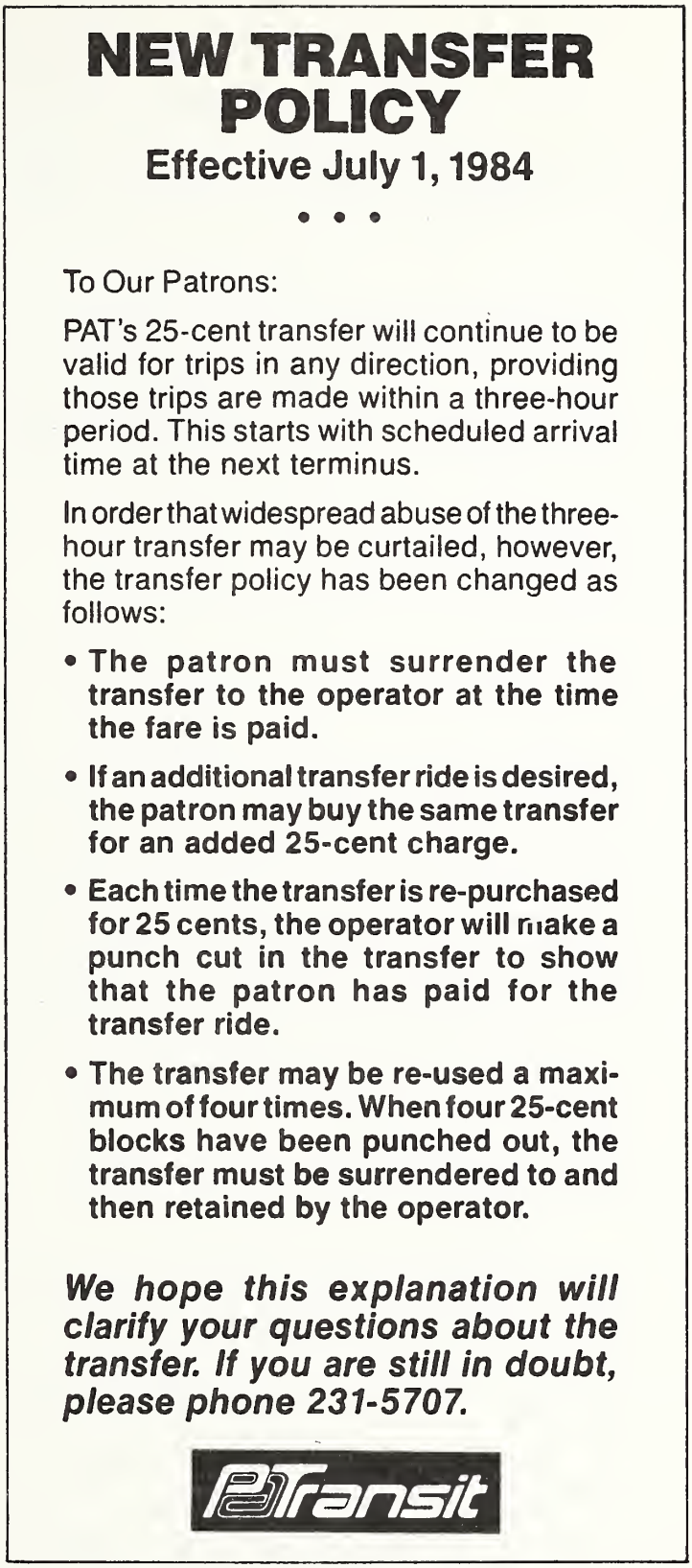


FIGURE 3-8. NEW TRANSFER POLICY

As shown in Table 3-3, the number of road service calls per million vehicle miles on diverted routes was about the same before and after the busway for the specific failure codes expected to be affected by operating on the busway. However, road service codes for all other failure codes actually increased after the busway.

TABLE 3-3. ROAD SERVICE CALLS PER MILLION VEHICLE MILES

	Before Busway	After Busway
Selected Failure Codes	55	50
All Other Failure Codes	460	782

Source: PAT records.

These results suggest that during the period after the busway there was a tendency for more vehicle failures to take place for reasons not related to the busway--perhaps because of unusually severe weather or an aging vehicle fleet. For the selected failure codes, the effect of the busway may have been to offset the general tendency for failure codes to increase. The increase is statistically significant to the 95 percent confidence level, using a two-tailed t-test. Data used was monthly road service calls between 8/82 and 2/83 for the before case, and between 8/83 and 2/84 for the after case. Data was provided by PAT, and is described in Appendix B.

3.8.2 Servicing Breakdowns

The driver survey showed that about 79 percent (n=32) of bus drivers who had breakdowns on the busway found that it created no special problems as compared to breaking down on the parkway. However, only 61 percent (n=18) found no special problems as compared to local streets. All of the drivers who found problems said that, at some places along the busway, it is hard to pull over far enough to avoid interfering with traffic. On the other hand, 94 percent (n=17) found that, in some ways, breakdowns are easier to handle on the busway; the major reason cited was that road service can respond more quickly.

3.9 SAFETY

3.9.1 Accidents Per Million Vehicle Miles

Buses were expected to have fewer accidents on the busway than on other roadways for the same reasons that they were expected to have fewer road service calls. The busway has fewer places for traffic to enter and exit, no intersections, and better road surface conditions.

About 30 percent fewer accidents of all types occurred on diverted routes after they began operating on the busway. However, accident records show great fluctuations from month to month, so that this result is not statistically significant using a two-tailed t-test and a 95 percent confidence interval. In addition, accidents involving passengers showed no decline. See Table 3-4.

Accident data was provided by PAT and it consisted of accidents by month for the period from 3/82 to 2/83 (before the busway) and for the period from 6/83 to 3/84 (after the busway). Accidents were classified into the following categories: collision with another company vehicle, pedestrian, fixed object, or motor vehicle; passenger accidents boarding, on-board, alighting, or involving doors; equipment damage; and witness type reports. The data is described in Appendix B.

Drivers generally had very positive attitudes about the facility. Of the regular drivers (not extra board), about 81 percent (n=31) said that a busway route was their first choice. The driver survey data is described in Appendix B.

TABLE 3-4. ACCIDENTS PER MILLION VEHICLE MILES

	Before Busway	After Busway	Percent Change
All Accidents	604	422	-30
Passenger Accidents	34	36	+ 6

Source: PAT Records.

3.9.2 Ease of Driving on the Busway Under Various Conditions

The survey of drivers on busway routes showed that almost all of them find driving on the busway easier than on other roads under all conditions. The exception is that 17 percent of the drivers said that the busway is harder than the parkway under snowy conditions. See Table 3-5.

TABLE 3-5. PERCENTAGE OF DRIVERS STATING THAT BUSWAY DRIVING IS EASIER THAN PARKWAY OR LOCAL STREET DRIVING

	PARKWAY	LOCAL STREETS
Good Weather	97 (n=65)	100 (n=64)
Rainy Weather	95 (n=65)	100 (n=64)
Foggy Weather	90 (n=61)	97 (n=64)
Snowy Weather	83 (n=59)	97 (n=63)
At Night	98 (n=59)	100 (n=61)

Source: Driver Survey

3.9.3 Pedestrian Activity and Safety

According to the driver survey, almost all busway drivers, 92 percent (n=61), think that pedestrian activity on the busway creates safety problems. Most of the comments written in on the survey were about the problem of pedestrians crossing in front of buses at the East Liberty station. However, no data to substantiate the drivers' opinions was available.

3.9.4 Use of the Busway by Emergency and Maintenance Vehicles

Busway usage by vehicles other than buses appears to be minimal, according to the station check counts shown in Table 3-6. These vehicles apparently have little effect on bus operations. About 92 percent of drivers (n=62) using the busway reported that they had little effect on bus speed and reliability. Similarly, about 78 percent (n=65) said that they did not affect busway safety.

TABLE 3-6. EMERGENCY AND MAINTENANCE VEHICLE VOLUMES (DAILY)

	Wilkinsburg	East Liberty Station
Emergency Vehicles	2	8
Maintenance Vehicles	7	9
Other	1	13
TOTAL	10	30

Source: Station Checks.

4. LEVEL OF SERVICE

In the following chapter, passenger travel times on busway routes are compared with those on routes used before the busway. In addition, changes in service reliability and in chances of getting a seat on both busway routes and other routes after the opening of the busway are documented.

4.1 PASSENGER TRAVEL TIME

4.1.1 Introduction

The objective of the following analysis is to determine the busway's effect on travel times for patrons of new, diverted, and nonbusway routes in the east end corridor. Travel time changes in all trip components were estimated--access, waiting, in-vehicle (composed of suburban, line-haul, and downtown), and transfer. These results are not completely transferable to other settings because changes in route length, which reflect the specific local street network and the chosen right of way for the busway, are not controlled for. However, the time analysis does provide a good measure of the busway's performance in Pittsburgh and actual benefits to passengers.

The analysis is based on data provided by ride checks, station checks, point checks, and schedules. A description of each of these data sources is provided in Appendix B. In addition, subjective appraisals of time changes were provided by the on-board survey, which is described in Appendix A. For the ride checks, bus travel time between stops was measured. The station checks were used to measure, at each busway station, the time between buses (headways) on a given route and the time for boarding and deboarding. They were also used to estimate the numbers of persons boarding, deboarding, and on the bus. Point checks indicated line-haul travel times before and after the busway.

4.1.2 Downtown Circulation

Downtown bus circulation patterns changed with the opening of the busway. For most passengers on most busway routes, downtown in-vehicle time and downtown walk time decreased. Busway routes enter the downtown at the intersection of the busway and Grant Street in the northeast corner of the CBD. Most busway routes use a downtown loop similar to the ones shown in Figure 4-1. Previously, buses entered the downtown from the southeast, rather than the northeast. Two typical loops are shown in Figure 4-2.

The new downtown loops bring a larger percentage of riders closer to their downtown destinations than did the previous loops. The new loops are shorter and should therefore reach all stops along the route more quickly. To a greater extent than the routes used before the busway, they pass through the areas of the downtown that were identified as the main destination zones in both the 1982 and the 1983 on-board surveys, zones 7 and 8. These zones are shown along with the downtown loops on Figures 4-1 and 4-2. At the same time, however, because the new routes loop further north and west than the previous routes, riders going to destinations on the south and east of the downtown will have farther to walk between their bus stops and destinations than they used to.

The new downtown loops are the routes that are to be used permanently; they are not loops put into effect temporarily because of the subway construction.

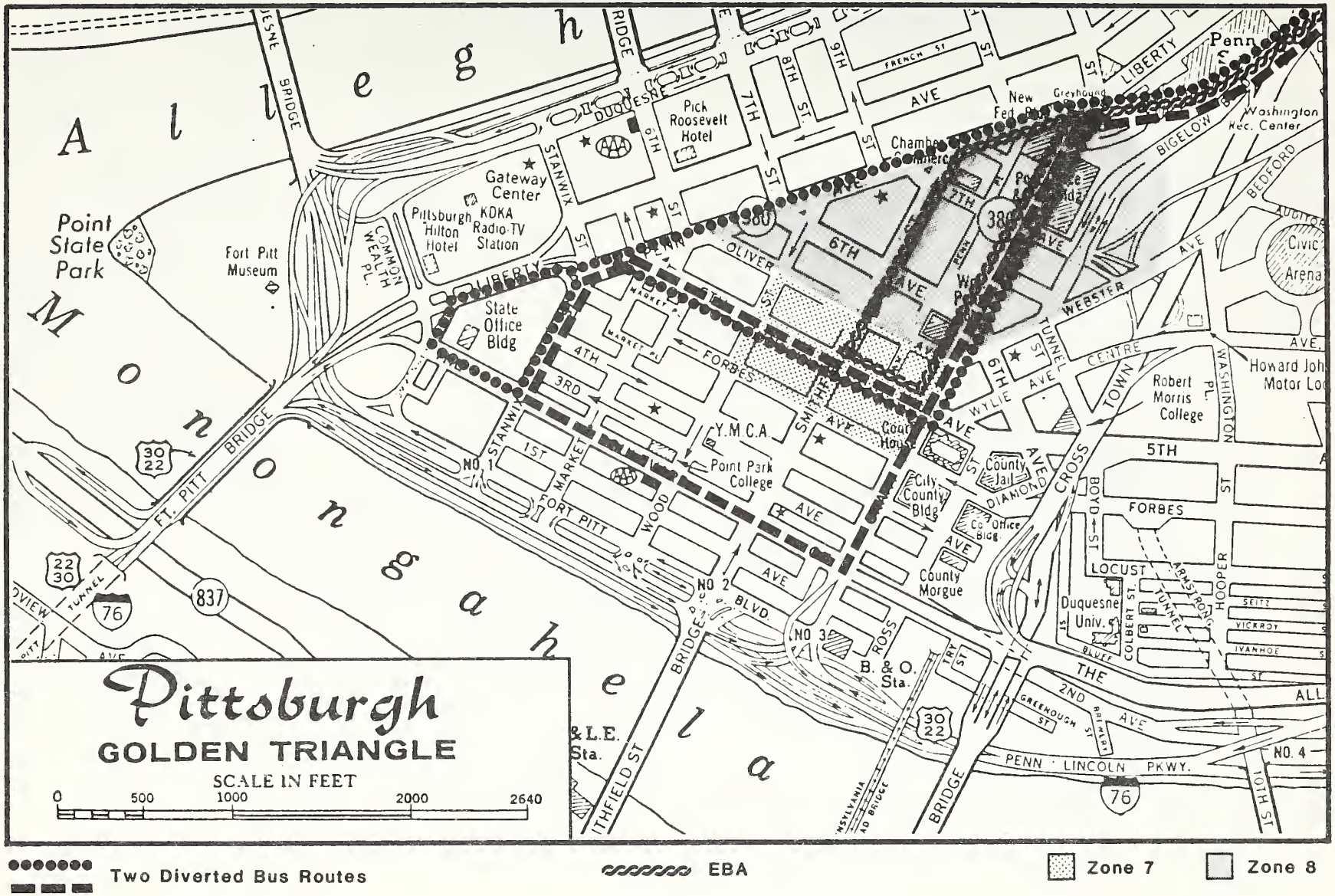


FIGURE 4-1. CURRENT DOWNTOWN LOOPS

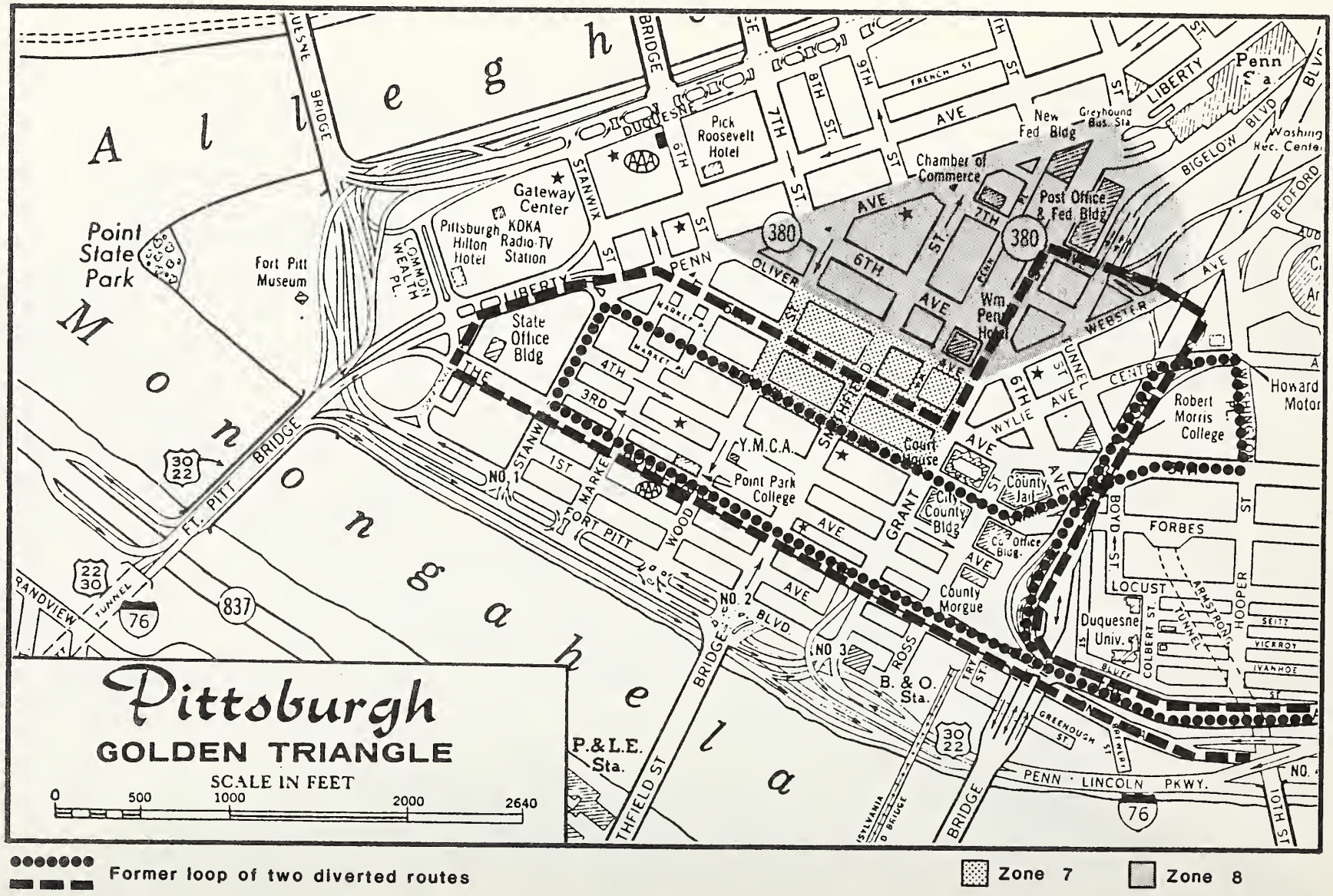


FIGURE 4-2. FORMER DOWNTOWN LOOPS

4.1.3 Changes in Travel Time to Key Downtown Destinations on Diverted Routes

The analysis assumed there was no change in travel time either from suburban rerouting or wait time changes. Very little suburban rerouting of diverted routes was necessary when they switched over to the busway. Before the busway opened, many of these routes used the Penn Lincoln Parkway, which passes less than a mile from the easternmost busway station, Wilkinsburg Station. Therefore, it was assumed that access time between the trip origin and initial bus stop did not change. Also, an examination of schedules showed that service frequency on these routes did not change significantly after moving to the busway, so wait times should have remained about the same.

Further evidence that an assumption of no change in suburban routing or wait times is reasonable and conservative comes from the on-board survey. Only slightly more diverted route riders than "control" route riders perceive an improvement in wait times:

> Is wait time better, no different, or worse than it was before the busway?

	DIVERTED ROUTE	CONTROL ROUTE
Better	29%	12%
No Difference	63	67
Worse	8	21

Routes that experienced no changes and that are located in the south corridor were selected as controls for comparison with routes put on the busway. These findings support the conclusion that only an insignificant change in service frequency took place. The perceived improvements in wait time are probably due to improvements in service reliability, which are discussed in a latter section.

The on-board survey results concerning distance to the bus stop also support the conclusion that very little suburban rerouting took place and that access time changed very little. Only small percentages of diverted route riders (and only slightly more diverted route riders than control route riders) reported decreases in distance to the bus stop:

Is distance to the bus stop better, no different, or worse than it was before the busway?

	DIVERTED ROUTE	CONTROL ROUTE
Better	13%	5%
No Difference	79	90
Worse	8	5

It follows that all changes in travel time for diverted routes can be attributed to the line-haul* and downtown circulation segments of the bus trip, and to walking between the bus stop and downtown destination. The combined time required for these trip components, before and after the busway, was estimated for six key downtown destinations, as shown in Table 4-1. The downtown destinations selected for the analysis are shown on Figure 4-3. The six downtown destinations were selected for the travel time analysis to represent the zones most frequently cited as downtown destinations on the 1983 on-board survey. Since 46 percent of diverted route riders were travelling to zones 7 and 8, two destinations were selected from zone 8 and one from zone 7. Since zones 2 and 6 were also among the most frequently cited zones, a destination located at the border of the two zones was selected. Destinations on the borders of zones 1 and 4 and in zone 5 were also chosen. The particular buildings used in the analysis were recommended by PAT staff.

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*That is the route portions on the busway (after), or on that portion of the parkway between downtown and the exit closest to the end of the busway (before).

TABLE 4-1. AVERAGE TRAVEL TIME (MINUTES) ON DIVERTED ROUTES TO KEY DOWNTOWN DESTINATIONS BEFORE AND AFTER USING THE BUSWAY

Downtown Destination	Walk Time		Downtown Circulation Time		Line-Haul Time		Total	
	Before	After	Before	After	Before	After	Before	After
A.M. PEAK INBOUND								
Gateway Center	2.9	2.0	12.1	11.8	19.2	14.1	34.2	27.9
Kaufman's	3.1	3.2	8.1	9.5	20.0	14.3	31.2	27.0
Gimbel's	3.9	2.4	7.2	3.9	20.0	14.3	31.1	20.6
Pt. Pk. College	1.8	4.4	9.6	12.6	20.8	15.4	32.2	32.4
Clark Bldg.	3.8	2.6	9.9	5.9	20.0	14.3	33.7	22.8
U.S. Steel	3.6	2.0	7.6	2.6	20.0	14.3	31.2	18.9
P.M. PEAK OUTBOUND								
Gateway Center	2.8	2.0	14.6	13.9	14.5	15.7	31.9	31.6
Kaufman's	3.0	3.4	9.7	11.3	14.8	16.0	27.5	30.7
Gimbel's	3.9	2.2	8.4	4.3	14.8	16.0	27.1	22.5
Pt. Pk. College	1.4	3.8	9.8	12.6	12.2	13.2	23.4	29.6
Clark Bldg.	3.7	2.0	10.0	6.0	14.8	16.0	28.5	24.0
U.S. Steel	2.9	1.7	7.7	2.4	14.8	16.0	25.4	20.1

FIGURE 4-3. MAP OF KEY DOWNTOWN DESTINATIONS

Line-haul travel times were estimated using PAT's before and after point check data for diverted routes. Appendix B provides a description of this data source. Downtown circulation time was determined by using the downtown bus speed data obtained from PAT's downtown ride checks and schedule information on before and after downtown loops. Downtown bus speed during the a.m. peak was found to be 4.2 m.p.h. and p.m. peak speed was 3.5 m.p.h. Walk speed was assumed to be 3.0 m.p.h. The diverted routes examined were 68A, 68B, 68F, 68J, 78A, and T.

Travel time decreased during the a.m. peak by an average of eight minutes. A decrease occurred at all but one of the six destinations and was due mainly to a decrease in line-haul travel time. Savings in this trip component alone averaged five or six minutes. While some downtown circulation time savings occurred for four of the destinations, large savings (four or five minutes) occurred for only two destinations, Clark Building and U.S. Steel Building. Walk time savings of one or two minutes occurred for four of the six destinations.

Travel time to Pt. Pk. College remained the same during the a.m. peak. Most busway downtown loops pass a few blocks north of this location, while former downtown loops had stops right next to it.

During the p.m. peak, travel time decreased at four of the destinations after the busway, but the time savings were smaller than for the a.m. peak--about 3.5 minutes on average. Because travel times increased slightly for the line-haul segment, the decrease in total travel time was due to compensating decreases in downtown circulation and walk time. A possible explanation for the lack of improvement in the p.m. peak was discussed in the presentation on bus speeds in Section 3.5.

4.1.4 New Routes--Comparison of Door-to-Door Travel Time On Current and Former Routes

Current door-to-door travel times of EBA passengers were compared with the travel times these passengers experienced,

using other routes, before the busway opened. EBA passengers save about 21 minutes on a.m. peak and midday trips, and about 24 minutes on p.m. peak trips--a travel reduction of about 40 to 45 percent. The results of this analysis are shown in Figure 4-4 and Appendix C.

As with the diverted routes, most of the time savings are due to decreases in in-vehicle travel time. However, travel time also decreased for the other trip components: walking to and from the bus stop (access time) and waiting for the bus. Wait time savings are due to the fact that service on the EBA is much more frequent than service on the routes that these passengers used to take. Access time savings in the downtown result from the downtown loop that was put into effect after the busway opened, so that stops are located closer to the major downtown destinations than they were previously.

