
APRIL2013
LEFT
24ColorCard CameraTrax.com

T NO. UMTA-MA-06-0026-79-1

PRT IMPACT STUDY
The Phase I PRT Impact on Morgantown Travel Traffic and Associated Activities

Samy E.G. Elias
Richard E. Ward

WEST VIRGINIA UNIVERSITY
Morgantown WV 26506

JULY 1979

FINAL REPORT

DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Transportation Systems Center

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Washington DC 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0026-79-1		

4. Title and Subtitle
PRT IMPACT STUDY
The Phase I PRT Impact on Morgantown Travel Traffic and Associated Activities

5. Report Date
July 1979

6. Performing Organization Code

7. Author(s)
Samy E.G. Elias, Richard E. Ward

8. Performing Organization Report No.
DOT-TSC-UMTA-79-1

9. Performing Organization Name and Address
West Virginia University*
Morgantown WV 26506

10. Work Unit No. (TRAIS)
UM941/R9720

11. Contract or Grant No.
DOT-TSC-1316

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Urban Mass Transportation Administration
Office of Technology Development and Deployment
Washington DC 20590

13. Type of Report and Period Covered
Final Report
Feb. 1977 - June 1978

14. Sponsoring Agency Code

15. Supplementary Notes
*Under Contract To: U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Cambridge MA 02142

16. Abstract
This is a study of the impact of the Phase I Morgantown PRT, the first fully automated, origin to destination, nonstop, demand activated, transportation system operational in a city environment. The study was designed to record the effect of the system operation on traffic and associated activities in the areas adjacent to the PRT. To achieve this objective a similar study was also conducted in 1975-76 prior to passenger service.

The system served a large segment of the community reaching some 38% of the Morgantown residents. During the course of the study, it was concluded that the system was a major force in influencing travel habits within its service areas. It was further concluded that while auto traffic along the two main arterial thoroughfares experienced a large increase over the two year study period, residents of the service area used autos for their trips less often than they did prior to the PRT. Moreover, compared to the bus system, which it replaced, the PRT is carrying more than the bus's previous share of the total trips. The increase in transit travel was assumed to be, at least, partly due to favorable attitudes towards the PRT. The advantages to using the PRT within its service area included reduced travel time compared to the automobile and the bus. This study is reported in three reports: Volume I - Operational Phase Travel Analysis; Volume II - Operational Phase Data Collection Procedure and Coding Manual; and The Phase I PRT Impact on Morgantown Travel Traffic and Associated Activities.

This volume, Impact on Morgantown Travel, contains an analysis and a comparison of the travel, traffic and associated activities in Morgantown before and after the PRT became operational.

17. Key Words
PRT, Travel Impact, Trip Distribution

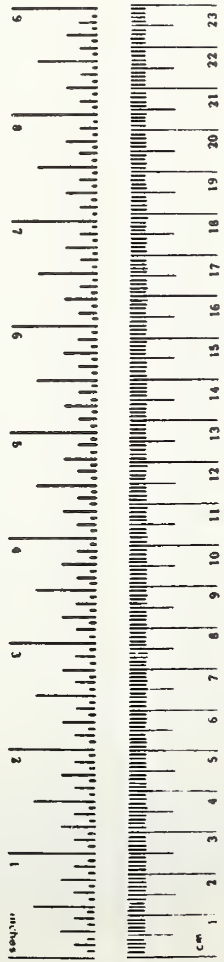
18. Distribution Statement
DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	90	

METRIC CONVERSION FACTORS

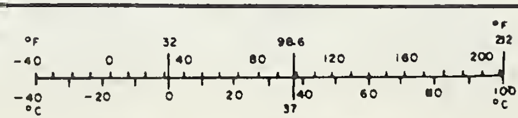
Approximate Conversions to Metric Measures

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)		
°F	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	hectares (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



PREFACE

This report documents the local impact of having installed the Morgantown Personal Rapid Transit (PRT) System. Including this report, a total of six reports (Volumes) were produced over the life of the two stages.

The Pre-PRT stage of the study was completed in 1975 and is reported in three volumes:

-- Volume I - Pre-PRT Phase Travel Analysis

-- Volume II - Pre-PRT Phase Data Collection Procedure and Coding Manual

-- Volume III - Pre-PRT Phase Frequency Tabulations from Four Transportation-Related Surveys.

This work was sponsored by the Transportation Systems Center (TSC), United States Department of Transportation, Cambridge, MA, under Contract No. DOT=TSC-985.

The Operational Stage, which was also sponsored by TSC, under Contract No. DOT-TSC-1316, was completed in 1977 and is reported in two volumes directly comparable to Volumes I and II of the Pre-PRT Stage:

-- Volume I - Operational Phase Travel Analysis

-- Volume II - Operational Phase Data Collection Procedure and Coding Manual.