As shown below, the on-board survey results support the finding that wait times improved on new routes:

> Is wait time and distance to the bus stop better, no different, or worse than before the busway?

	WAIT TIME		DISTANCE TO BUS STOP	
	New Routes	Control Routes	New Routes	Control Routes
Better	78	12	26	5
No Difference	18	67	45	90
Worse	4	21	29	5

While the travel time estimation showed access time savings, the on-board survey results shown here suggest that the amount of time required for access (distance to the bus stop) remained about the same, on the average. However, the computed savings in access time contributed very little (about 10 percent) to the total door-to-door time savings estimated.

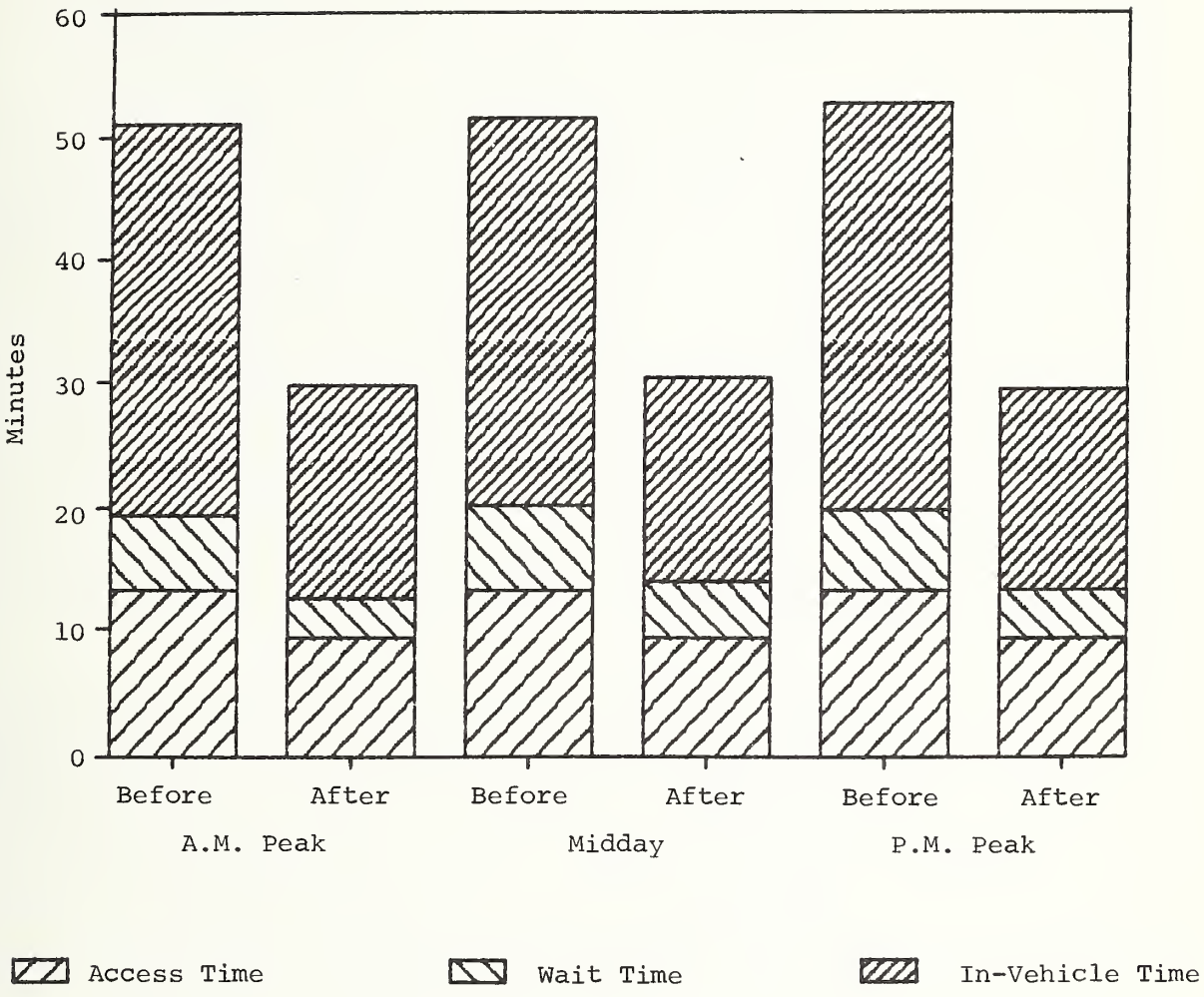

FIGURE 4-4. COMPARISON BETWEEN DOOR-TO-DOOR TRAVEL TIMES ON THE EBA ROUTE AND ROUTES TAKEN BY EBA PATRONS BEFORE THE BUSWAY

The comparison between current and former travel times of EBA passengers was based on schedules, rather than on actual travel time measurements. Therefore, the conclusions may not be realistic, even though they were based on the best available information and judicious assumptions. Information in the on-board surveys was used to determine selected passengers' present and former routes between certain trip origin and destination points. Sixteen individual cases were selected by first drawing a random sample of EBA route riders, then picking representative cases from the 14 major suburban origin zones. A case was considered representative if its origin point (particular intersection) within the zone was near several other passengers' origin points. The 16 cases were used to generate a total of 48 cases by estimating a.m. peak, p.m. peak, and midday travel times for the same trip. The destination points and walk times within the downtown were assumed to be the average of those shown in Table 4-1.

About 75 percent of all new route riders indicated that their trips originated in these 14 zones. A map showing these origin points is provided in Appendix C. To estimate access time, the distances to and from the bus stop (EBA stop and stop on former route) were measured and a walking speed of 3 m.p.h. was assumed. Bus schedules were used to determine in-vehicle travel times. None of the cases, either before or after, involved a transfer.

Wait times for the EBA route were estimated using headway data from the station checks, as shown in Figure 4-5.* Scheduled headway times were used to estimate wait times on the routes taken before the busway.

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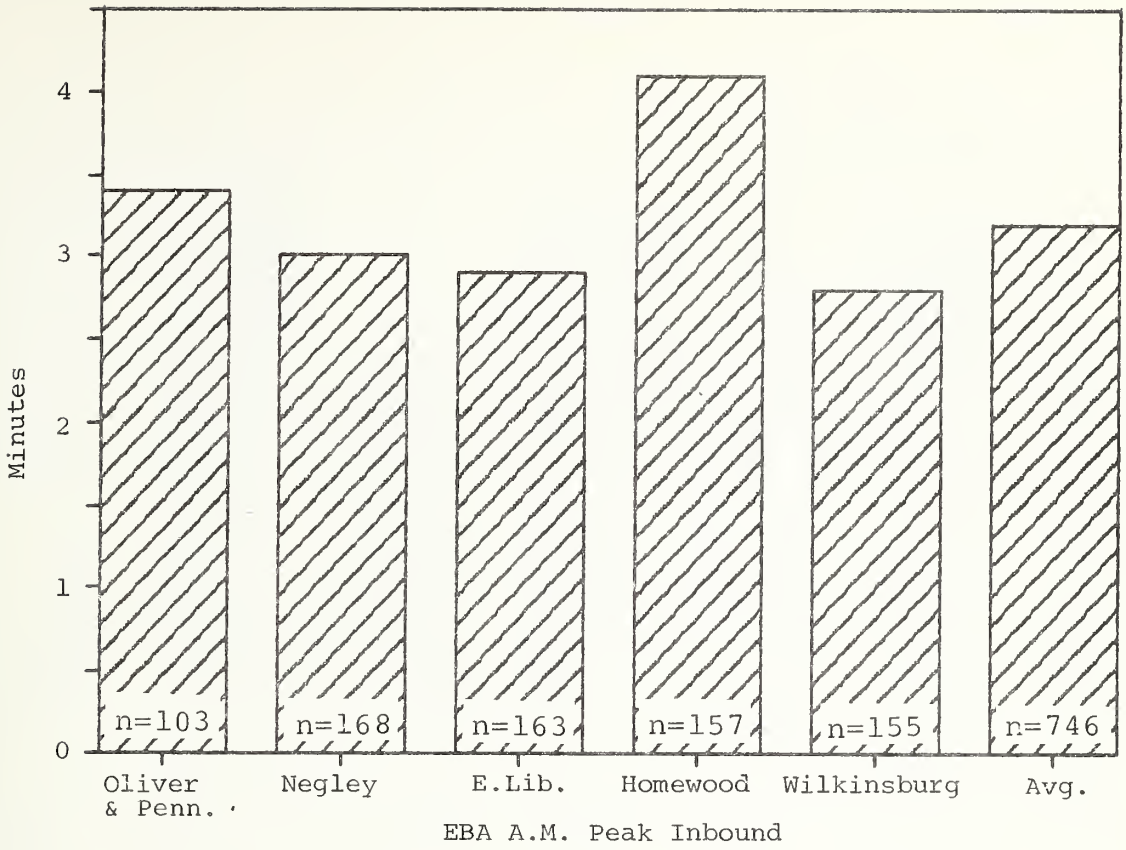
*According to the following formula:

$w = (h/2) + (1 + var(h)/h^2)$ where w = wait time, and h = headway time



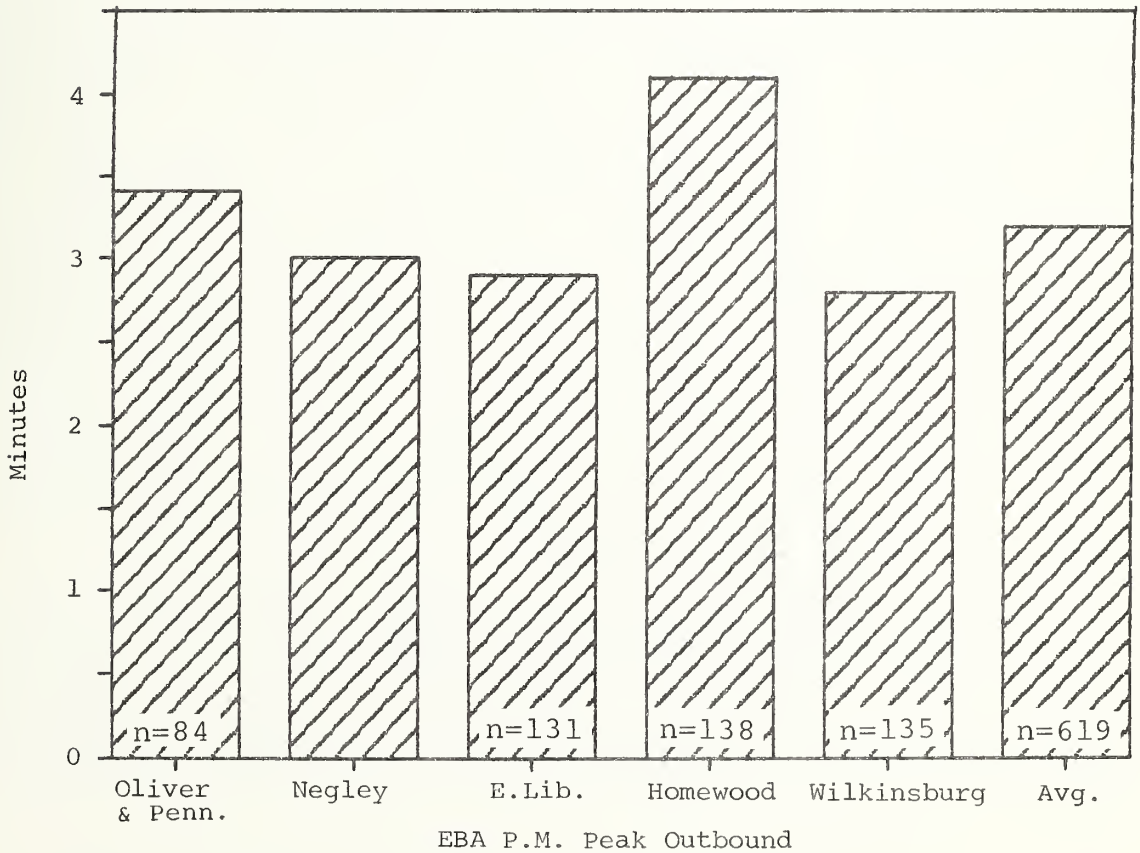


FIGURE 4-5. AVERAGE WAIT TIMES ON EBA ROUTE

4.1.5 Transferring

Door-to-door travel times for trips involving a transfer to the EBA Route were compared with travel times to the same destination on routes taken before the busway opened. This analysis is intended to show the effect on travel time of transferring to the busway. The trips made before did not involve a transfer because, while many EBA Route riders reported having transferred for their current trip, very few indicated that they used to transfer.

Figure 4-6 (and Appendix C) show that, in spite of transferring, EBA patrons saved 8 to 12 minutes on trips to downtown; their trips are 15 to 23 percent shorter in each direction than they were. Note that in Figure 4-6, walk time combines access time both to and from the bus stop. After the busway, in-vehicle time combines regular route and EBA Route bus time. Wait time is time spent both waiting for the regular bus and transferring to the EBA Route. Because of the transfer, wait times are longer after the busway, especially at midday when EBA service is less frequent. However, the longer wait time is offset by the far shorter in-vehicle times.

Eight cases (passengers) were used for this analysis. However, if a selected case involved a trip made during the a.m. peak, the travel time for the same trip during the p.m. peak and midday periods was also estimated. In this way, the 8 cases were used to generate a total of 24 cases. A map of the origin points of these cases is provided in Appendix C. The method of selecting the routes and measuring travel times was the same as for the analysis in the previous section.

Evidence about transferring is also available from the on-board survey. A large portion, about 52 percent, of new route passengers perceived that transferring had gotten easier, probably because of the frequent service on the EBA, the major new route.

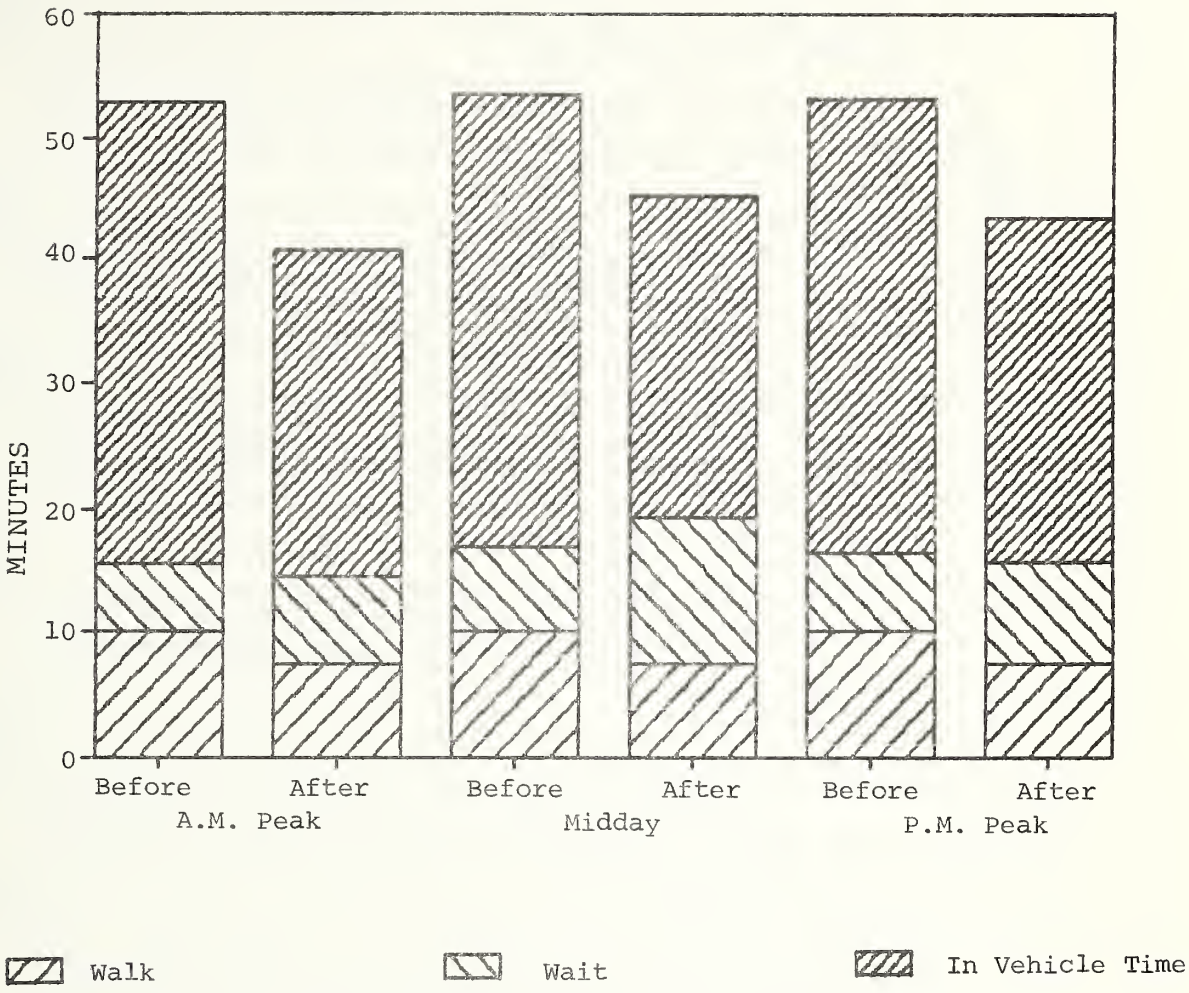


FIGURE 4-6. BEFORE AND AFTER DOOR-TO-DOOR TRAVEL TIMES FOR PATRONS NOW TRANSFERRING TO THE EBA

4.1.6 Perceived Changes In Travel Time to Downtown Zones On New and Diverted Routes

According to the on-board survey, new and diverted route passengers perceived large time savings after using the busway. Figure 4-7 shows how much time the riders of the four route types felt that they had saved since before the busway in travelling to downtown zones. Perceived time savings were between 13 and 21 minutes for new route passengers and between 4 and 8 minutes for diverted route passengers. These results are particularly striking considering that control route riders revealed a tendency to perceive that travel time had increased by between one and six minutes. These results also support the findings shown in Figure 4-4, that EBA Route passenges save about 21 to 24 minutes. The difference between new and control route riders' perceptions is statistically significant for each downtown zone using a two-tailed t-test and 95 percent confidence interval. In the case of the diverted routes, passengers' perceptions are similar to the measured AM-peak time savings reported in Table 4-1, but much more favorable than the measured PM-peak savings in the same table. The difference between diverted route and control route riders' perceptions is statistically significant for four of the eight downtown zones.

Table 4-2 shows the percentage of EBA and EBO Route riders who reported that they have saved time or increased their travel time since switching to these routes. About 77 percent of all new route riders reported saving at least ten minutes.

4.1.7 Perceived Travel Time Changes On Nonbusway Routes

Because PAT decreased service on nonbusway routes slightly when the busway opened, patrons of these routes were expected to perceive increases in travel times after the busway. As shown in Figure 4-7, nonbusway route riders generally perceived small increases in travel times, but the perceived changes were not significantly different from zero or the changes reported by control route riders.

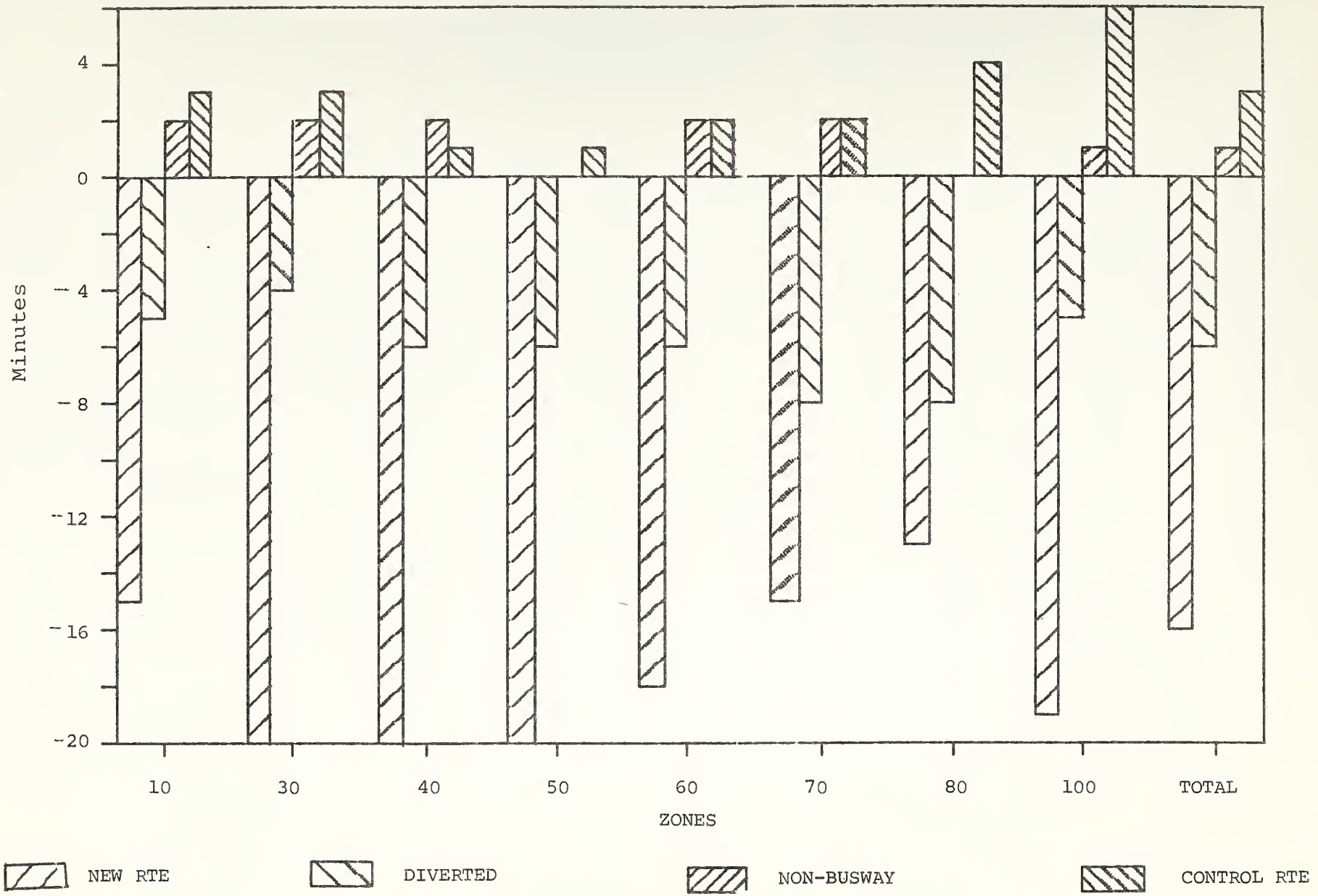


FIGURE 4- 7. PERCEIVED CHANGES IN TRAVEL TIME TO DOWNTOWN ZONES ON NEW, DIVERTED, AND NON-BUSWAY ROUTES

TABLE 4-2. CHANGES IN TRAVEL TIME SINCE SWITCHING TO EBA AND EBO ROUTES

Minutes Shorter	Percent
45 or more	5.0
30 to 44	19.2
20 to 29	23.8
10 to 19	28.5
1 to 9	4.6
0	11.1
Minutes Longer	
1 to 10	1.0
11 to 20	2.6
21 to 30	2.9
31 to 45	0.9
46 or more	0.4
	100.0

4.1.8 Boarding and Deboarding Time

Fares are collected when passengers board on inbound a.m. peak trips and when they deboard on outbound p.m. peak trips. The time required for the boarding and deboarding can make up a sizable portion of overall in-vehicle travel time. Table 4-3 shows that a bus that stops at all four of the stations shown, an EBA Route bus, for example, adds about 3 minutes onto a one-way trip, on average, because of boarding and deboarding.

TABLE 4-3. BOARDING AND DEBOARDING TIME AT BUSWAY STATIONS (seconds)

	Boarding a.m. Peak Inbound	N	Deboarding p.m. Peak Outbound	N
Wilkinsburg	36	246	35	179
Homewood	36	192	35	145
East Liberty	51	282	60	197
Negley	50	227	47	167
TOTAL	173	947	179	688
	(2.9 minutes)		(3.0 minutes)	

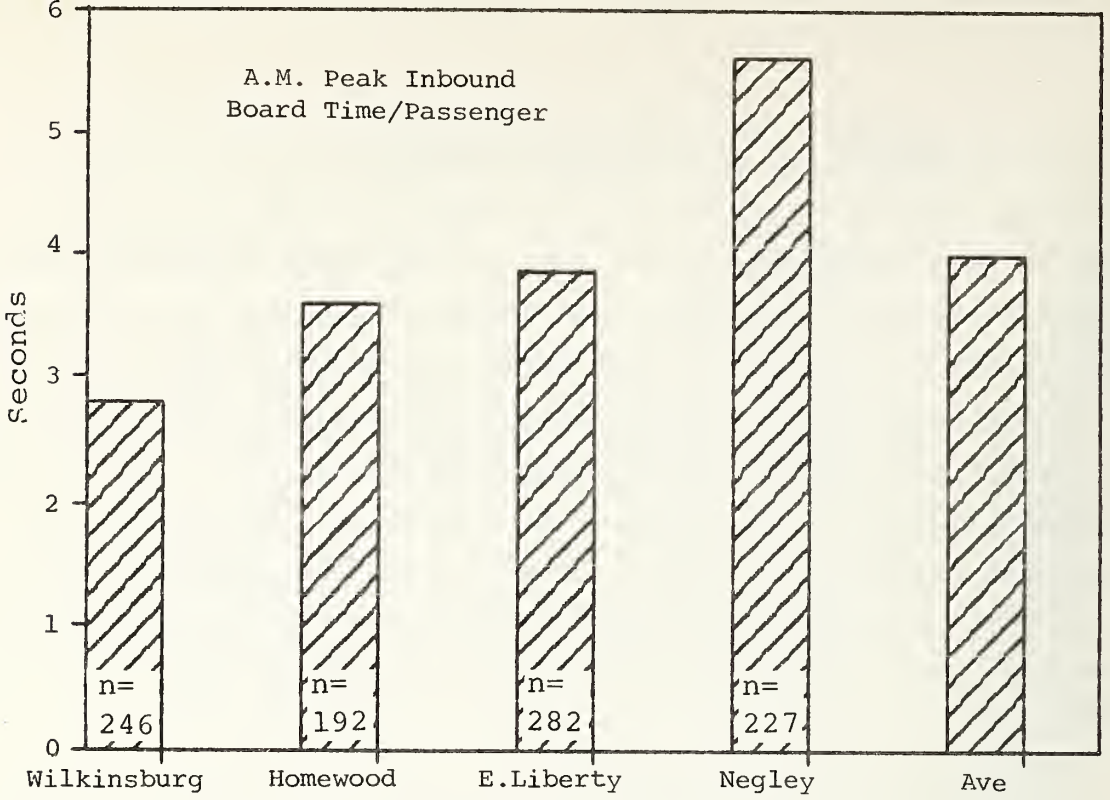
Source: Station Checks.

If the average time for boarding and deboarding at Herron Avenue is about half of what it is at these four stops because it is a little used stop, the total time at all busway stops together would be about 3.3 minutes, or about 11 percent of the door-to-door travel time for the EBA Route (as shown in Figure 4-4).

The average time required per passenger for boarding during the a.m. peak and for deboarding during the p.m. peak is about 4 seconds, as shown in Figure 4-8. The time required varies somewhat between stations. At each station, however, there is very little difference between boarding time per passenger during the a.m. peak and deboarding time per passenger during the p.m. peak.

The variation between stations can probably be accounted for by examining the numbers of passengers that typically board or deboard at each station. At stations such as Negley, where relatively few passengers board each bus that stops, time per passenger is high. A bus takes a certain amount of time to stop and start up again; this time becomes less significant on a per passenger basis as more and more passengers board or deboard.

Unlike regular buses, the articulated buses used on the EBA and EBO Routes have double doors that allow a line of passengers to deboard at the same time that a line of passengers is boarding. When the double doors are used in this way, boarding and deboarding time per passenger can be much lower than it is on regular buses. However, passengers on the articulated buses that PAT runs on the EBA and EBO Routes do not form the two lines. Drivers have not urged passengers to get into the habit and passengers themselves have not established this pattern. Travel times on the EBA and EBO could be reduced significantly if the double doors were used more efficiently.



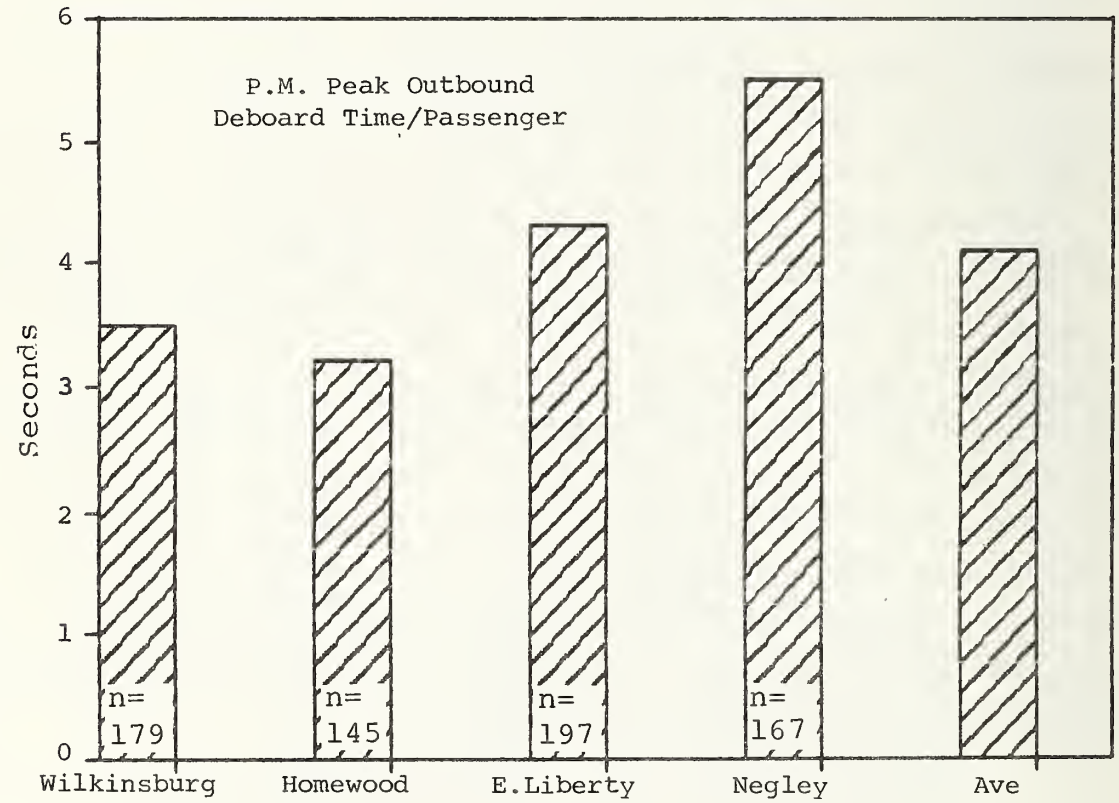


FIGURE 4-8. AVERAGE BOARDING AND DEBOARDING TIME PER PASSENGER AT EAST BUSWAY STATIONS

4.2 SERVICE RELIABILITY

4.2.1 Variability of Speeds on Diverted Routes

Service on diverted routes appears more reliable than before the routes began using the busway for trips made during the p.m. peak in the outbound direction. However, in the case of a.m. inbound service, reliability appears to have improved for some routes and to have remained about the same for others.

The standard of reliability used in this analysis is whether during the a.m. peak, for example, it takes buses about the same amount of time to make each scheduled trip. For computational convenience, travel times have been converted to speeds. This measure of reliability is an operational one that may or may not translate into service reliability from passengers' point of view. The effect of the busway on service reliability was estimated by examining changes in the standard deviations of line-haul speeds before and after various diverted routes began using the busway. Point check data was used for estimating speeds.

As shown in Table 4-4, for the p.m. peak outbound, standard deviations declined (reliability improved) after using the busway for each diverted route considered. The change was statistically significant for all but one of the eight routes analyzed. For the a.m. peak in-bound, a statistically significant decrease in standard deviation occurred for one third of the routes.

Another measure of operational reliability is standard deviation of speed as a percentage of mean speed (coefficient of variation). Before and after values for the coefficient of variation of line-haul speeds for diverted routes are shown below:

	BEFORE	AFTER
AM Peak Inbound	18.8	10.2
PM Peak Outbound	20.0	11.7

The percentages are considerably smaller (reliability greater) in the after case. In both the before and the after case, bus service is slightly less reliable in the p.m. peak than in the a.m. peak.

TABLE 4-4. STANDARD DEVIATIONS OF LINE-HAUL SPEEDS ON DIVERTED ROUTES BEFORE AND AFTER USING THE BUSWAY (m.p.h.)

A.M. PEAK INBOUND

Route	Before Busway	Before N	After Busway	After N	Statistical Significance*
P	4.59	17	3.25	30	Yes
PG	12.32	22	2.96	17	Yes
M	7.87	15	3.32	18	Yes
68A	3.78	18	2.65	24	No
68F	3.75	28	3.06	40	No
T	4.12	6	2.65	6	No
68J	2.28	24	2.87	23	No
MD	2.29	5	4.29	6	No
78A	1.93	16	5.31	13	Yes
AVERAGE	4.77		3.37		

P.M. PEAK OUTBOUND

Route	Before Busway	Before N	After Busway	After N	Statistical Significance*
68A	7.29	23	3.08	24	Yes
68F	5.49	23	3.66	22	Yes
68J	6.24	23	4.24	23	Yes
P	6.17	12	3.48	12	Yes
PG	6.23	41	3.72	41	Yes
M	6.47	22	4.09	23	Yes
MD	9.96	6	3.20	6	Yes
T	6.33	4	3.74	6	No
AVERAGE	6.77		3.65		

*An F-test at a 95 percent confidence level was used.

SOURCE: PAT point checks.

4.2.2 Passenger Perceptions Concerning Reliability

The on-board survey shows that diverted route patrons perceived some improvement in service reliability. About 38 percent of diverted route passengers, as compared to 20 percent of control route passengers reported that the buses stayed on schedule more often than before the busway (see Figure 4-9). These results do not seem quite as strong as might be expected from the measured improvements in reliability in line-haul travel time for diverted routes shown in Table 4-4. Possibly, the more consistent line-haul travel times have not been completely translated into better schedule reliability from the passengers' point of view. It is also possible that perceived changes in service reliability do not correspond to measured changes very accurately.

A comparison of on-board survey results for new route and control route passengers indicates that far more new route passengers perceived an improvement in reliability.

4.3 CHANCES OF GETTING A SEAT

4.3.1 Perceptions of Chances of Getting a Seat

New route passengers generally responded that their chances of getting a seat had improved after switching to busway routes. Increased service frequency and increased bus capacity on the EBA route because of the use of articulated buses, probably explain these results. Diverted route riders and nonbusway route riders also reported that their chances of getting a seat had improved somewhat, although to a lesser degree than new route riders:

> Are the chances of getting a seat better, no different, or worse than before the busway?

	New Routes	Diverted Routes	Nonbusway Routes	Control Routes
Better	60	31	27	13
No Difference	29	64	62	74
Worse	12	5	12	13

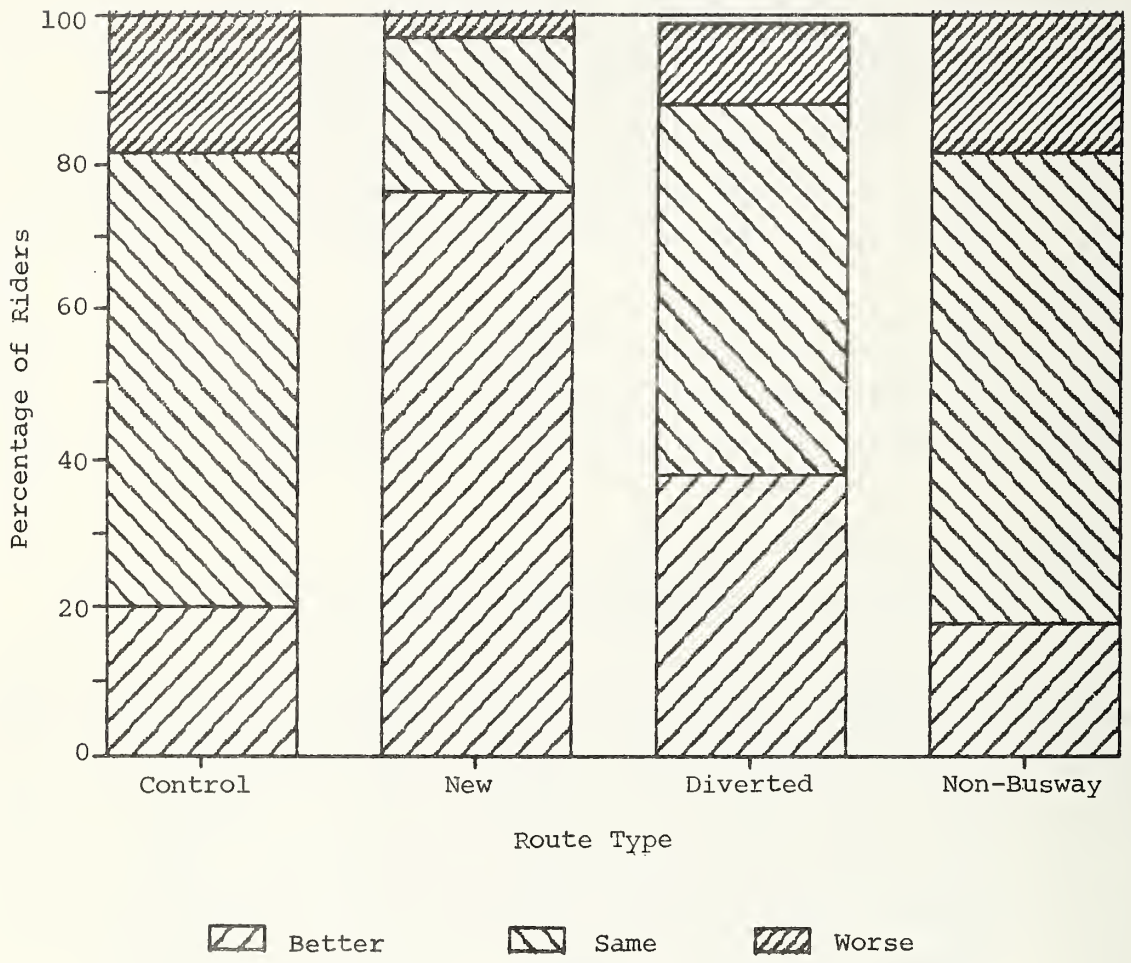


FIGURE 4-9. PERCENTAGE OF RIDERS WHO PERCEIVED THAT BUSES STAY ON SCHEDULE BETTER THAN BEFORE THE BUSWAY

In the case of the diverted routes, one possible explanation is that, as reported in the next chapter, ridership was down compared to the year before the survey due to a fare increase and economic conditions. In the case of nonbusway route riders, it is possible that because many patrons switched over to busway routes, more seats became available on the nonbusway routes.

4.3.2 Buses Arriving at Busway Stations With All Seats Taken

Station check data indicates the percentage of buses arriving at Negley Station filled to seating capacity. This data provides an indication of the chances of getting a seat.

PERCENTAGE OF BUSES ARRIVING AT
NEGLEY STATION WITH ALL SEATS TAKEN

EBA	a.m. Inbound	33.1	(n=163)
	p.m. Outbound	46.0	(n=126)
Other Routes	a.m. Inbound	29.7	(n=37)
	p.m. Outbound	20.5	(n=44)

Negley Station was used for this analysis because it is closer to Pittsburgh than the major busway stations (East Liberty and Wilkinsburg), and is therefore the station where passengers boarding buses for commuter trips would be least likely to get seats. East Liberty Station which is one stop further from Pittsburgh than Negley and which is the major boarding point along with Wilkinsburg, would have a much smaller percentage of buses arriving with all seats taken. (Boarding patterns are discussed further in the next chapter.) For the EBA Route, which uses all articulated buses, seat capacity was assumed to average 62. For the other routes, it was assumed to be 44 seats.

5. BUSWAY RIDERSHIP

The busway carries about 21,000 passengers per weekday, about 62% of them on the EBA and EBO. This chapter examines their trip making patterns, attitudes and characteristics, and estimates the extent to which the busway has increased ridership overall.

5.1 RIDERSHIP INCREASES

The busway offered a dramatic, highly visible, change in service in the east corridor. It appeared to offer improved service on many routes and a new, high-speed service in the form of the EBA and EBO routes. These new routes imitate, in many respects, the service that would be offered by a light rail line. One question raised by the busway is whether such a service will attract significant patronage compared to the type of service more traditionally operated on busways, consisting of express buses with extensive collection and distribution routings through suburban areas. And, as with a light rail line, the question arises whether the passengers on the new service are new riders, or ones who would have been riding anyway had the service not been changed.

5.1.1 Patronage Trends

Figure 5-1 shows ridership trends for the east corridor, which includes the busway, and the west corridor.* The west corridor was chosen as a comparison, or control, corridor because it experienced no major service changes during the period studied.

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*Figures 5-1 and 5-2 show ridership excluding transfers. Each rider is counted only on the route of first boarding.

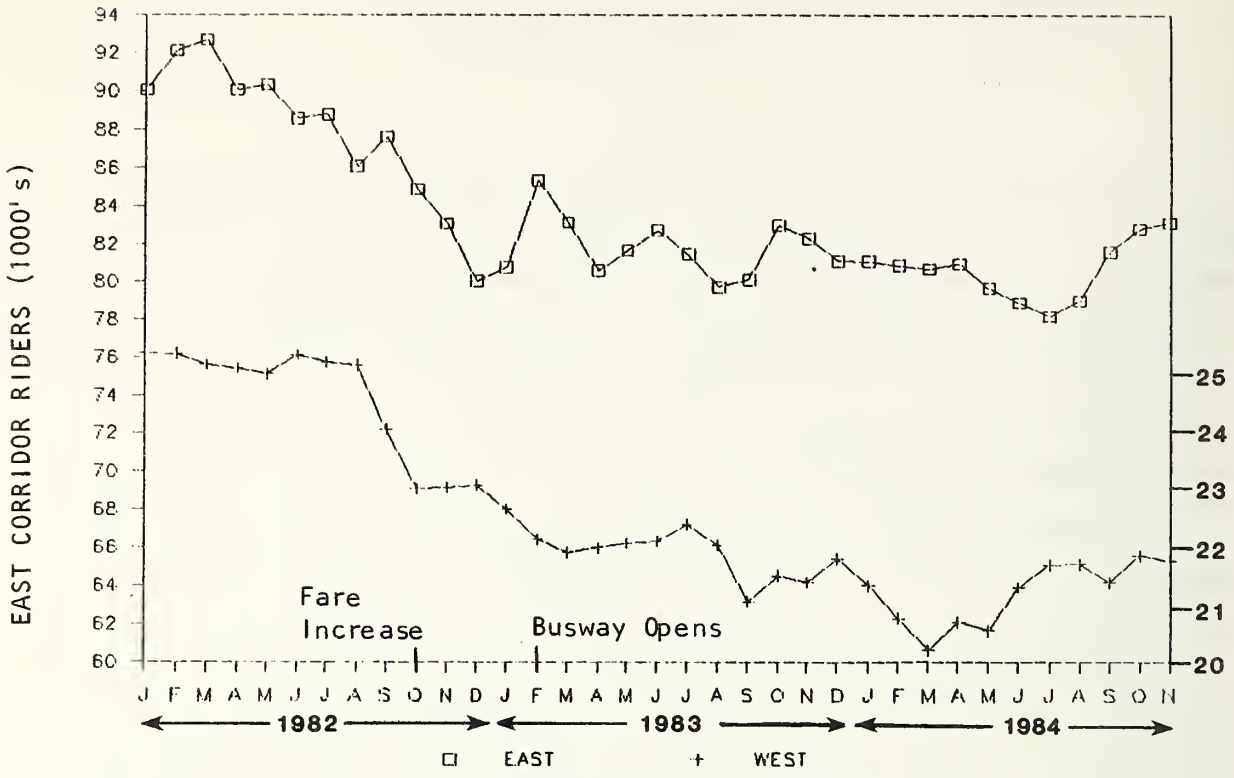

FIGURE 5-1. AVERAGE DAILY RIDERSHIP
(By Corridor, without transfers)

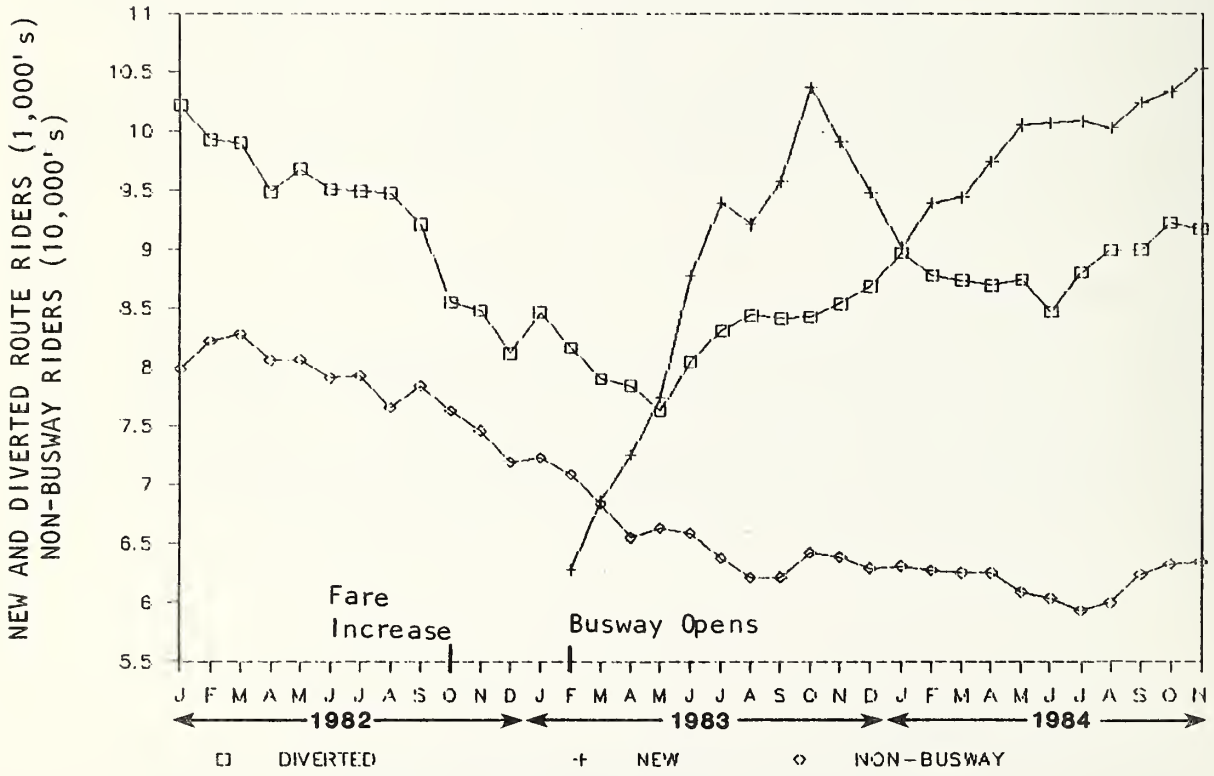

FIGURE 5-2. AVERAGE DAILY RIDERSHIP
(In East Corridor, without transfers)

In October 1982, four and a half months before the Busway opened, PAT's base fare was increased from $.75 to $1.00. Up until the fare increse, ridership in both corridors was stable or on a slight downward trend. After the fare increase, average weekday ridership in both corridors fell by a few thousand riders. At this crude level of analysis no definite impact of the Busway is apparent.