This report, which cluminates the basic study objectives, was prepared under the latter contract.

This report was made possible through the tremendous individual efforts of four Graduate Assistants at West Virginia University who assisted the principal investigators in practially every phase of the Impact Study. The principal Graduate Assistants, in alphabetical order, were:

Patricia Goeke
Ahmed Syed
Phaisal Vejpongsa
Kam-Luan Young.

Additional credit must also be given to three other student assistants who participated in certain aspects of the project:

James R. Penman
Amy L. Rovelstad
Jane A. Hiteshew.

Mrs. Janet Alderman was responsible for the typing and much of the administrative work.

Several agencies and other individuals cooperated in making the PRT Impact Study possible. They include Dr. Mary Stearns and Mr. K.H. Shaeffer of TSC, The City of Morgantown, and the Institutional Research Office of West Virginia University

Special acknowledgment is also made of the significant contribution made by Mr. Govind K. Deshpande who left the project after the data collection phase of the study was completed.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (Continued)

1. EXECUTIVE SUMMARY

In October 1975, Phase I of the Morgantown Personal Rapid Transit (PRT) System, a revolutionary new mode of public transportation built as a research development and demonstration project by the Urban Mass Transportation Administration, commenced passenger service in Morgantown, West Virginia. Because the PRT is the first system of its kind ever operated in a city, it provides a unique opportunity to study the interaction between a new mode and its service area.

Although the present system installation in Morgantown represents only the first phase of a much larger system, it was believed that some measurable impacts could still be derived from its first few years of operation, prior to the initiation of the larger Phase II installation. Phase I consists of a three station system connected by 2.2 miles of guideway and served by 45 vehicles. These vehicles operate at maximum speeds of 30 mph and minimum headway of 15 seconds. Phase II will expand this system to 5 stations, 3.4 miles of guideway, and 73 vehicles.

The PRT Impact Study was designed to record the effects of PRT system operation on traffic and associated activity in the area of Morgantown adjacent to the PRT Phase I. The intent of the study was to provide information which should be useful to other areas contemplating public transit, particularly those planning for Automated Guideway Transit (AGT) type installations. The Operational Phase was called Post-PRT Phase in earlier work and has been renamed due to the development of Phase II of the PRT system and an altering of the earlier Pre-Post design of the Impact Study. The Phase I study utilized two data collection stages; the Pre-PRT stage (Spring, 1975), and the Operational stage (Spring, 1977), following the commencement of revenue service on the Phase I installation. The data collected during both stages was essentially the same consisting primarily of vehicle counting, home interviews, roadside and onboard travel surveys, and demographic and land use characteristics of established zones within the study area.

Compared principally to the University bus system which it replaced, the PRT, once it was in full scale operation, provided a higher level of public transportation service both in terms of speed and frequency of service, to say nothing of its inherent personalized service features such as demand activated non-stop trips in relatively small eight seat vehicles (standing capacity of 12). Moreover, for a comparable trip, the PRT had a clear travel time advantage over both the buses and the automobiles. One measure of this is based on the before (Pre-PRT) and after measure of the relative ratio of travel time by transit to the travel time by automobile. The lower the ratio the greater the advantage transit has over the automobile. Looking specifically at trips between zones directly served by PRT stations, there was only one zone pair where there was not a significant increase in transit's advantage, otherwise transit's advantage increased anywhere from sixteen (16) to sixty-two (62) percent.

The increased level of service of the PRT caused a marked shift in mode choice by residents of the study area for trips which they made within the study area. Before the PRT there were 10,371 such average weekday person trips made by automobile and 7,524 made by the University buses. After the PRT was operational, the number of auto trips dropped to 8,627 and the PRT captured 8,698. The PRT also captured an increased share of the trips being made along the PRT corridor, which includes travel by persons living outside of the study area, or beyond 1/4 mile radius from the PRT stations. These results are viewed as a positive impact.

Firm conclusions regarding the PRT's impact on general traffic congestion and automobile accidents were not possible because of the overall general increase in Morgantown traffic, presumably due to urban area growth. However, it was noted that in all the zones directly served by PRT stations, there was a decrease in traffic accidents for the first six months of 1977, compared to the same period in 1975.

System safety and noise pollution were also investigated. In the first instance, PRT operating logs indicated a perfect safety record. However, there was never any recorded safety incidences on the University bus system either. As to noise pollution, a separate study concluded that the replacement of the University bus system resulted in a decrease in community noise levels.

While this study did not specifically study economic or land use impacts, note was made where, in several instances, the PRT was a factor in the selection of sites for major city and university development projects.

In regard to attitudes about the PRT, a survey was only made following commencement of revenue service. Therefore, except in one case, data was not available to permit an explicit investigation of attitudinal changes or impacts. The single exception dealt with safety. In a separate study prior to the PRT, the PRT's safety was identified as the chief concern of Morgantown residents, who expected it to be potentially the least safe mode of transportation in Morgantown. This was in sharp contrast to the results of the later 1977 attitude survey in which PRT was ranked first in safety relative to the bus and the automobile.