Figure 5-2 provides more detail on average weekday ridership in the east corridor. Nonbusway routes, those never shifted to use the busway, show a downward trend continuing throughout the analysis period. In addition to the drop following the October 1982 fare increase, there may have been a further drop corresponding to the introduction of the new busway routes. The diverted routes show depressed ridership following the October 1982 fare increase, followed by an increase beginning in the summer of 1983, a month or two after the time most of them were shifted to the busway.

5.1.2 Reported Increases and Shifts

Table 5-1 summarizes passengers' responses to the question, "How did you make this trip before the busway?" (or "before February 1983," in the case of nonbusway and comparison routes).

TABLE 5-1. HOW DID YOU MAKE THIS TRIP BEFORE THE BUSWAY?

	NEW	DIVERTED	NONBUSWAY	CONTROL
Same Route	---	57%	79%	87%
Other Route	79%	25%	4%	4%
Car	11%	7%	2%	1%
No Trip	10%	11%	15%	8%

Both the new and diverted routes appear to have attracted some "new" riders, who used to travel by car, compared to both the nonbusway and comparison routes. There is no evidence of trips having been created that were not made at all before. The great

majority of new route riders, and about a fourth of diverted route riders, used to ride other bus routes. These figures suggest that the net increase in average weekday corridor ridership was no more than about 1,900. This figure is computed by applying the percentage of riders who switched from automobiles to the average weekday boardings (including transfers) of about 13,000 for the new routes and 7,000 for the diverted routes. In fact some of these passengers represent normal turnover (balanced by shifts away from transit), as indicated by the few nonbusway and control route passengers who are former car users. Another piece of evidence is that about two-thirds of former auto users said that the busway was an important factor in their decision to start using the bus. The percentage of new and diverted route riders who reported that they did not make the trip at all is not significantly greater than for the nonbusway or control routes, so these trips are probably all normal turnover rather than trips created by the busway.

5.1.3 Analysis of Total Corridor Ridership

To further examine to what extent the busway may have increased total east corridor ridership, a multiple regression analysis was undertaken. The analysis used the same data shown in Figures 5-1 and 5-2, including adjustments to eliminate seasonal fluctuations and to eliminate double counting of riders whose trips included transfers. Computational details are provided in Appendix F.

The best model (based on significant coefficients and goodness of fit) is given below (t statistics are shown below the estimated coefficients):

$$\underset{}{\text{RIDERS}} = \underset{137.8}{90{,}307} + \underset{0.6}{(837)} * \text{PCTBWAY} - \underset{-2.2}{(141)} * \text{PERIOD} - \underset{-6.0}{(6{,}416)} * \text{FAREDUMMY}$$

(Adjusted R^2 = .82)

where:

RIDERS = Average daily east corridor passengers, seasonally adjusted, excluding transfers

PCTBWAY = Percentage of service switched to the busway - zero until February 1983, growing to 1.0 by November 1984.

PERIOD = A trend variable, starting at zero and increasing by one for each month.

FAREDUMMY = A variable representing the October 1982 fare increase - zero before October 1982, one thereafter.

In addition to the variables shown, three others were tested. One was a dummy variable representing a minor fare decrease in July 1984, mostly decreasing some zone changes and liberalizing the use of transfers. The others were total vehicle miles of service in the corridor and total nonagricultural employment. None of these variables had significant coefficients, and in fact, they often had coefficients with the wrong sign.

The regression results give an estimate that ridership in the east corridor may be higher by only 800 riders per average weekday, compared to levels that would be expected without the busway. What is more, the degree of error in this estimate is ±2,700 (95% confidence limit), so the model results do not rule out the possibility that no net increase occurred at all.

5.2 TRIP MAKING PATTERNS

5.2.1 Origins and Destinations

The great majority of all busway users are going to downtown Pittsburgh.* Of EBA/EBO passengers, 71% are going to downtown and 23% are going to Oakland. Of diverted routes (mostly expresses), 87% are going to downtown and 13% are going to various suburban locations.

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*For simplicity of expression results are stated in terms of inbound trips. Inbound deboarding locations and outbound boarding locations have been aggregated; similarly inbound boarding and outbound deboarding locations have been combined.

On the other trip end, only 3% of diverted route passengers board at a busway station; the remainder board at various suburban locations. EBA/EBO passengers board mostly at the beginning of the busway or at the East Liberty Station as shown below:

EBA/EBO Boarding Locations

Wilkinsburg	39%
Homewood	15
East Liberty	27
Negley	11
Herron	(less than 1%)
Other locations	8

The category "other locations" includes a few passengers boarding the EBO in Oakland; it may also include some answers based on a misunderstanding of the survey question.

Figure 5-3 shows the home-end origin of surveyed EBA and EBO passengers. The origins are mostly near the outer half of the busway, and mostly to the north of the busway. Relatively few come from more outlying locations. These patterns make sense considering that most EBA and EBO patrons reach the busway on foot. Passengers living in more suburban locations would be more likely to board a bus which goes directly to downtown without a transfer, especially since the peak period runs mostly use the busway. Figure 3-5 illustrates the draw area of many such routes. Passengers to the south also have many other options for a direct trip downtown.

5.2.2 Ridership by Route

The EBA is the most heavily used route in PAT's system. Weekday ridership in November 1983 averaged 11,468 (including transfers), with heavy usage in both peak and off-peak periods, as well as in the evening. Ridership on the diverted routes is heavily concentrated in the peaks. Boardings by route, direction and time period are given in Table 5-2.

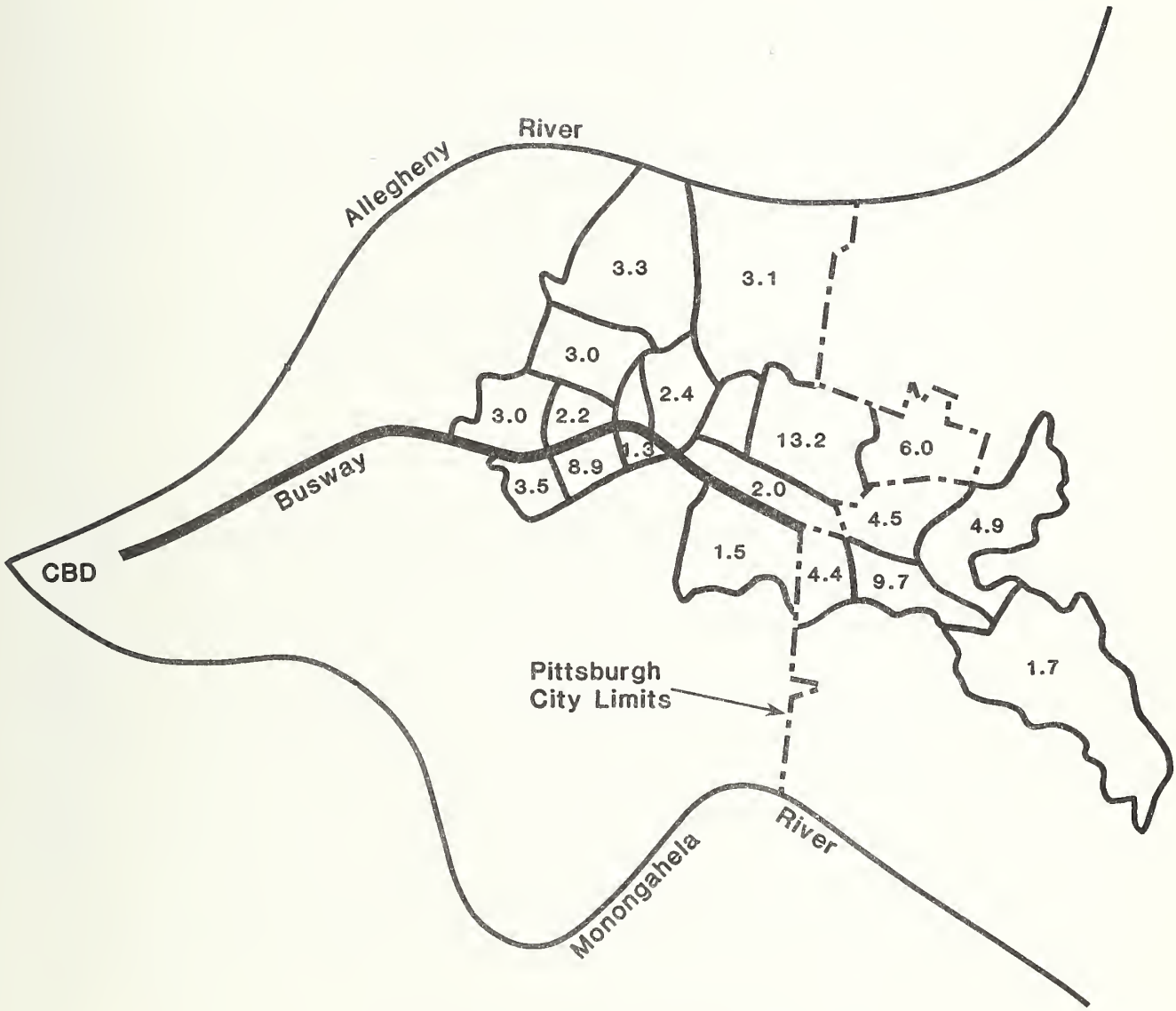

FIGURE 5-3. ORIGINS OF EBA AND EBO PASSENGERS
(Percent of passengers for all zones accounting for one percent or more of the total.)

TABLE 5-2. BUSWAY RIDERSHIP BY ROUTE AND TIME PERIOD

	AM PEAK		MIDDAY		PM PEAK		ALL DAY	
	In	Out	In	Out	In	Out	In	Out
New Routes								
73B	116	6	--	--	17	83	133	89
78C	39	--	--	--	--	10	39	10
88A	128	12	26	25	24	95	178	132
EBA	2,089	410	2,223	1,966	977	1,869	6,053	5,415
EBO	220	88	325	325	54	206	637	666
Total New	2,592	516	2,574	2,316	1,072	2,263	7,040	6,312
Diverted Routes								
68A	206	--	31	--	11	114	248	114
68B	122	1	15	--	1	201	138	213
68F	341	--	--	--	26	184	367	184
68J	218	8	--	38	17	183	235	229
68D	314	19	226	130	33	279	601	508
68G	428	12	401	304	54	427	900	892
77E	114	5	79	54	18	126	211	258
78A	--	--	--	--	--	82	--	82
G	16	--	--	--	--	18	16	18
U	--	--	--	--	--	30	--	30
HP	--	--	--	22	4	131	4	153
LP	225	9	198	151	43	205	466	365
M	--	--	--	--	--	108	5	108
MD	--	--	--	--	--	21	--	31
P	--	--	--	--	--	89	--	89
PG	287	10	71	63	5	405	363	494
S	--	1	--	--	--	55	--	56
T	--	--	--	--	--	22	--	22
TOTAL DIVERTED	2,298	64	1,021	762	212	2,680	3,554	3,790

Source: PAT Driver Counts, November 1983

5.2.3 Bus Stop Access Mode

Busway passengers are more likely to have transferred, or come by car, than passengers of nonbusway routes in the east corridor or the rest of the system, as shown in Figure 5-4. In the case of the diverted routes, 33% either park and ride or are dropped off, which conforms to expectations for peak period express service. In the case of the new routes, 22% transfer from another bus. What is more interesting perhaps is that nearly two-thirds walk to the stations to board the new routes, chiefly the EBA and EBO. Automobile access, at 15%, is also somewhat above average compared to nonbusway routes. Figure 5-5 shows that automobile access is primarily limited to the first two stations, Wilkinsburg and Homewood. Only the Negley station has little access by transferring, probably due to lack of transferring opportunities.

Among the park-and-ride passengers, there is only a moderate difference between new, diverted, and control route passengers in the percentage who carpooled to the bus stop. About 31 percent of new route passengers carpooled, as compared to 14 percent diverted route, and 26 percent control route passengers.

5.2.4 Load Profiles

Load profiles for the EBA, computed from the station checks, are summarized in Table 5-3. They show a pattern in agreement with the boarding patterns discussed before. Loads are highest at the end of the busway near downtown. Note that the loads shown are averages, so many buses have well over 70 passengers peak load.

TABLE 5-3. EBA LOAD PROFILES

	Average Passengers Per Bus	
	A.M. Peak Inbound	P.M. Peak Outbound
Wilkinsburg	12	23
Homewood	16	31
East Liberty	41	49
Negley	57	61
Herron	72	76
Downtown (Oliver & Penn)	19	34

Source: Station checks

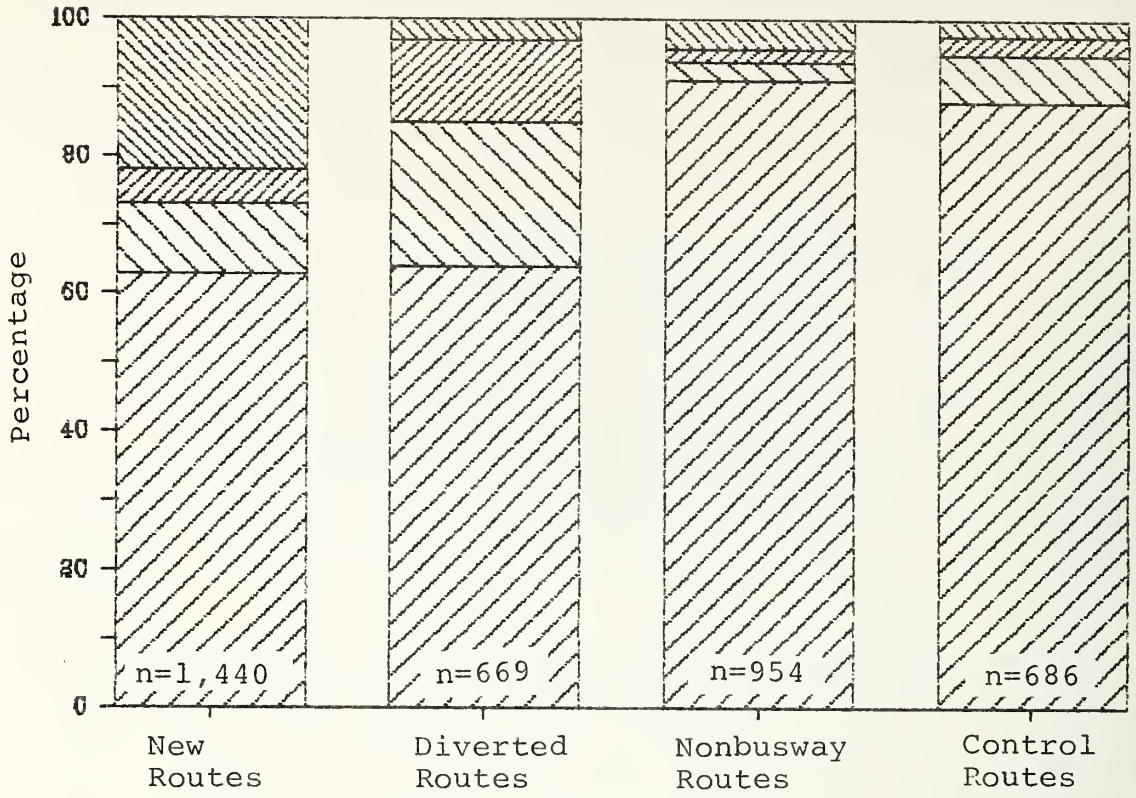

FIGURE 5-4. MODE TO BUS STOP BY ROUTE TYPE

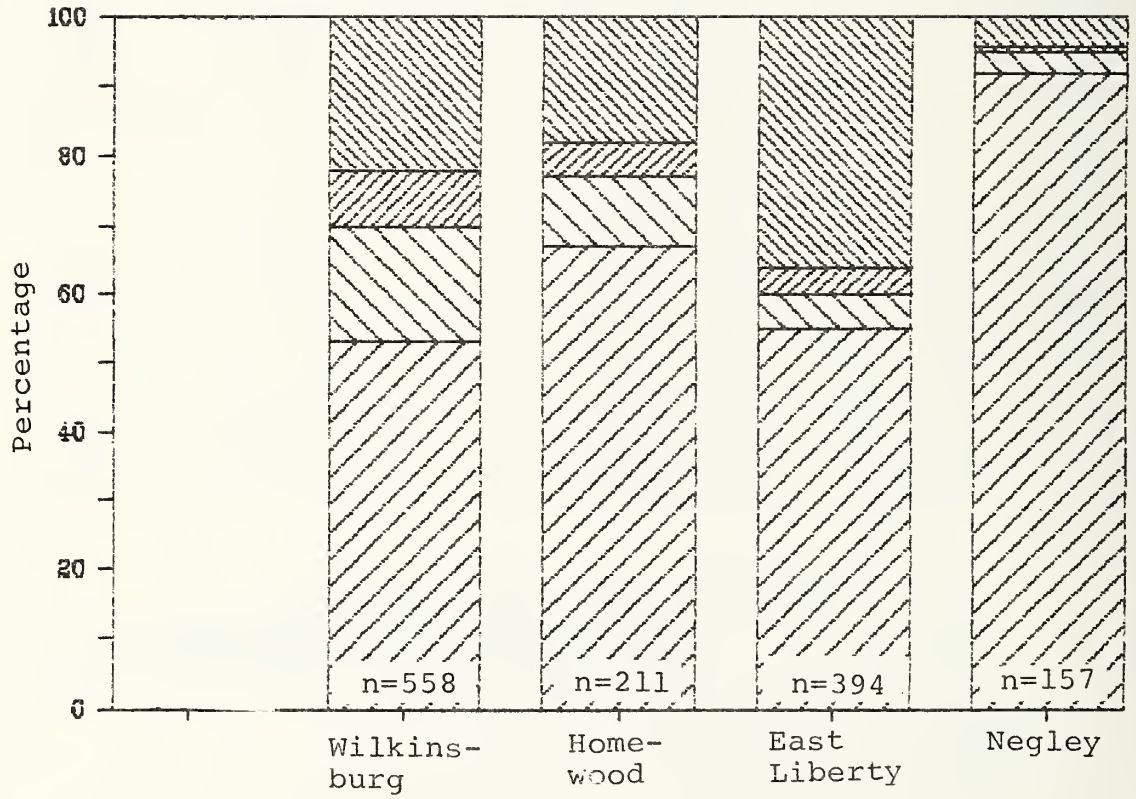

FIGURE 5-5. MODE TO BUS STOP FOR EACH BUSWAY STATION

Walk Park-N-Ride Dropped Off Another Bus

5.3 PARKING

5.3.1 Parking Space Availability Near Busway Stations

On-street parking is the only option at all busway stations except for Wilkinsburg, where a municipal metered parking lot is also available.

No parking lots were constructed to serve the busway. A parking survey was conducted by PAT in March 1984 of all areas within about two blocks of each busway station (see Appendix B). The total number of parking spaces found within these areas at each station is shown below:

NEGLEY	EAST LIBERTY	HOMEWOOD	WILKINSBURG STATION & TERMINAL
361	377	147	1,042

Parking does not appear to be a problem near busway stations. The survey found that parking space occupancy rates near busway stations are high, but still well below capacity during both the a.m. peak and midday periods. The survey also found that occupancy rates do not vary significantly between stations (see Figure 5-6). They ranged from about 60 to 71 percent during the a.m. peak, and from 60 to 74 percent at midday. Rates are slightly higher in parking areas within one block of the stations. It should be noted, however, that because local officials did report parking problems in the Negley and Wilkinsburg Station area, these results may not reflect the parking situation with complete accuracy (see Section 7.1).

The occupancy rates increased between the a.m. peak and midday at Homewood and Wilkinsburg Stations. At Wilkinsburg, the increase is probably due to shoppers coming into the nearby commercial district at midday, and to the influx of park-and-ride passengers. At Homewood, the increase is probably due just to park-and-ride passengers. At Negley Station, where there is very little park-and-ride patronage and no adjacent commercial development, occupancy rates decrease after the a.m. peak. Occupancy rates are about the same at a.m. peak and midday at

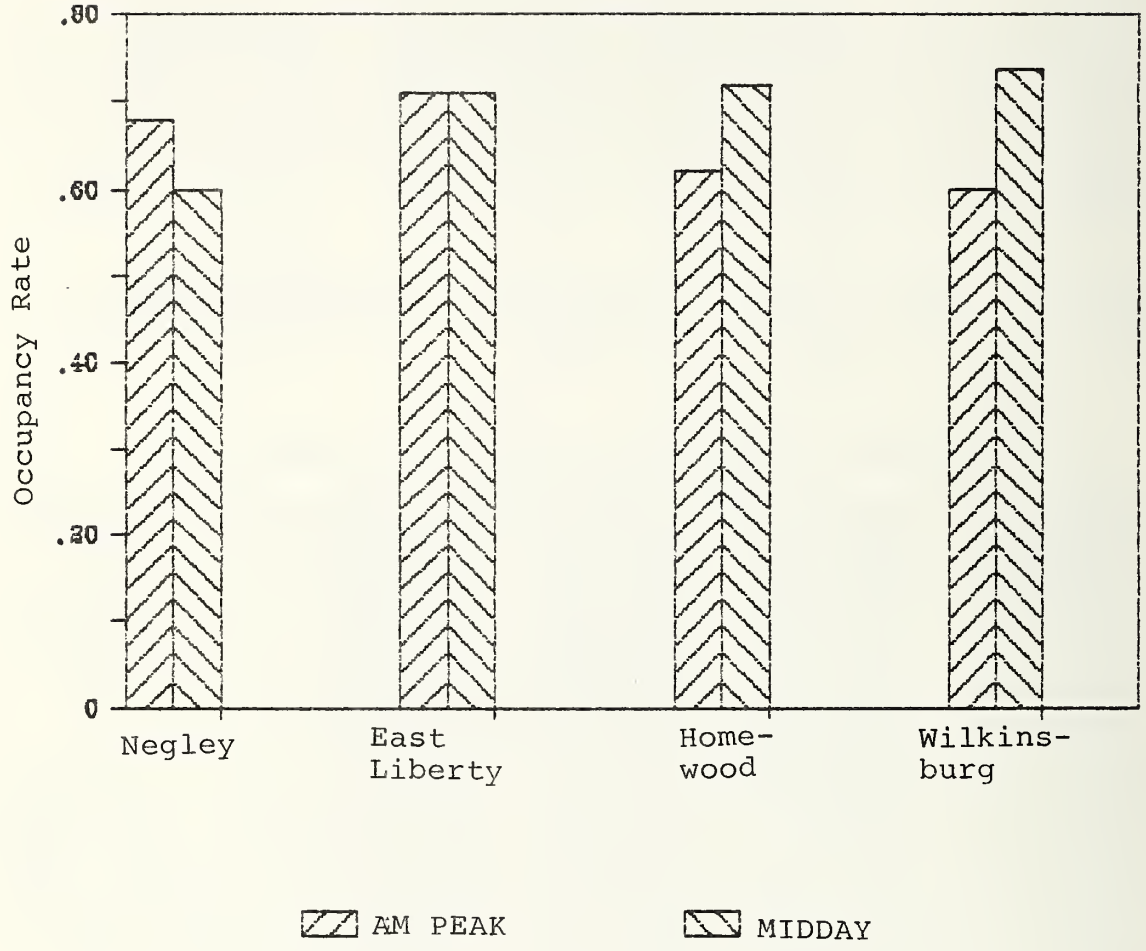

FIGURE 5-6. PARKING SPACE OCCUPANCY RATES AT BUSWAY STATIONS AT AM PEAK AND MIDDAY

East Liberty Station. This station has a moderate amount of park-and-ride usage. The influx of persons to the business district there is probably offset by residents who park on the street, leaving during the a.m. peak for jobs at other locations.

5.3.2 Distance Between Parking Space and Bus Stop

Fewer new route passengers than passengers of the other route types park within a block of the bus stop, and more park three or more blocks away. In addition, fewer new route passengers than passengers of the other route types reported finding a parking space immediately, and more new route passengers reported taking anywhere from a few minutes to more than five minutes to find parking. The results reflect the fact that most new route park-riders park on the street, while most diverted route park-riders use the free lots provided by PAT.

5.4 ATTITUDES AND CHARACTERISTICS

Because of the time savings offered by busway routes (new and diverted), they might be expected to attract a different type of passenger than other routes. The on-board survey shows that before the busway, a higher percentage of new and diverted route riders took cars for the trip than riders on other routes (see Table 5-1). Busway routes were therefore expected to have fewer transit-dependent and low income passengers than other routes.

In addition, different characteristics were expected because much higher percentages of new and diverted route passengers than other route passengers changed bus routes when the busway opened. Most control and nonbusway route passengers took the same bus route before and after the busway. The busway routes could have attracted only certain types of passengers from other routes. For example, these routes could be very convenient to residents of particular neighborhoods (who have certain socioeconomic characteristics) and these residents could account for most of the riders who switched routes.

Since a large portion of new and diverted route riders reported time savings after taking busway routes, they were also expected to show very positive attitudes towards transit.

5.4.1 Passenger Characteristics

Figure 3-5 on page 27 is a schematic map of most diverted routes. It shows where most of the patronage for these routes is drawn from. The diverted routes are mostly expresses, and many run in peak hours only. As might be expected, a smaller percentage of diverted route riders than other route passengers are transit-dependent. Table 5-4 shows that the percentage of persons on these routes with no usable vehicles in the household changed very little after the busway, but a higher percentage had two or more usable vehicles in the household. Similarly, a higher percentage had a vehicle available for the trip. The control route riders changed very little with regard to these characteristics.

The diverted route passengers had higher incomes than the other route types both before and after the busway. An explanation for this is that the diverted routes are mostly expresses that run at commute hours and are used for work trips; therefore, few diverted route passengers are unemployed, while the percentage of unemployed people might have been fairly high on other routes. After the busway, incomes of diverted route passengers were about the same as before (allowing for inflation). However, the incomes of nonbusway and control route passengers declined (probably because of unemployment). Similarly, almost all diverted route passengers reported that they were making work trips both before and after the busway, but the percentage of control and nonbusway riders taking work trips declined by about 20 percent.

New route passengers are only slightly less transit-dependent than control route passengers and slightly more affluent. New route and control route passengers reported a similar distribution of trip purposes. This result is somewhat surprising since a much higher percentage of new route passengers used to make the trip by car.

TABLE 5-4. PASSENGER CHARACTERISTICS BY ROUTE TYPE

	Diverted		Nonbusway		Control		New
	1982	1983	1982	1983	1982	1983	1983
Usable Vehicles in Household							
0	12.8	10.7	27.5	35.3	23.9	22.3	31.6
1	59.0	41.6	45.9	44.6	46.1	43.8	42.9
2+	28.2	47.7	26.6	20.0	30.0	33.9	25.5
Was Vehicle Available For This Trip?							
Yes	50.0	61.6	43.1	36.1	46.6	48.8	45.0
No	50.0	38.4	56.9	63.9	53.4	51.2	55.0
Household Income							
$10,000 or less	13.0	6.7	22.2	25.9	23.5	23.7	19.9
$11,000 to $20,000	21.7	20.9	29.7	30.0	33.9	29.3	29.9
$21,000 to $40,000	39.1	48.1	32.8	29.9	31.0	31.9	38.8
$41,000 or more	26.1	24.3	15.3	14.2	11.6	15.0	11.6

Note: 1982 data are from October 1982 PAT systemwide on-board survey.

5.4.2 Attitudes Toward the Busway

Both new and diverted route riders revealed very positive attitudes towards the busway. Of the riders who switched modes, about 78 percent of new route passengers (n=144), and 61 percent of diverted route passengers (n=36) said that the busway was a very important consideration in their decision to start taking the bus. Comments written in on the on-board surveys were mostly favorable.

5.5 CHANGES IN TRIP STARTING TIME

Many passengers on new and diverted routes reported starting their trips later than they used to before the busway. This is undoubtedly a result of travel time savings. Because a

significant share of the east corridor bus patronage is composed of new and diverted route passengers, the pattern of peaking in the corridor has probably been altered by these changes in trip starting time. During the a.m. peak, about 54 percent of new route passengers and 29 percent of diverted route passengers started their trips later and very small percentages started their trips earlier. See Figure 5-7. Almost none of the non-busway and control route passengers left later, but a large percentage of control route passengers, 30 percent, reported leaving earlier. The percentages of new and diverted route passengers who left later to start their trips during the p.m. peak were not quite as high as during the a.m. peak.

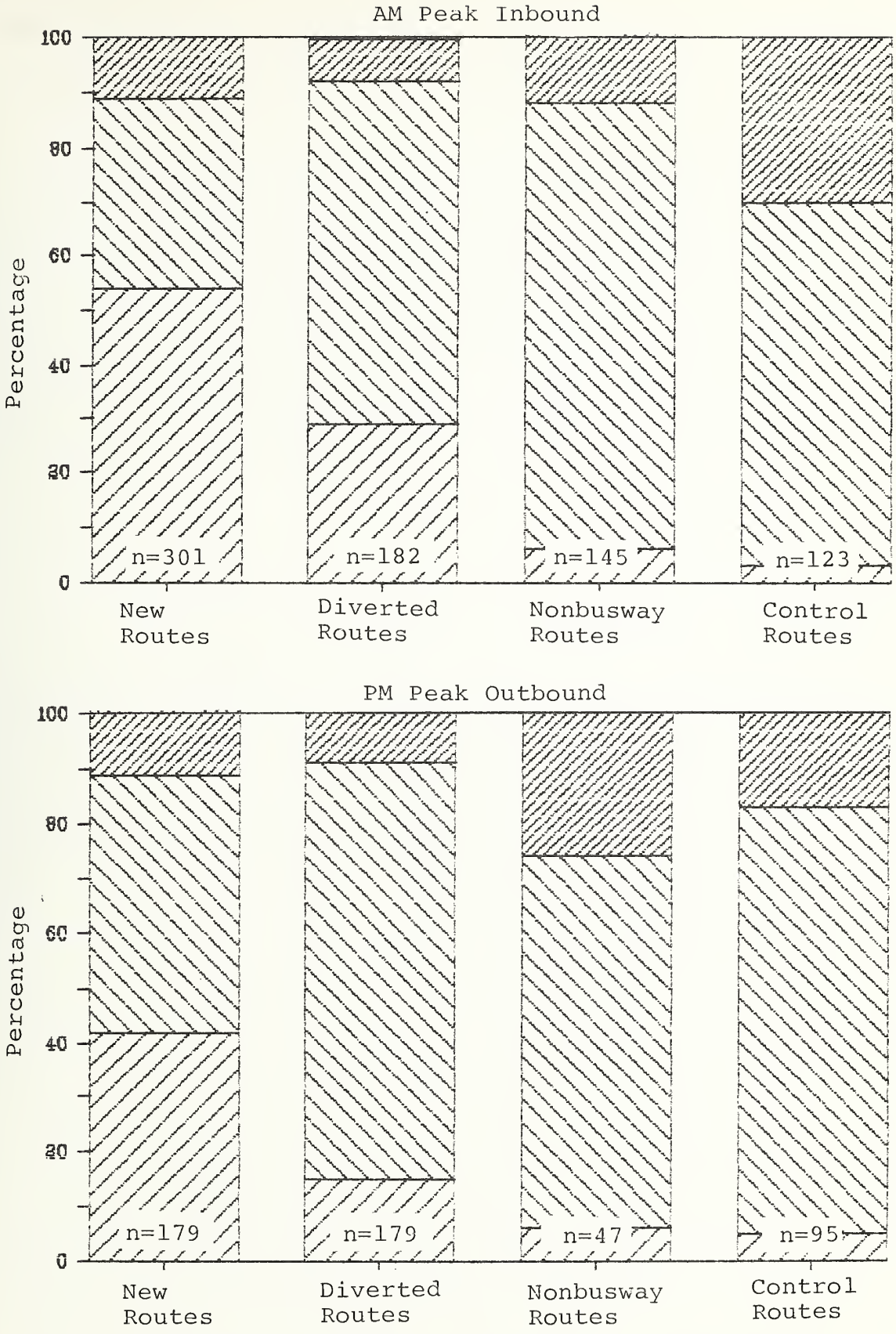

Figure 5-7. DO YOU LEAVE FOR YOUR TRIPS LATER, AT THE SAME TIME, OR EARLIER THAN YOU DID BEFORE THE BUSWAY?

6. COST ANALYSIS

This section documents the capital costs and labor hours for all phases of busway construction--planning, design, track relocation, and busway construction. Operating costs are estimated for new routes, diverted routes, and all other routes in PAT's system. Operating costs per service unit are presented for comparing busway routes with other routes and with light rail systems. A capital cost comparison between the busway and light rail systems is also included.

6.1 CAPITAL COSTS

6.1.1 Budget Items

Costs and labor hours for planning, designing, and constructing the East Busway are shown in Table 6-1. Planning costs covered mainly PAT staff time for community outreach between 1974 and 1983. Two staff members each spent about 25 percent of their time on this effort at an average hourly rate of $21.50,* including burden. Community outreach involved introducing the busway concept and later, soliciting citizen input on facility design. All federal capital assistance grant requirements were met regarding alternative analyses. About two-thirds of Engineering Services was for design of the facility and the remaining third was for engineering inspections and record keeping during the construction. Inspections included soil and concrete tests. All of these costs were for labor at an estimated average hourly rate of $25.00, including burden. Construction and Procurement contract costs included materials and labor for the Conrail track and utility relocation and for building the busway. PAT Project Administration costs covered staff time to oversee the design and construction contracts.

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*Interview with Norman Voigt, PAT.

TABLE 6-1. CAPITAL COST SUMMARY
(1983 Dollars)

COST ITEM		COST (1983 Dollars)	HOURS
PLANNING		223,600	10,400
ENGINEERING SERVICES		14,801,050	592,042
PROJECT ADMINISTRATION (PAT)		3,917,680	195,884
REAL ESTATE/RELOCATION		24,304,420	
SUBTOTAL		43,246,750	798,326
CONSTRUCTION CONTRACTS:			
EB-1	Walls	9,800,660	70,927
EB-2	Grading/Drainage	12,114,690	158,661
EB-3	Centre Avenue Bridge	2,324,060	47,362
EB-4	Graham/Lang Bridge	746,430	7,995
EB-5	Line Section, Highland Ave. to East Liberty Station; East Liberty Station	16,473,110	266,216
EB-6	Line Section, Grant to 16th Street	3,130,680	45,729
EB-7	Line Section, 16th Street to Bloomfield	9,663,140	149,352
EB-8	Line Section, Bloomfield Street to Highland Avenue	10,602,080	168,055
EB-9	Line Section, East Liberty Station to Murtland Street; Brilliant Bridge	6,546,830	94,902
EB-10	Line Section, Murtland Street to Wilkinsburg Station	8,758,940	121,928
EB-13	Roadway lighting, signing, marketing, and traffic signals	1,960,540	31,607
EB-14	Station Finishes and Landscaping	2,964,640	58,725
EB-15	Neville Ramp	5,160,256	87,451
EB-16	Penn Station Basement, Cut-off Wall	722,852	22,582
SUBTOTAL		90,968,908	1,331,492
OTHER CONSTRUCTION CONTRACTS:			
	Conrail Relocation	20,276,880	
	B&O Relocation	74,980	
	Utility Relocation:		
	Duquesne Light	582,630	
	Bell Telephone	685,370	
	Equitable gas	97,260	
SUBTOTAL		21,717,120	
TOTAL		155,932,778	

Real Estate and Relocation was for the land purchase, relocation of residents, and all related appraisals and legal fees.

All costs in Table 6-1 were adjusted for 1983 dollars.* PAT provided information on cost estimates. The inflation adjustments were based on the year in which half of the contract was completed, as shown in Appendix E.

6.1.2 Capital Costs Per Service Unit

For new and diverted routes combined, on-busway seat miles were used for estimating capital costs per service unit, as shown in Table 6-2. The maximum peak seat miles theoretically possible

TABLE 6-2. CAPITAL COSTS PER SERVICE UNIT
(1983 Dollars)

SERVICE UNIT	UNIT COST (1983 dollar)
On Busway Seat Miles	2.60
On Busway Peak Seat Miles	4.63
Theoretical On-Busway Peak Seat Miles	2.13

was estimated assuming 24 second headways**, a 2.25-hour peak period, 63 seats per articulated bus, and an average trip length of 13.6 miles (2 lengths of the busway). Busway seat miles and peak seat miles were estimated by determining the portion of route travelled on the busway and the portion of all trips made at peak. Information from PAT on the make and model of buses allocated to each route was used to estimate average seats per bus for each route.

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*U.S. Bureau of Labor Statistics. Monthly data (Producer Price Index) in U.S. Bureau of Economic Analysis, Survey of Current Business.

**Michael Baker, Jr., Inc., Capacity Analysis and Peak Hour Loading for PATWAYS, Rochester, PA: 1968.

6.2 OPERATING COSTS

6.2.1 Operating Costs for New, Diverted, and Other Routes

Weekday operating costs for 1983 were estimated for new busway routes, diverted routes, and all other bus routes in PAT's system. The method used was developed for a recent PAT study.* The method first determined which operating cost items relate to the service units of number of vehicles, vehicle hours, vehicle miles, and passengers; then it calculated a unit operating cost for each item, which was used to estimate expenses for each route type. Inaccuracies result from this method because many operating costs 1) are dependent on the size of more than one service unit, and 2) are not proportional to the service unit size. Operating costs broken down by budget item are shown in Table 6-3. Appendix G shows how these costs were calculated. Annual maintenance costs for the East Busway Facility are shown in Table 6-4. These costs appear under Table 6-3's budget items of "Maintenance of Track and Roadway" and "System Security." Operating costs include all downtown and suburban circulator service by busway routes. Costs for service connecting to busway routes are not included.

6.2.2 Operating Costs Per Service Unit

Operating costs per service unit were calculated so that the operating efficiency of new and diverted busway routes and all other routes could be compared. Operating costs per unit of service were expected to be lower for new and diverted routes than for the other routes. Some of the major operating costs, such as labor, are based on vehicle hours. As shown on the following page, vehicles operate more miles per hour, on average, on new and diverted routes than on other routes:

VEHICLE MILES PER VEHICLE HOUR	
New Routes	15.8
Diverted Routes	19.6
All Other Routes	11.5
System Total	13.6

*PAT Technical Memorandum, "Methodology Used in the Fare Structure Study," Barton-Aschman, March 1982.

TABLE 6-3. ANNUAL WEEKDAY OPERATING COSTS (1983 Dollars)

Functions Per Bus Hour (2,411,596 bus hours)	NEW BUSWAY ROUTES (45,540 bus hrs.)	DIVERTED ROUTES (82,970 bus hrs.)	REST OF PAT'S BUS SYSTEM (2,283,086 bus hrs.)
Revenue Vehicle Operation (Labor)	882,638	1,608,091	44,249,860
Personnel Administration	23,361	42,561	1,171,155
General Legal Services	6,909	12,587	346,344
General Insurance			
Regular Buses	319	1,709	47,032
Articulated Buses	962		
Data Processing	9,472	17,257	474,859
Finance and Accounting	20,707	37,726	1,038,119
General Management	14,814	26,990	742,688
SUBTOTAL	959,182	1,746,921	48,070,057
Functions Per Bus Passenger (73,068,930 pass.)	(3,381,090 pass.)	(2,157,330 pass.)	(67,530,510 pass.)
Vandalism Repairs of Revenue Vehicles	5,072	3,236	101,296
Maintenance of Fare Collection Equipment	8,791	5,609	175,579
Ticketing and Fare Collection	45,780	29,210	914,363
System Security			
Busway	110,880	87,120	
Rest of System	1,910	8,410	381,547
Customer Service	37,192	23,731	742,836
Promotion	12,882	8,219	257,291
Injuries and Damages	95,685	61,052	1,911,113
Safety	5,748	3,667	114,802
SUBTOTAL	323,940	230,254	4,598,827

TABLE 6-3. ANNUAL WEEKDAY OPERATING COSTS (1983 Dollars)
(Continued)

Functions Per Bus Mile (28,618,850 bus miles)	NEW BUSWAY ROUTES (717,260 bus mi.)	DIVERTED ROUTES (1,630,590 bus mi.)	REST OF PAT'S BUS SYSTEM (26,271,000 bus mi.)
Revenue Vehicle Operation (Fuel and Tires)			
Regular Buses	72,481	588,480	9,481,204
Articulated Buses	289,446		
Maintenance Administration (Vehicles)	42,963	97,672	1,573,633
Inspection and Maintenance of Revenue Vehicles			
Regular Buses	91,720	744,690	11,997,966
Articulated Buses	366,279		
Accident Repairs of Revenue Vehicles	17,329	39,395	634,707
Maintenance of Track and Roadway			
Busway	53,514	42,046	
Rest of System	41	641	14,974
Operation and Maintenance of Electric Power Facilities	1,578	3,587	57,796
Purchasing and Stores	14,317	32,547	524,369
SUBTOTAL	949,668	1,549,058	24,284,649
Functions Per Scheduled Bus (319,620 buses)	(11,890 buses)	(19,990 buses)	(287,740 buses)
Transportation Administration	91,249	153,411	2,208,232
Revenue Vehicle Movement Control	95,516	160,586	2,311,502
Scheduling of Transportation Operations	30,274	50,899	732,644
Servicing and Fuel for Service Vehicles	10,854	18,249	262,678
Inspection and Maintenance of Service Vehicles	17,032	28,636	412,188
Maintenance of Vehicle Movement Control Systems	5,361	9,013	129,742
Maintenance of Garage and Shop Buildings	39,054	65,659	945,111
Maintenance of General Administration Buildings	13,803	23,206	334,037
Accident Repairs of Buildings	2,346	3,944	56,771
General Engineering	11,758	19,768	284,546
Real Estate Management	3,629	6,101	87,818
Office Management and Services	8,570	14,405	207,345
Planning	4,966	8,350	120,189
General Function	22,793	38,321	551,598
SUBTOTAL	357,205	675,699	8,644,401
TOTAL	2,589,995	4,201,932	85,597,934

TABLE 6-4. ANNUAL MAINTENANCE COSTS FOR EAST BUSWAY FACILITY (1983 dollars)

BUDGET ITEM	MARCH-DECEMBER 1983 $	MARCH '83-FEBRUARY '84 (Estimated $)
Roadway Maintenance	16,300	19,560
Snow Removal	7,440	8,928
Light Maintenance	30,200	36,240
Land Support Maintenance and Utility Service	25,700	30,840
Security		198,000
Station Maintenance		
TOTAL		293,558

As shown in Table 6-5, new routes have the lowest operating costs per passenger trip and passenger mile, while diverted routes' unit costs are the highest for these service unit measures.

TABLE 6-5. WEEKDAY OPERATING COSTS PER SERVICE UNIT BY TYPE OF ROUTE* (1983 Dollars)

	NEW ROUTES	DIVERTED ROUTES	ALL OTHER ROUTES IN THE SYSTEM
Per Passenger Trip	0.76	1.95	1.27
Per Peak Passenger Trip	1.32	3.19	3.09
Per Passenger Mile	0.15	0.37	0.24
Per Peak Passenger Mile	0.27	0.60	0.58
Per Seat Mile	0.06	0.06	0.07
Per Peak Seat Mile	0.12	0.09	0.16
Per Vehicle Mile	3.61	2.58	3.26

*Includes suburban and downtown circulator service.

According to the method used to allocate operating costs to the different route types, only a very small portion of the costs are related to ridership levels. Because the new routes operate closer to capacity than the other routes (or with more passengers per vehicle mile of service), operating costs per passenger or passenger mile are low. Diverted routes costs are high because they operate further below capacity than the others. The efficiency of diverted routes is somewhat higher at peak, however.

Costs per vehicle mile are lowest for diverted routes because these routes operate at higher speeds than the others. For the new routes, costs per vehicle mile may be the highest because these routes operate more buses per hour than the other routes, and the cost method allocates a large portion of operating costs according to the number of scheduled buses.

Even though the unit costs for new routes are high per vehicle mile, they are similar to the other route classifications on a seat mile basis because of the higher seat capacity of the articulated buses used on new routes. For peak seat miles, however, diverted route costs are lowest because a higher portion of diverted route trips are made at peak than the new routes and all other routes.

6.3 LIGHT RAIL SYSTEM--NEW BUSWAY ROUTE COMPARISON

6.3.1 Operating Costs

Busways are viewed as a way of improving bus service and as a potential alternative to building light rail systems. Table 6-6 shows how operating costs for the new busway routes compare with those of several light rail systems per vehicle mile, per passenger, and per passenger mile*. They are lower than the average for the light rail systems for each service unit.

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*1983 Operating Report. American Public Transit Association, Washington, D.C.: 1982.

TABLE 6-6. LIGHT RAIL SYSTEM--NEW BUSWAY ROUTE COMPARISON OF OPERATING COSTS PER SERVICE UNIT (1983 Dollars)

	Per Vehicle Mile	Per Passenger Mile	Per Passenger	Per Seat-Mile
PAT (New Busway Routes)	3.61	0.15	0.76	0.06
Light Rail Systems:				
GCRTA - Cleveland, OH	6.38	0.18	1.46	0.078
MBTA - Boston, MA	12.55	0.50	0.70	0.186
RTA - New Orleans, LA	6.76	0.25	0.71	--
San Diego MTDB	3.26	0.12	1.01	--
Muni - San Francisco, CA	7.45	0.21	0.62	0.099
SEPTA - Philadelphia, PA	7.04	0.36	0.88	0.104
Light Rail Average:	7.24	0.27	1.38	0.117

6.3.2 Capital Costs

The average capital cost per mile of two-track light rail guideway has been estimated at $6.8 million* for at-grade facilities and $22.8 million for cut or fill**. By comparison, the cost per mile of the busway, which involved cut and fill construction, is estimated at $22.9 million.

The average values used for the comparison must be viewed with caution. There are large variations in construction costs from one site to another because of differences in construction conditions, such as geology and ground-water, building methods, the amount of utility relocation, local labor relations, and the

*Costs are in 1981 dollars and were adjusted using the ENR cost index.

**Urban Rail in America, an Exploration of Criteria for Fixed-Guideway Transit; U.S.DOT; November 1980.

prospect for delays which increases bid prices as contractors try to anticipate future inflated expenses.

The East Busway capital cost was similar to the average for light rail facilities requiring cut and fill construction and was higher than could be expected for other busways because of the East Busway's unique site characteristics. Extra costs were incurred for relocating the Conrail track and utilities, building the retaining wall between the facilities, and lowering the track bed in places. Several auto and pedestrian bridges had to be reconstructed. Unanticipated problems with soil conditions also added to the busway's construction cost.

6.4 TOTAL ANNUAL COST

The total annual costs of the busway routes are shown in Table 6-7. These costs include the annualized capital costs for both the busway itself and the buses used on these routes and the annual operating costs. Total annual costs are also presented in Table 6-8 on a per passenger trip and per passenger mile basis to allow for comparison with other bus routes and with light rail systems. Note that operating costs and passenger miles include both suburban and downtown off-busway miles.

TABLE 6-7. ANNUAL COSTS (1983 dollars)

COST ITEM	NEW ROUTES	DIVERTED ROUTES	TOTAL
Annualized Capital Costs-Busway	10,132,000	6,397,000	16,529,000
Annualized Capital Costs-Buses	940,000	1,098,000	2,038,000
Operating Costs	2,590,000	4,202,000	6,792,000
TOTAL	13,662,000	11,697,000	25,359,000

The annualized capital costs for the busway, shown above, are based on a 10 percent discount rate, and 30 year life. The costs were then allocated to the new routes or diverted routes in proportion to the on-busway seat miles for the two route types. The annualized capital costs for buses assume a 10 percent discount rate and 12 year life. PAT provided data on the number and make of buses used on each route by time of day and the purchase prices of the buses. This data enabled the allocation of buses to routes according to the number of buses needed at peak. In addition, since PAT estimated that about 15 percent of the fleet is for backup, another 15 percent of the cost for each route was added in to account for this cost.

TABLE 6-8. TOTAL COST PER SERVICE UNIT
(1983 dollars)

SERVICE UNIT	NEW ROUTES	DIVERTED ROUTES	BUSWAY ALL-ROUTES
Passenger Trips	4.04	5.42	4.58
Peak Passenger Trips	6.97	8.89	7.74
Passenger Miles	.81	1.02	0.90
Peak Passenger Miles	1.40	1.68	1.52

7. COMMUNITY IMPACTS

Several Pittsburgh officials were interviewed about their perceptions of the busway stations' effects on the surrounding communities.* Specifically, they were asked if traffic near the stations had increased noticeably, if parking space availability had declined, and if noise and air pollution levels had changed perceptibly, as a result of the increased bus and park-and-ride traffic. In addition, they were asked whether or not new development appeared to have been attracted to the area by the new busway service.

7.1 TRAFFIC AND PARKING IMPACTS

The local officials generally agreed that parking has gotten slightly tighter near the Negley and Wilkinsburg stations since the busway opened. However, park-and-ride all day parkers have always been considered a moderate problem near Negley Station in the residential neighborhood of Shadyside, and parking is not considered a problem in Wilkinsburg. Parking near East Liberty and Herron Stations has not appeared to change. The officials felt that the bus traffic had not affected noise or air pollution levels in the stations' neighborhoods.

Hourly traffic volumes near the East Liberty and Wilkinsburg stations after the busway opened were examined to determine whether or not park-and-ride traffic, auto passenger drop-off traffic, or city buses accessing the stations to allow passengers to transfer may have impacted the traffic there. The level of service, which is a qualitative measure that represents the

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*Interviews were conducted with: Karen LaFrance, East Liberty Development, Inc.; Robert Hanlon, SPRPC; Gary Erenrich, Pittsburgh Planning Department; Ed Gergerich, Pittsburgh Public Works; and Bill Fontana, Redevelopment Authority of Allegheny County.

collective factors of speed, freedom to maneuver, safety, driving comfort and, convenience under particular volume conditions, was noted for each traffic volume count. Level of service A is the highest quality of service. Level of service B is a stable flow condition, but operating speed is beginning to be restricted by other traffic. Stable flow is also characteristic of level of service C but at this traffic volume level, most drivers are becoming restricted in their freedom to select speed and pass. Level of service D approaches unstable flow, driving comfort and freedom to maneuver are low, and driving speed is subject to sudden variations.

As shown in Table 7-1, after the busway, traffic congestion was not a problem near the Wilkinsburg Station at either the AM or the PM peak. Service levels A prevailed at three of the four traffic count stations. However, at the East Liberty Station, level of service D, unstable flow, was found near one of the two traffic count stations during the PM peak (see Table 7-2). Busway generated traffic has undoubtedly contributed to the congestion at this location. Service levels are based on assumptions of 50% cycle split and average density and speed criteria.

Before the busway, traffic counts were not taken at the same spots as after the busway, so a good comparison cannot be made. Also, no traffic counts were taken close enough to the other busway stations to get a sense of what traffic can be attributed to these stations.

7.2 NEW DEVELOPMENT NEAR BUSWAY STATIONS

When the busway was conceived, state and local officials expected the facility to stimulate a whole corridor of development through the eastern Pittsburgh suburbs. Wilkinsburg and East Liberty have made considerable efforts to market themselves to developers, now that the busway has effectively brought them closer to Pittsburgh. In May 1983, a week long festival was held which included special busway trips and seminars for local businesses to promote the neighborhoods as development sites.

TABLE 7-1. AVERAGE WEEKDAY TRAFFIC VOLUMES NEAR WILKINSBURG STATION

Time and Location	Traffic Volume/Hour Each Lane	Level of Service*
South Ave. East of Hay St.		
7-8 AM	298	A
8-9 AM	270	A
3-4 PM	277	A
4-5 PM	287	A
5-6 PM	277	A
South Ave. at Pennwood Ave.		
7-8 AM	304	B
8-9 AM	313	B
3-4 PM	297	A
4-5 PM	304	B
5-6 PM	309	B
Hay St. North of South Ave.		
7-8 AM	142	A
8-9 AM	147	A
3-4 PM	172	A
4-5 PM	158	A
5-6 PM	155	A
Hay St. North of Ross Ave.		
7-8 AM	190	A
8-9 AM	173	A
3-4 PM	253	A
4-5 PM	282	A
5-6 PM	266	A

*Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers, Englewood Cliffs, NJ: 1976.

TABLE 7-2. AVERAGE WEEKDAY TRAFFIC VOLUMES NEAR EAST LIBERTY STATION

Time and Location	Traffic Volume/Hour Each Lane	Level of Service
Penn Ave. West of Dahlem St.		
8-9 AM	592	C
9-10 AM	470	B
3-4 PM	637	D
4-5 PM	675	D
5-6 PM	641	D
Penn Ave. East of Penn Circle		
8-9 AM	429	B
9-10 AM	386	B
3-4 PM	517	C
4-5 PM	554	C
5-6 PM	516	C

At this point, several local officials feel that the busway has interested commercial and high rise residential developers in building near the East Liberty and Wilkinsburg Stations, but that development attributable to the busway has not yet taken place. Other officials think that the busway, in conjunction with the development funds provided to East Liberty and Wilkinsburg because of being designated State of Pennsylvania "Enterprise Development Areas" has caused new development and renovations to occur.

It is felt that especially at Wilkinsburg, the busway commuter traffic has helped businesses that already exist. One official mentioned that at rush hour you can clearly see commuters heading for markets near the busway.

8. CONCLUSIONS AND TRANSFERABILITY

The busway is a very popular, heavily used improvement to transit in the east corridor. The following sections highlight some of the findings that can be made about the busway and the extent to which they may apply to other areas.

8.1 SPEED AND RELIABILITY IMPROVEMENTS

Moving routes from a congested parkway and local streets increased the speed of operations, decreased passenger travel times, improved predictability of vehicle travel times, and enabled passengers to leave later to reach their destinations. Schedule reliability was not perceived by passengers to have improved as much as operational reliability. PM peak travel times may not have improved significantly because they were already shorter than AM peak travel times before the busway. Routes switched to the busway have reduced their level of breakdowns and drivers perceive operating on the busway as easier than operating on the parkway.

The improvements in bus speeds should be transferrable to other sites. Changes in passenger travel times should be applied with more caution, since they partially result from the improved downtown loop patterns that became possible when the busway opened.

8.2 EBA/EBO SERVICE

Routes imitating the operation of a light rail line offer a high level of service and attract high patronage levels. The EBA is now the most heavily used route in PAT's system. Passengers who have switched to the EBA or EBO have, on the average, decreased their travel times, even when switching has added a transfer to their trips. Three-minute peak period service makes transferring easy, at least for inbound trips.

The success of the EBA/EBO service may depend on the level of development in the neighborhoods near several stations. Most EBA/EBO patrons arrive on foot, rather than by bus or automobile. A busway built in a right-of-way where development patterns are less intense could not expect to attract as much walk-on patronage. In that event, greater coordinated transfer service and parking opportunities might allow an EBA-type service to be successful; however, the Pittsburgh experience provides no evidence one way or the other.

8.3 COSTS

The busway cost as much per mile to build as a typical light rail line requiring similar right-of-way preparation, that is involving cut and fill construction. Other busways might be significantly cheaper to build if they did not involve expenses such as those to relocate the Conrail tracks and rebuild some bridges.

Operating costs per service unit are lower for busway service than for all but one of six light rail systems examined. EBA/EBO service costs much less than other service in PAT's system based on passenger and capacity-related measures, but slightly more on a vehicle-mile basis. Diverted route service is more expensive than other service per passenger or passenger-mile, but less expensive per vehicle mile; it is probably not more expensive than other express services. These results reflect the high patronage levels and load factors on the EBA/EBO, and the high speeds achieved on the diverted routes.

8.4 RIDERSHIP

The diverted routes increased their patronage levels after being moved to the busway, and the EBA has attracted over 11,000 boardings per day. Most of these increases reflect shifts from other routes and increased transfer activity. Although service quality has improved for service accounting for about one-sixth of east corridor patronage, total corridor ridership has

increased by at most one to two percent compared to predicted levels without the busway. By comparison, total vehicle miles of service in the corridor increased by about 3.5 percent. Under 10 percent of busway patronage is trips attracted away from automobiles.

There are at least two factors which might limit the transferrability of these results. One is the continuing high levels of unemployment in the period studied. Another is that major construction on the Penn-Lincoln Parkway in the period before the busway opened may have increased ridership in that period. Some construction occurred in the post-busway period as well; however, driving conditions may, on the average, have been better in the post-busway period.

8.5 COMMUNITY IMPACTS

Parking in the vicinity of two stations, including the end of the line at Wilkinsburg, appears to have become slightly more difficult. Traffic in the vicinity of the East Liberty station is congested but it is not known whether this congestion is an impact of the busway. Some positive impact on local businesses may have occurred at the end of the line. Factors limiting the transferrability of these results include: that PAT has not taken steps to encourage park-and-ride trips on the EBA/EBO; that extensive suburban collector and transfer service is available; and that most EBA/EBO patrons walk to the stations.

APPENDIX A
1983 ON-BOARD SURVEY

One on-board survey was done in late October and early November 1983, when most of the service to be put on the busway was in place, but before downtown circulation patterns were changed to take advantage of the extended contra flow lane on Smithfield Street. The survey covered patrons travelling in inbound and outbound directions on the following services: new busway service; pre-existing service transferred to the busway; nonbusway east end service; and some routes outside the east corridor as a control group. Eight different versions of the questionnaire were used, for inbound and outbound trips on the four route types sampled. The form for the pre-existing routes, that transferred to the Busway, is shown in Figure A-1.

As much as possible, the Fall 1983 survey was designed to permit comparisons with PAT's October 1982 on-board survey. That survey was distributed by drivers on most inbound runs on one day. Because of high nonresponse rates, however, comparisons with the 1983 survey will be suspect and should be supplemented by direct questions about changes.

PTransit 7997 **INBOUND**
PRE-EXISTING BUSWAY

TRANSIT SURVEY

DEAR RIDER: Please help us evaluate the East Busway by answering all of the following questions. After completing the survey, return it to the survey taker or drop it in the mail — no postage required. All information will be kept confidential.

1. **Where are you coming from?**
   ☐ Home ☐ Other School ☐ Personal Business ☐ Other: _____
   ☐ Work ☐ Medical ☐ Church
   ☐ College ☐ Social ☐ Shopping

2. **Where is it located?** ___ _____
   (GIVE CROSS STREETS, OR ELSE ADDRESS OR BUILDING NAME, etc.)

3. **At what stop did you board this bus?** _____
   (GIVE CROSS STREETS, OR ELSE STATION NAME OR BUILDING, etc.)

4. **How did you get to the bus stop?**
   ☐ Walking or bicycling
   ☐ Another bus or buses. Please list all route numbers: _____
   ☐ Automobile — dropped off
   ☐ Automobile — parked →

ANSWER THESE QUESTIONS IF YOU CAME BY AUTOMOBILE AND PARKED

5. **Were you the driver or a passenger?**
   ☐ Driver ☐ Passenger

6. **How many people were in the car?**
   ☐ You only ☐ You + 2 others
   ☐ You + 1 other ☐ You + 3 others

7. **Where is the car parked?**
   ☐ In a free lot
   ☐ In a pay lot. How much did it cost? _____
   ☐ On the street

8. **How many blocks from the station or stop is the car parked?**
   _____ blocks

9. **How long did it take you to find a space?**
   ☐ No time at all ☐ About 5 minutes
   ☐ A few minutes ☐ More than 5 minutes

PLEASE CONTINUE ON NEXT PAGE →

FIGURE A-1. 1983 ON-BOARD SURVEY

10. How did you pay for this trip?

☐ Full Cash ☐ U-Ticket ☐ Annual Pass ☐ Other: _____
☐ Transfer ☐ Weekly Permit ☐ Senior Citizen Pass
☐ Trip Ticket ☐ Monthly Pass ☐ Handicapped Pass

11. Where are you going?

☐ Home ☐ Other School ☐ Personal Business Other: _____
☐ Work ☐ Medical ☐ Church
☐ College ☐ Social ☐ Shopping

12. Where is it located? _____
(GIVE CROSS STREETS, OR ELSE ADDRESS OR BUILDING NAME, etc.)

13. At what stop will you get off this bus? _____
(GIVE CROSS STREETS, OR ELSE STATION NAME OR BUILDING, etc.)

14. After you get off this bus, will you transfer to get to the place in Question 12?

☐ No
☐ Yes, please list all route numbers: _____

15. Before this route began using the East Busway, how did you get from the place in Question 2 to the place in Question 12?

☐ Same bus route(s) as now
☐ Other transit routes:
First route boarded: _____
Route transferred to, if any: _____
Second route transferred to, if any: _____

ANSWER THESE QUESTIONS IF YOU USED TO GO BY TRANSIT

☐ Did not go there (PLEASE CONTINUE ON BACK PAGE)
☐ Automobile driver
☐ Automobile passenger
☐ Walked or bicycled
☐ Other: _____

ANSWER THIS QUESTION IF YOU WENT SOME WAY OTHER THAN BY TRANSIT

16. How important was the East Busway in your decision to start going by bus?

☐ Very important
☐ Fairly important
☐ Slightly important
☐ Not important at all

FIGURE A-1. 1983 ON-BOARD SURVEY
(Continued)

17. **Before this route began using the East Busway, how did you get to your initial transit stop?**

- ☐ Walked or bicycled
- ☐ Another bus
- ☐ Automobile — parked
- ☐ Automobile — dropped off

18. **Consider the total time it takes you to make this trip, from where you started out to where you are going. Count getting to and from the bus stop, waiting, riding, and any transfers. How does the time now compare to the time before this route began using the East Busway?**

- ☐ About the same as before the Busway
- ☐ _____ minutes longer (PLEASE FILL IN)
- ☐ _____ minutes shorter (PLEASE FILL IN)

19. **In the months since this route began using the East Busway, have you changed the time you leave to begin this trip?**

- ☐ No (leave at the same time as before)
- ☐ _____ minutes earlier (PLEASE FILL IN)
- ☐ _____ minutes later (PLEASE FILL IN)

20. **Consider each of the following aspects of transit service. How has each changed for you since this route began using the East Busway?**

	Better	No Difference	Worse
a. Chance of getting a seat	☐	☐	☐
b. Convenience of time you arrive at your destination	☐	☐	☐
c. How long you have to wait for bus	☐	☐	☐
d. Distance to the bus stop	☐	☐	☐
e. Distance from the bus stop	☐	☐	☐
f. Buses staying on schedule	☐	☐	☐
g. Ease of transfering	☐	☐	☐

PLEASE CONTINUE ON BACK →

FIGURE A-1. 1983 ON-BOARD SURVEY
(Continued)

21. **In the last seven days, how many times did you ride this bus route?** _____
(COUNT ROUND-TRIPS AS TWO RIDES)

22. **How many usable cars, vans or trucks does your household have?** _____

23. **Was one of your household's vehicles available to make this trip today?**
☐ No ☐ Yes

24. **Age:**
☐ under 15 years ☐ 25-34 years ☐ 50-64 years
☐ 15-24 years ☐ 35-49 years ☐ 65 or over

25. **What is the total annual income of your entire household?** (OPTIONAL)
☐ under $10,000 ☐ $30,001 to $40,000
☐ $10,000 to $20,000 ☐ $40,001 to $50,000
☐ $20,001 to $30,000 ☐ over $50,000

26. **Comments or suggestions:** _____

_____

_____

THANK YOU.

(PLEASE FOLD HERE BEFORE MAILING)

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 11291 PITTSBURGH, PA.

POSTAGE WILL BE PAID BY ADDRESSEE

PTransit

PORT AUTHORITY OF ALLEGHENY COUNTY
PLANNING, DEVELOPMENT AND PUBLIC SERVICES DIVISION
Beaver and Island Avenues
Pittsburgh, Pa. 15233

FIGURE A-1. 1983 ON-BOARD SURVEY
(Continued)

APPENDIX B
DESCRIPTIONS OF DATA USED

DRIVER SURVEY

In December 1984, PAT surveyed bus drivers on the busway routes to obtain information on how driving on the busway compares to the parkway and local streets under various weather conditions. The survey also asked how the busway compares in terms of handling breakdowns. Questions were included concerning pedestrian safety and how emergency vehicles affect service safety and reliability. The survey was completed by 65 drivers, both extra board and regular. A copy of the driver survey is shown in Figure B-1.

STATION CHECKS

Station checks were used to determine whether or not ridership on busway routes is capacity constrained, to determine the level of service offered by the EBA route, and to address the issue of delays due to fare collection. The checks were conducted in November 1983, using the form shown in Figure B-2. They covered five days including a Monday, a Friday, and the day before Thanksgiving. The observations included at least the peak hours each day. The Negley and East Liberty stations required two observers each, and the downtown terminus required four observers. The checks consisted of observing arriving and departing times, passenger loads and loading times for buses at all stations on the Busway and at the downtown terminus. The observers also counted emergency, maintenance, and other official vehicles using the Busway.

EAST BUSWAY OPERATOR OPINION POLL

The Port Authority is participating in a Federal Study of the Martin Luther King, Jr. East Busway, so that other transit operators who may consider building busways can learn from PAT's experience.

1. a. When did you qualify on the East Busway? _____ Month/Year

   b. Do you operate on the Busway regularly? _____ yes _____ no

2. Which Busway routes have you driven? _____

   _____

3. Was a Busway assignment your first choice for the current pick?

   _____ yes _____ no. Why? _____

   _____

4. What, if anything, do you like about the Busway? _____

   _____

5. What, if anything, do you dislike about the Busway? _____

   _____

6. How does driving on the Busway compare to driving on the Parkway . . .

   a. In good weather? _____ easier _____ harder _____ same

      Why? _____

      _____

   b. In rainy weather? _____ easier _____ harder _____ same

      Why? _____

      _____

   c. In foggy weather? _____ easier _____ harder _____ same

      Why? _____

      _____

FIGURE B-1

d. In snowy weather? _____ easier _____ harder _____ same

Why? _____

_____

e. At night? _____ easier _____ harder _____ same

Why? _____

_____

7. How does driving on the Busway compare to driving on local streets and roads. . .

a. In good weather? _____ easier _____ harder _____ same

Why? _____

_____

b. In rainy weather? _____ easier _____ harder _____ same

Why? _____

_____

c. In foggy weather? _____ easier _____ harder _____ same

Why? _____

_____

d. In snowy weather? _____ easier _____ harder _____ same

Why? _____

_____

e. At night? _____ easier _____ harder _____ same

Why? _____

_____

8. Have you had any bus breakdowns while driving on the Busway?

_____ no _____ yes. How many? _____

9. Compared to breakdowns on local streets, are there any special problems pertaining to breakdowns on the Busway?

_____ no _____ yes. Please explain: _____

_____

_____

10. Compared to breakdowns on the Parkway, are there any special problems pertaining to breakdowns on the Busway?

_____ no _____ yes. Please explain: _____

_____

_____

11. Is there any way in which dealing with breakdowns is easier on the Busway than on other streets or highways?

_____ no _____ yes. Please explain: _____ _____

_____

_____

12. Does pedestrian activity on the East Busway create any safety problems?

_____ no _____ yes. Please explain: _____ _____

_____

_____

13. Do vehicles other than buses which are currently using the East Busway have a positive or negative effect on:

a. bus speeds and schedule reliability?

_____ positive _____ negative _____ makes little difference.

Please explain: _____

_____

b. safety of the operation of the Busway?

_____ positive _____ negative _____ makes little difference.

Please explain: _____

_____

14. What is your overall opinion of the Busway design?

15. Additional comments on any aspect of the Busway:

FIGURE B-2

EAST BUSWAY STATION CHECK

SHEET ___ OF ___

LOCATION CHECKED: _____ NAME: _____

DATE: _____ TIME: Begin _____ A.M. P.M. End _____ A.M. P.M.

DIRECTION (circle one): INBOUND OUTBOUND

Route	Vehicle Number	Time of Arrival	VEHICLE TYPE: Standard Bus (45 cap)	Artic. Bus (62 cap)	Other Vehicle (E, M or O)	Number on Bus	Number De-Boarding	Number Board-ing	Time for Boarding & Deboarding (min:sec)	Time of Departure

E = Emergency Vehicle O = Other Vehicle M = Maintenance Vehicle

END POINT CHECKS

PAT conducted a point checks program for measuring changes in line haul travel times. For each bus observed, they recorded the time and vehicle ID number at two locations. On the outbound end, before and after observations are at identical or very close, comparable locations. At the downtown end, observations are at the entry point to downtown from the parkway or other arterial (before) or at the end of the busway (after). These points are generally widely separated. The pre-busway checks were made shortly before a route was transferred, and the post-busway checks were made a few months later. For a given route, the number of observations in one direction during a peak period varies from 4 to 46. Most suburban observations are clustered together in the area where the busway and the Penn Lincoln Parkway converge. PAT completed about 260 "before" observations and 280 "-after" observations in each peak period in the primary commute directions.

RIDE CHECKS

PAT has an ongoing program of ride checks, in which observers record boarding and alighting activity and arrival times at stops. As of October 1983, this program had produced the following sample of checks in the East End corridor:

Route Type	Total Checks	In-bound	Out-bound	AM	PM	Before Busway	After Busway
Transferred to Busway	30	17	13	11	19	13	17
New Busway	18	9	9	10	8	0	18
Not on Busway	52	25	27	18	34	not known	

In addition, there were 102 ride checks on routes outside the East End corridor.

In November 1983, as part of the evaluation, PAT conducted some additional ride checks on the downtown portions of several routes still using the Parkway.

PARKING STUDY

PAT conducted a parking study in the fall of 1984 to identify parking space occupancy rates by time of day within about two blocks of each busway station. It was not possible to distinguish busway users from other parkers. The data from this study was used to determine whether or not there is sufficient convenient parking for busway users.

ACCIDENT AND ROAD SERVICE CALLS

PAT provided a printout of road service calls and of accidents by month for each route before and after the busway. This data is shown in Tables B-3 and B-4.

TABLE B-1. ROAD SERVICE CALLS ON DIVERTED ROUTES

	8/82	9/82	10/82	11/82	12/82	1/83	2/83	TOTAL
Selected Failure Codes	7	5	7	9	11	8	8	55
All Other Failure Codes	20	60	53	70	71	87	99	460
TOTAL	27	65	60	79	82	95	107	515

	8/83	9/83	10/83	11/83	12/83	1/84	2/84	TOTAL
Selected Failure Codes	5	4	6	7	11	7	10	50
All Other Failure Codes	104	103	118	106	112	119	120	782
TOTAL	109	107	124	113	123	126	130	832

Selected Failure Codes are:

Front Axle	Clutch	Transmission
Rear Axle	Air Suspension	
Brakes	Springs	

All Other Failure Codes are:

Body	Fuel & Exhaust	No Trouble
Cooling	Steering	Air Conditioning
Electrical	Propeller Shaft	
Engine	Wheels & Hubs	
Frame	Out of Fuel	

TABLE B-2. ALL ACCIDENTS ON DIVERTED ROUTES

ROUTE	3/82	4/82	5/82	6/82	7/82	8/82	9/82	10/82	11/82	12/82	1/83	2/83
68G	2	5	2	2	1	0	2	2	0	2	4	2
78A	0	1	0	0	0	0	0	0	1	0	1	0
HP,M,MD	5	1	1	2	0	3	2	0	2	1	0	1
68A	1	0	1	0	2	1	1	0	0	3	0	1
68B	1	0	1	0	2	1	1	0	0	3	0	1
68D	7	2	1	1	1	3	0	4	1	2	1	0
68F	1	0	1	1	0	0	1	0	0	0	0	1
77E,77U P,PG,77B	3	1	1	5	0	2	2	1	0	2	0	0
TOTAL	20	10	8	11	6	10	9	7	4	13	6	6

	6/83	7/83	8/83	9/83	10/83	11/83	12/83	1/84	2/84	3/84
68G	1	2	2	1	2	1	0	0	0	2
78A	1	1	0	0	0	0	1	0	0	0
HP,M,MD	1	1	0	0	0	3	0	0	2	0
68A	1	0	0	1	0	0	0	0	0	0
68B	2	0	0	1	0	1	0	0	0	1
68D	1	0	1	0	2	1	6	0	2	1
68F	0	0	0	0	0	0	1	0	0	0
77E,77U 77B,P,PG, U	0	2	2	3	2	4	4	4	6	3
TOTAL	7	6	5	6	6	10	12	4	10	7

APPENDIX C

COMPARISON OF DOOR-TO-DOOR TRAVEL TIME OF EBA PASSENGERS ON CURRENT AND FORMER ROUTES (Cases without a Transfer)

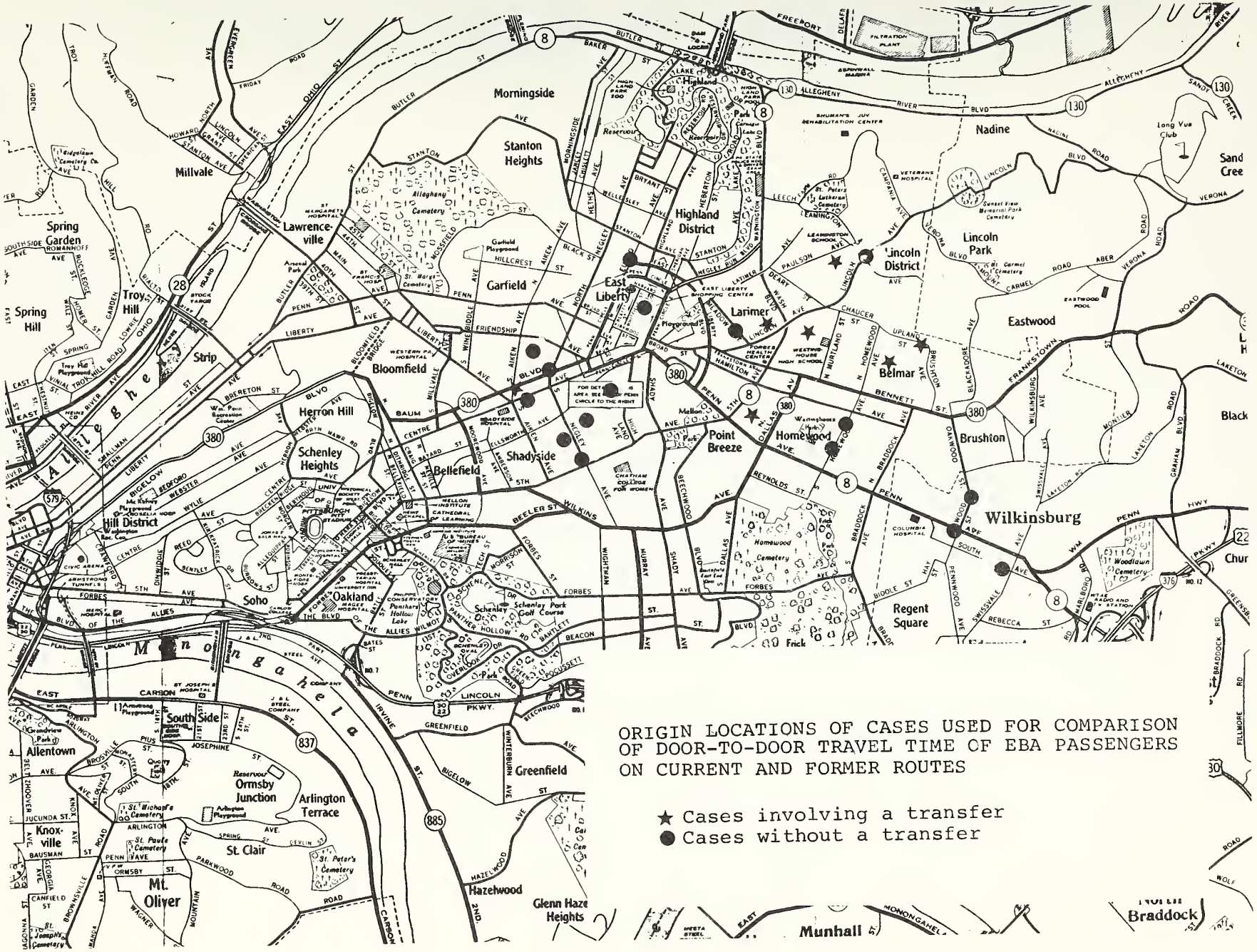
		Access		Wait		In-Vehicle	
		Before	After	Before	After	Before	After
1.	ZONE 550 Broad St. Mall						
	AM	10	14	7	2	33	17
	Base	10	14	7	2	33	17
	PM	10	14	7	5	35	17
2.	ZONE 560 Negley & Baum						
	AM	4	4	7	2	16	16
	Base	4	4	7	5	23	16
	PM	4	4	7	2	25	18
3.	ZONE 580 Meadow St.						
	AM	10	10	6	7	33	10
	Base	10	10	6	7	33	10
	PM	10	10	5	7	33	10
4.	ZONE 590 Lehigh Avenue						
	AM	10	6	3	2	32	17
	Base	10	6	7	2	32	19
	PM	10	6	7	2	35	19
5.	ZONE 590 Summerlea						
	AM	6	6	7	3	30	16
	Base	6	6	7	2	32	19
	PM	6	6	7	2	30	18
6.	ZONE 740 East Hill						
	AM	16	20	7	2	51	25
	Base	16	20	7	2	51	25
	PM	16	20	7	2	51	25
7.	ZONE 690 McPherson						
	AM	10	2	7	2	34	21
	Base	10	2	7	5	29	21
	PM	10	2	7	2	34	23

		Access		Wait		In-Vehicle	
		Before	After	Before	After	Before	After
8.	ZONE 700 Hanewood						
	AM	16	2	7	2	31	21
	Base	16	2	7	5	32	23
	PM	16	2	7	2	34	23
9.	ZONE 440 S. Graham						
	AM	14	6	4	2	20	16
	Base	14	6	7	5	22	16
	PM	14	6	7	2	22	18
10.	ZONE 440 Stratford						
	AM	10	6	2.5	2	23	16
	Base	10	6	7	5	20	16
	PM	10	6	5	2	24	16
11.	ZONE 430 S. Negley						
	AM	10	6	4	2	20	16
	Base	10	6	7	5	22	16
	PM	10	6	7	2	22	16
12.	ZONE 430 Ivy St.						
	AM	6	6	7	2	30	16
	Base	6	6	7	5	30	16
	PM	6	6	7	2	30	16
13.	ZONE 1490 Penn & Wood						
	AM	14	4	6	2	39	21
	Base	14	4	7	5	43	23
	PM	14	4	5	2	43	17
14.	ZONE 1480 South & Coal						
	AM	8	8	7	2	29	23
	Base	8	8	7	5	26	23
	PM	8	8	7	3	30	17
15.	Zone 1450 Rebecca & Hay						
	AM	4	6	7	2	29	23
	Base	4	6	7	2	26	23
	PM	4	6	7	2	30	17

	Access		Wait		In-Vehicle	
	Before	After	Before	After	Before	After
16. ZONE 1470						
Hill & Wood						
AM	2	8	6	2	43	23
Base	2	8	7	5	43	23
PM	2	8	7	2	43	17
AVERAGE	9.4	7.1	5.9	2.4	30.8	18.6
	9.4	7.1	6.9	3.6	31.1	19.1
	9.4	7.1	6.6	2.7	32.6	17.9

COMPARISON OF DOOR-TO-DOOR TRAVEL TIME OF EBA PASSENGERS ON CURRENT AND FORMER ROUTES (Cases Involving a Transfer)

	Access		Wait		In-Vehicle		Transfer	In-Vehicle	
	Before	After	Before	After	Before	After	Before	After	Before	After
1. Laketon Road										
AM	6	6	7	7	52	5		2		21
Base	6	6	7	7	53	5		5		21
PM	6	6	7	7	48	5		2		23
2. Wiltsie St.										
AM	11	11	5	5	39	10		2		15
Base	11	11	7	7	41	10		5		15
PM	11	11	6	6	41	10		2		17
3. Upland										
AM	10	2	5	5	35	8		2		19
Base	10	2	7	7	37	8		5		19
PM	10	2	6	5	37	9		2		21
4. Frankstown & Collier										
AM	3	2	6	3	34	11		2		15
Base	3	2	7	6	30	11		5		15
PM	3	2	7	4	37	11		2		17
5. Penn & Graham										
AM	2	2	7	7	45	13		2		21
Base	2	2	7	7	40	13		5		21
PM	2	2	7	7	40	13		2		23
6. Lincoln & Shetland										
AM	2	2	5	5	32	4		2		15
Base	2	2	7	7	33	4		5		15
PM	2	2	6	6	33	4		2		17
7. Meadow St.										
AM	10	10	5	7	33	10		2		15
Base	10	10	6	7	33	10		5		15
PM	10	10	6	7	33	10		2		17
8. Mt. Vernon										
AM	10	10	5	7	27	5		2		21
Base	10	10	7	7	25	5		5		21
PM	10	10	7	7	25	5		2		23
AVERAGE	6.75	5.63	5.63	5.75	37.13	8.25		1.5		17.75
	6.75	5.63	6.88	6.88	36.5	8.25		5		17.75
	6.75	5.63	6.50	6.13	36.75	8.38		2		19.75



ORIGIN LOCATIONS OF CASES USED FOR COMPARISON OF DOOR-TO-DOOR TRAVEL TIME OF EBA PASSENGERS ON CURRENT AND FORMER ROUTES

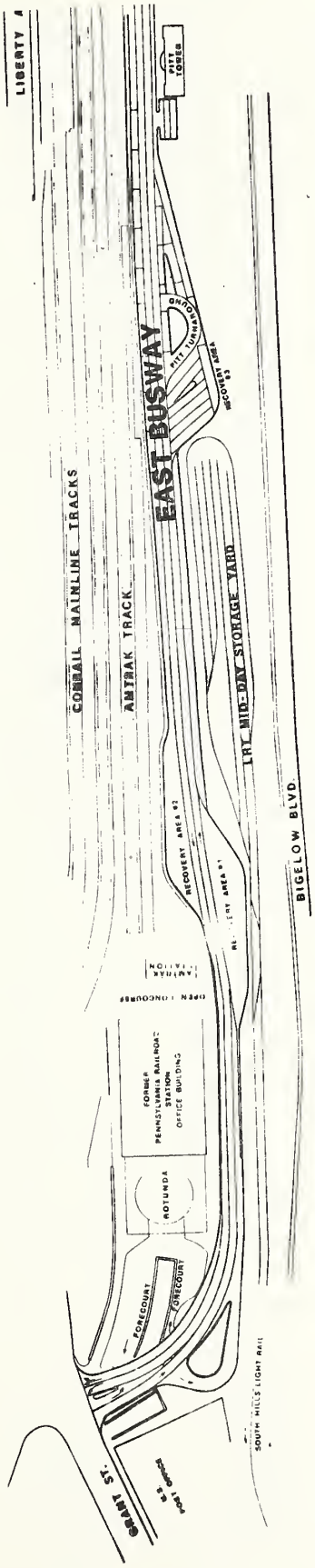
★ Cases involving a transfer
● Cases without a transfer

C-5/C-6

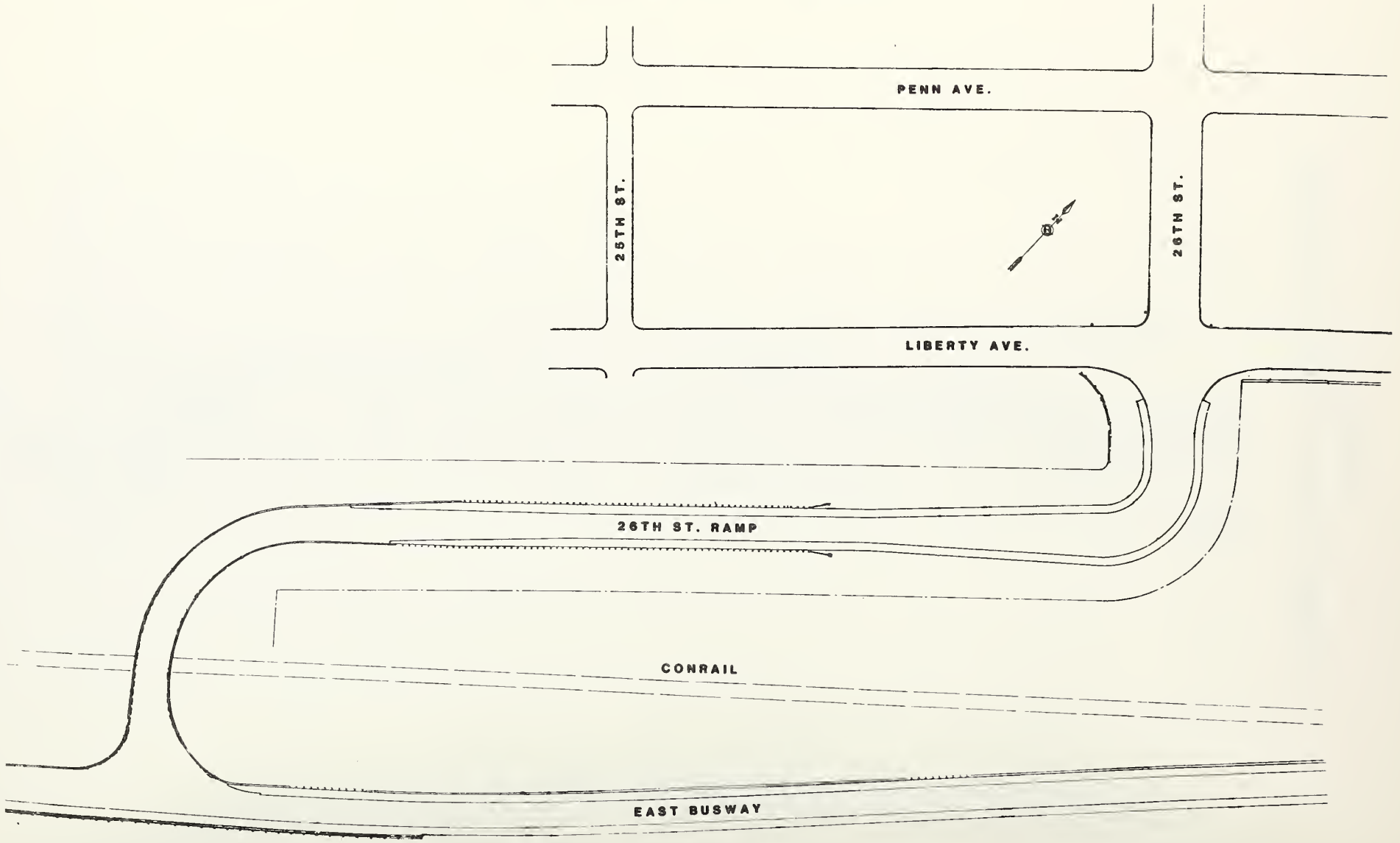
APPENDIX D

DIAGRAMS OF BUSWAY RAMPS AND STATIONS

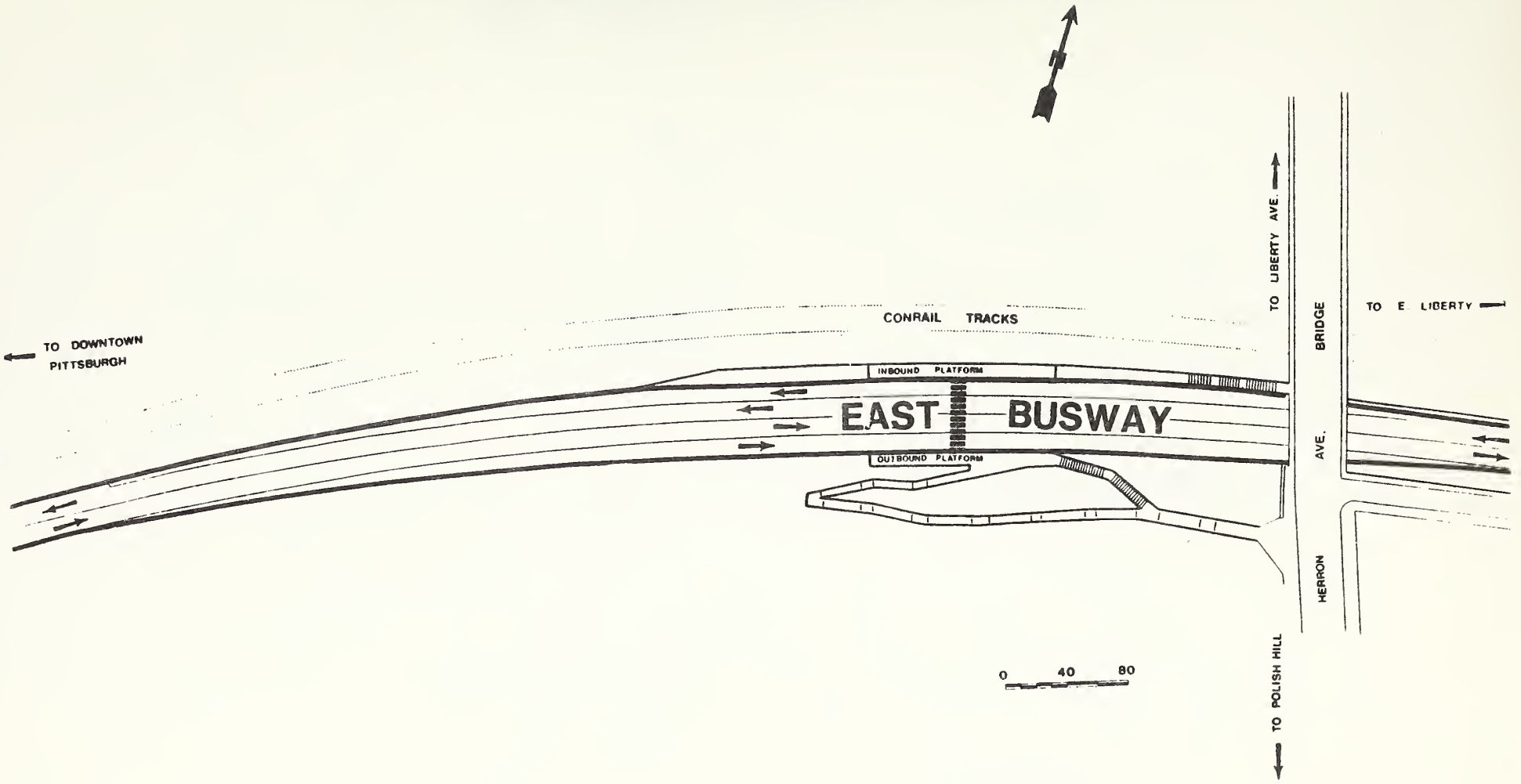
GRANT ST. RAMP



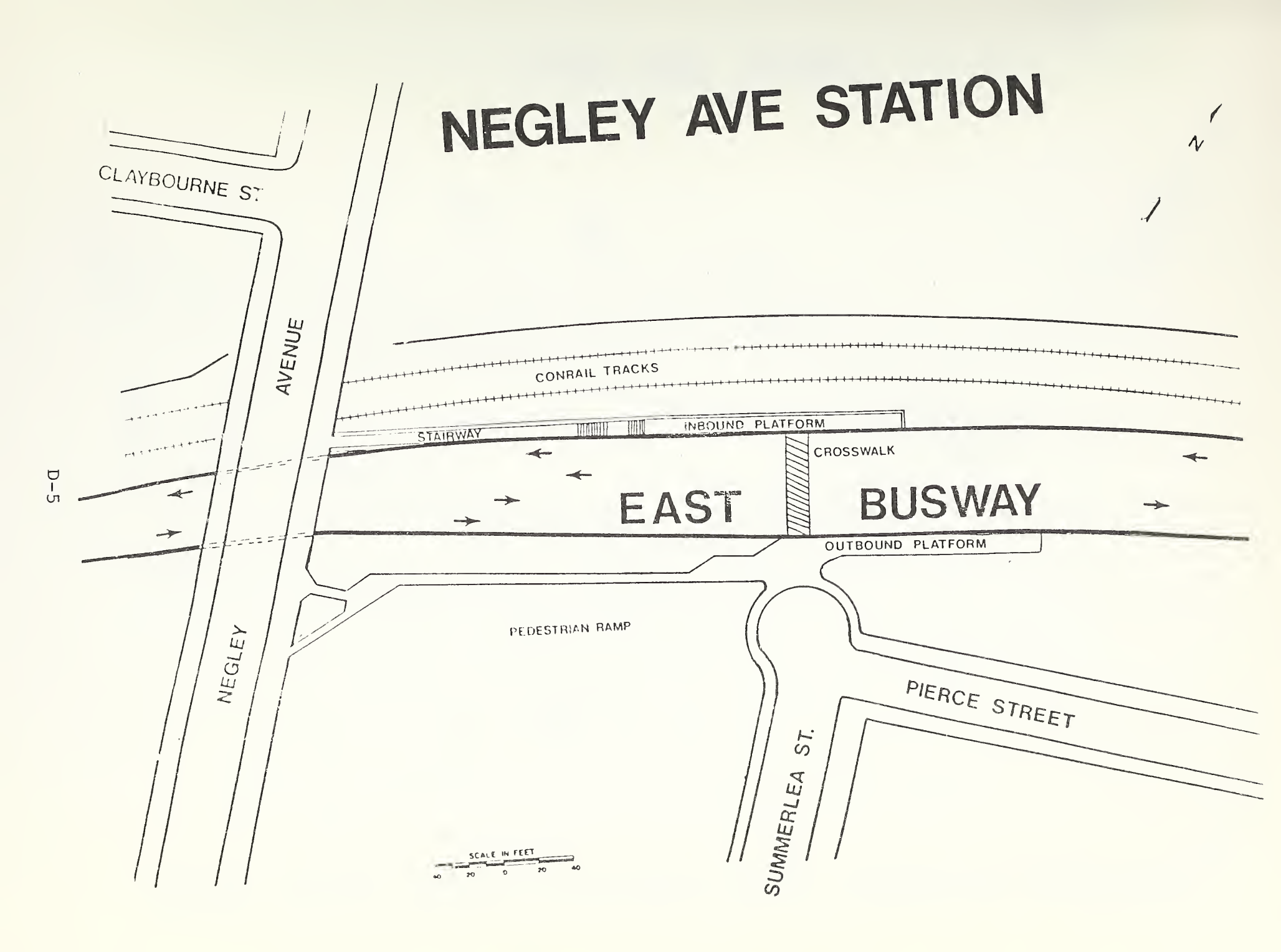
26TH ST. RAMP


PENN AVE.
25TH ST.
26TH ST.
LIBERTY AVE.
26TH ST. RAMP
CONRAIL
EAST BUSWAY

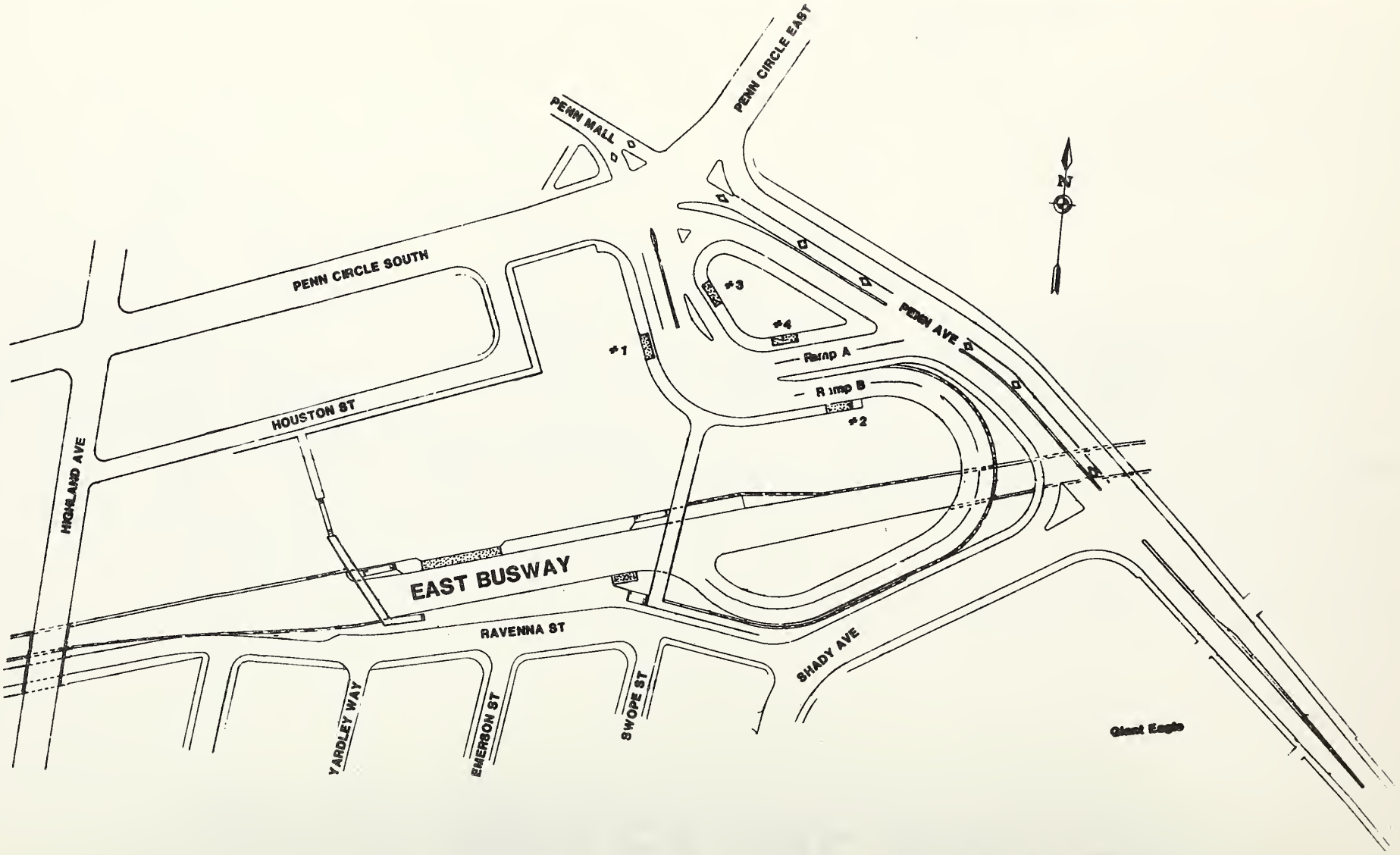
HERRON STATION



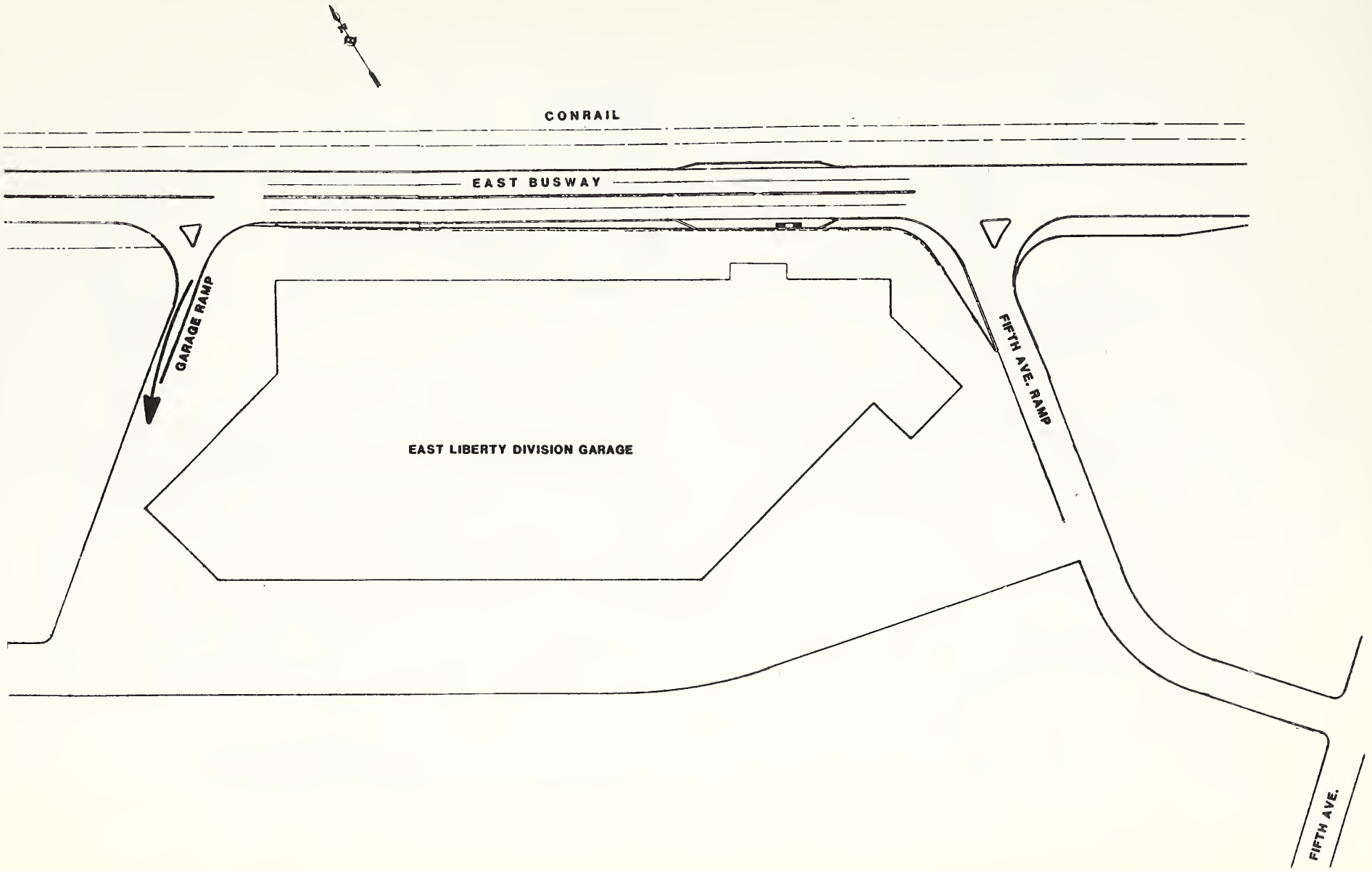
NEVILLE RAMP


NEGLEY AVE STATION
CLAYBOURNE ST.
AVENUE
NEGLEY
CONRAIL TRACKS
STAIRWAY
INBOUND PLATFORM
CROSSWALK
EAST
BUSWAY
OUTBOUND PLATFORM
PEDESTRIAN RAMP
PIERCE STREET
SUMMERLEA ST.
SCALE IN FEET
N

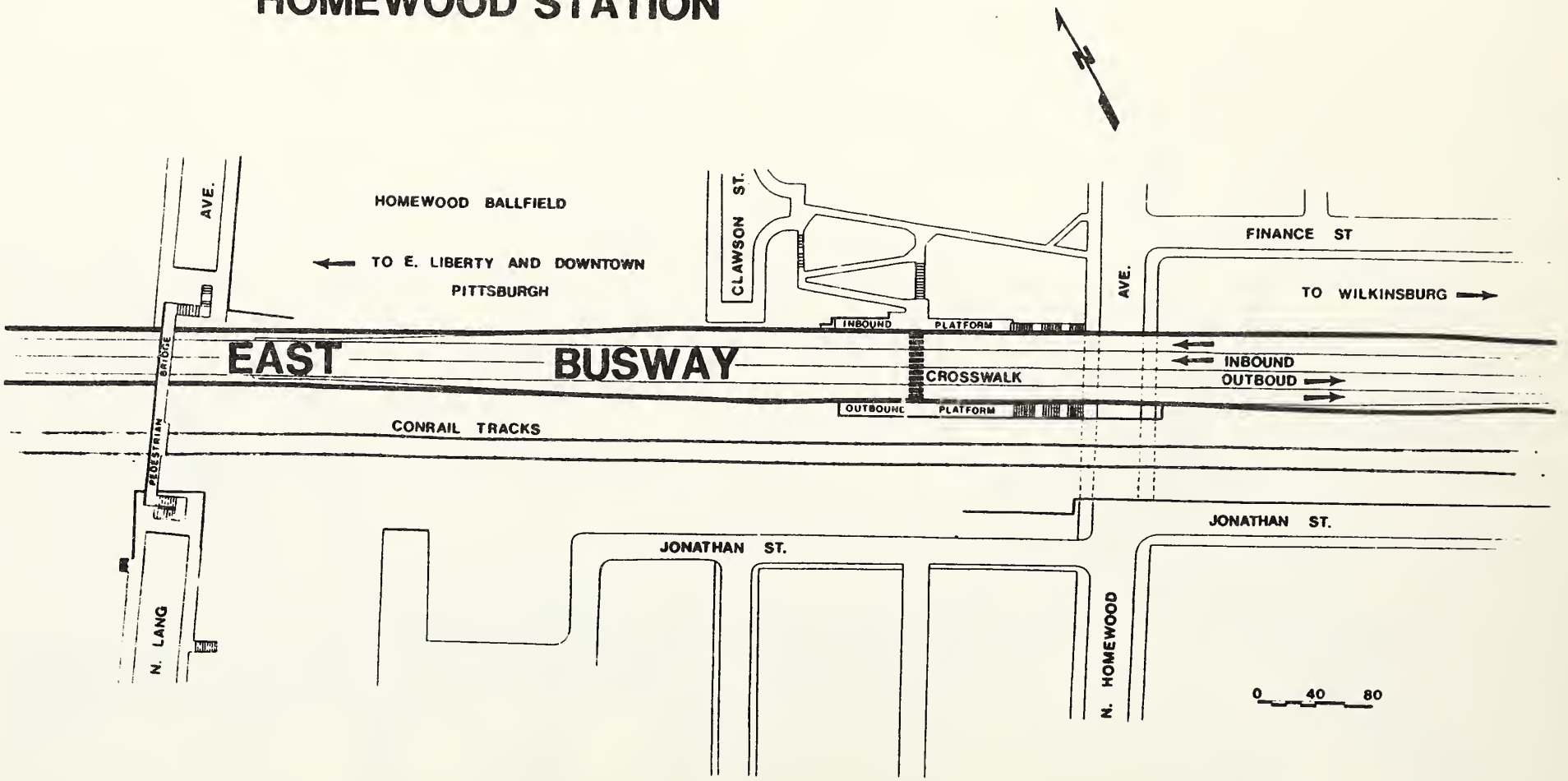
PENN MALL RAMP/STATION EAST LIBERTY STATION



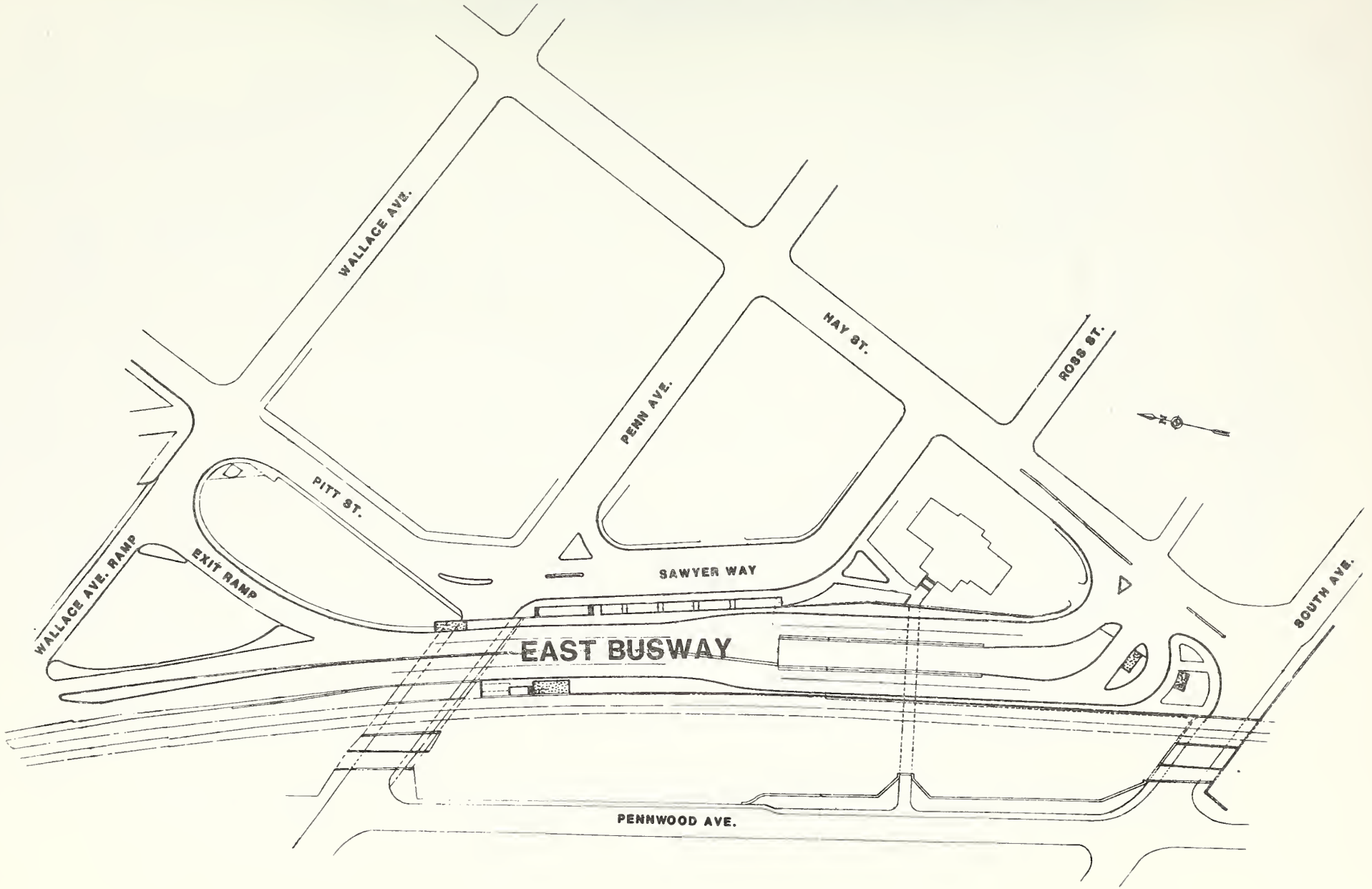
5TH AVE. RAMP


CONRAIL
EAST BUSWAY
GARAGE RAMP
EAST LIBERTY DIVISION GARAGE
FIFTH AVE. RAMP
FIFTH AVE.

HOMEWOOD STATION



WILKINSBURG STATION/RAMP



D-9/D-10

APPENDIX E

CAPITAL COST SUMMARY

COST ITEM		COST ($)	DOLLAR YEAR
ENGINEERING SERVICES		12,286,087	1980
PROJECT ADMINISTRATION (PAT)		3,252,000	1980
REAL ESTATE/RELOCATION		15,997,115	1978
CONSTRUCTION CONTRACTS:			
EB-1	Walls	6,450,775	1978
EB-2	Grading/Drainage	7,973,863	1978
EB-3	Centre Avenue Bridge	1,529,689	1978
EB-4	Graham/Lang Bridge	491,296	1978
EB-5	East Liberty Station	12,041,746	1979
EB-6	Grant to 16th Street	2,598,721	1980
EB-7	Line Section	8,021,199	1980
EB-8	Line Section	8,800,595	1980
EB-9	Brilliant Bridge	4,785,694	1979
EB-10	Line Section	6,402,735	1979
EB-13	Roadway lighting, signing, marketing, and traffic signals	1,627,413	1980
EB-14	Station Finishes and Landscaping	2,460,894	1980
EB-15	Neville Ramp	5,160,256	1983
EB-16	Penn Station Basement Cut-off Wall	722,852	1983
	Subtotal	69,067,730	
OTHER CONSTRUCTION CONTRACTS:			
	Conrail Relocation	11,597,696	1979
	B&O Relocation	8,166	1978
	Utility Relocation:		
	Duquesne Light	334,460	1980
	Bell Telephone	393,439	1980
	Equitable Gas	55,835	1980
	Subtotal	12,424,470	

APPENDIX F

DATA SOURCES AND ADJUSTMENTS FOR THE RIDERSHIP ANALYSIS

The ridership analysis is based on daily "registration" counts, taken by PAT drivers. The drivers count boarding passengers in five categories: transfers, senior passes, handicapped passes, half-fare, and all other registrations. The last category includes all those paying a full cash fare or using a regular monthly or annual pass, trip ticket, U-Ticket, or weekly pass. The data were provided by PAT on computer tape containing the daily registrations, by route, from January 1982 through November 1984.

For this analysis, the raw data were summarized and adjusted in several ways. First, the daily counts were summarized into average weekday counts by route for each month. Next, an adjustment was made to eliminate transferring passengers who were counted in the "all other registrations" category because they used a pass or permit. Results from the busway on-board survey were used to allocate passengers in this category into pass users and cash payers. Then, for each route, the ratio of counted transfers to estimated cash payers was used to estimate the percentage of pass users who had transferred. The resulting estimates of average weekly, non-transferring passengers, were then summarized by route type to give average weekday counts by month for four categories: new busway routes, routes diverted to the busway, other east corridor routes, and west corridor routes. The last group was chosen as a control group because the west corridor had no major service changes during the period studied. A final adjustment was made to eliminate seasonal effects. Seasonal adjustment factors were estimated based on system-wide counts of total registrations by month for the 15-year period from 1970 through 1984, using a procedure, developed by the Bureau

of the Census, designated X11.* The X11 procedure produced better results than an ARIMA analysis, which was also executed.

It was also necessary to estimate the percentage of service which had been moved to the busway. PAT's records show the total vehicle miles of service by sign-up for the new routes. For the diverted routes, however, the only available records show vehicle miles, combined with other "related routes," many of which remained off the busway. Therefore, ridership by route was used to estimate the quantity of service on each route. The period July to November 1984 was chosen as a reference period when no more significant service additions were made on the busway and ridership had stabilized. For November 1983 and all months after that, the variable GRADBWAY was set to 1.0. Before February 1982, when the busway opened, GRADBWAY was set to zero. For months in between, the percentage of service switched was estimated based on the actual ridership on each route in the second half of 1984. For example, for February and March 1983, GRADBWAY = 0.776 because routes carrying 77.6% of July to November 1984 total busway ridership were operating on the busway at that time.

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*SAS/ETS User's Guide, 1980 Edition.

APPENDIX G

CALCULATION OF OPERATING COSTS FOR NEW ROUTES, DIVERTED ROUTES, AND ALL OTHER ROUTES

The method used for estimating operating costs for each route type was developed for a recent PAT study.[1] It involved first determining which operating cost items relate to the service units of number of vehicles, vehicle hours, vehicle miles, and passengers, then calculating a unit operating cost for each item, which was used to estimate expenses for each route type. Inaccuracies result from this method because many operating costs (1) are dependent on the size of more than one service unit and (2) are not completely proportional to service unit size. A recent pre-busway fiscal year, 1982, was selected for estimating unit costs, which were adjusted to equal 1983 dollars. Operating costs incurred by the busway were then added in as well as costs for the articulated buses used on the new routes.

Operating costs for 1983 to maintain the busway facility itself were allocated between new and diverted routes on the basis of the number of vehicle miles travelled on the busway. About 90 percent of new route vehicle miles and about 31 percent of diverted route vehicle miles were travelled on the busway.

A recent study found that the maintenance (including labor), fuel, and insurance costs of articulated buses are 50 percent higher than regular buses on a per vehicle mile basis.[2] The EBA Route uses articulated buses exclusively. Also, almost all of the articulated buses in PAT's fleet are

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[1]PAT Technical Memorandum, "Methodology Used in the Fare Structure Study;" Barton-Aschman; March, 1982.

[2]Richard Albright, Stephen Cummings, William Jessiman, Howard Slavin, Robert Wakeman, The Articulated Bus Report, U.S. DOT, UMTA ITSC, Cambridge, MA: 1982.

allocated to this route. The exceptions are the 63A and the 67/68J, which use one articulated bus each during the peak periods. The following new route vehicle maintenance costs were adjusted for articulated buses--Revenue Vehicle Operation (fuel and tires), Inspection and Maintenance of Revenue Vehicles, and Insurance. The first two items were adjusted on the basis of the portion of new route vehicle miles travelled by articulated buses, which was estimated at 72 percent. The third item was adjusted using the assumption that 66 percent of new route vehicle hours were articulated bus hours.

The new and diverted routes' operating costs do not include operating costs for other bus routes used to access the busway routes. The reason for this is to make the busway cost figures more comparable to those prepared for light rail systems--costs for other transportation modes used to access the system are not included in the light rail operating cost estimates.

Vehicle hours and vehicle miles data by route for 1983 and 1984 was provided by PAT. For the cases in which data for two or more routes is combined (e.g., 67J-68J) and only one of the routes is a busway route, an estimate was made of the portion of the vehicle hours or miles attributable to the busway route. Schedule information on the length of the route and the number of trips per day was used for this estimation. Vehicle hours and vehicle miles for the whole bus system was found in a PAT brochure, "1983 Statistics, Transit Operations." Passenger miles were estimated on the basis of passenger data. The UMTA Section 15 Report for 1983 showed that there were about 5.29 passenger miles per passenger for the system. The same number of passenger miles per passenger was assumed for diverted routes. For the new routes (EBA and EBO routes), 4.98 passenger miles per passenger was assumed; this figure was gleaned from the on-board survey results concerning where passengers boarded and deboarded. Peak passengers and peak passenger miles were estimated using PAT data on the average number of passengers per trip by time of day, and schedule information on the number of trips by time of day for each

route. For the system, 41 percent of passengers ride at peak, while 61 percent and 58 percent ride at peak on the diverted and new routes respectively. Annual scheduled buses were based on PAT data on weekday bus requirements for maximum peak, base, and night for each route. The requirements for the time periods were totalled and mutiplied by the number of weekdays per year (253) to arrive at an annual estimate of weekday scheduled buses.

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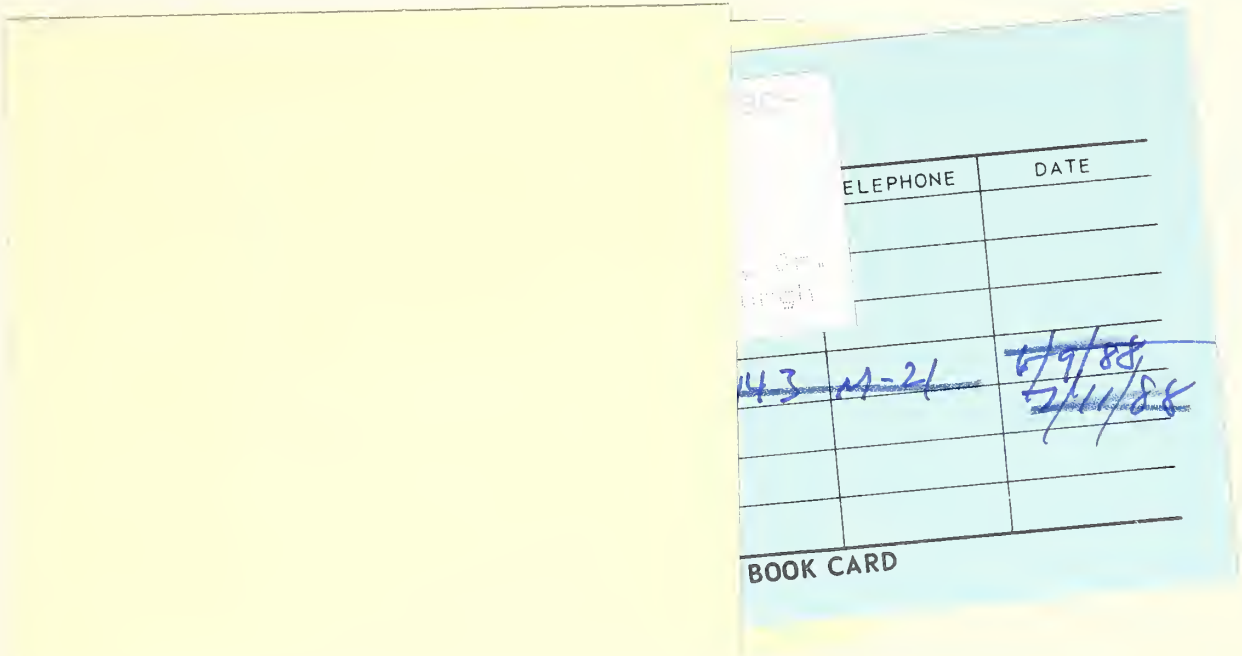
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