Demand modeling of the form: Travel by Mode = f(supply, demand, attitudes), implied that differences between expected and observed trips, by mode, were due in part to changes in attitudes regarding the PRT between the time of the two data collection periods. However, the study did not reach any firm conclusions in this regard.

Considering the 1977 attitude survey only, the combined overall scores consistently ranked the automobile first (most desirable), the PRT second, and the Bus third. A summary of attitudinal rankings, according to seven different criteria, is shown below:

	1st	2nd	3rd
SAFETY	PRT	BUS	AUTO
RELIABILITY	AUTO	BUS	PRT
CONVENIENCE	AUTO	PRT	BUS
COMFORT	AUTO	PRT	BUS
PLEASANT ATMOSPHERE	AUTO	PRT	BUS
TRAVEL TIME	AUTO	PRT	BUS
COST TO USE	PRT BUS	BUS PRT	AUTO

The apparent difference of opinion regarding "cost to use" was correlated to the likely frequency with which two different groups of respondents use the PRT. Specifically, placing the PRT first were WVU dorm students who had the most immediate access to the PRT stations.

Eighty-seven (87) percent of the PRT riders during the 1977 survey were WVU students. The remaining riders were nearly equally WVU faculty and staff, as one category, and non-university people as another. The six (6) percent non-university ridership was far higher than expected, especially as Phase II of the system had not yet been completed.

The perceived convenience of the system was not conclusive from the data which was collected. On one hand, evidence suggested that it was very convenient, but on the other hand there was data which implied that it was not so convenient. Interpretations as to this inconsistency in the findings is brought out in the body of the report.

Ridership, by the end of June 1977, had reached the 2,459,727 mark, and by the time the system shut down for Phase II integration in the summer of 1978, it had climbed to 4,472,491 passengers.

In summary, the svstem has been accepted bv Morgantown and has had a very positive and measurable impact on automobile travel in and by residents of the study area. A reduction of 17.2% was measured in the study area while an increase of 18.8% was measured in other sections of Morgantown. There was an apparent change in the public attitude towards the system in general and its safety in particular. There was a steady increase in system dependability and system ridership and a steady decline in the passenger trip cost as the PRT matured. Lastly, there was a measurable use of Phase I by the townspeople although Phase I was originally thought to be of little value to them.

2. INTRODUCTION

A new and revolutionary public transportation system, the Morgantown Personal Rapid Transit System (M-PRT), began regular passenger service operation in Morgantown, West Virginia, in October 1975. To study the impact of the PRT on Morgantown, a substantial amount of data was collected in an attempt to capture the state of transportation related conditions before and after passenger service. This report contains an analysis of the comparison between the results of both sets of data. Moreover, this report presents an assessment of the PRT system impacts on the City of Morgantown. This assessment should provide other cities considering implementation of AGT systems, information which could help them determine whether they can effectively and efficiently utilize a Morgantown type PRT system to satisfy their transportation needs.

For a period of time following its inauguration, the M-PRT experienced all of the characteristics and growing pains of a new technology. While the system to date has experienced a perfect safety record,* its early operation was anything but perfect - with sporadic interludes of failures due to component "infant mortalities" and the emergence of system/subsystem level "bugs", particularly during the first winter of operation.** Moreover, the overall effect of a fluctuating performance record did little to encourage regular use by those who were at least willing to give the system a chance. For many travelers in the Morgantown area, the introduction of the M-PRT represented a novelty, an attraction, and as a result, trips were generated just for the fun of riding the futuristic looking PRT system.

All of the above conditions were expected: a fairly erratic level of service to start with, people who in the beginning would refrain from regularly using the system, and those who would go out of their way to take a ride. Therefore, travel habits in Morgantown were expected to

---

*Durant, P., and Ward, R., "The Inspection of an AGT System Safety Record: The Status of the Morgantown Personal Rapid Transit System," College of Engineering, WVU, Morgantown, 1978.

**Barker, T.C., et al., "1976-77 Winter Operation: Morgantown Personal Rapid Transit System," College of Engineering, WVU, Morgantown, 1978.

be highly unstable for at least a one-year period following the inauguration of PRT service, and that any attempt to study the impact of the M-PRT during this period would be misleading.

With these thoughts in mind, the comprehensive operational phase study was planned for the spring of 1977, approximately 1½ years after the commencement of regular service, and approximatelv two years after the completion of a similar study which was conducted prior to the inauguration of service. By the spring of 1977, system performance had essentially stabilized and it was felt that travel patterns had likewise reached a similar level of stability.

2.1 Objectives

Since this system is the first of its kind ever built and operated in a city and is expected to be the forerunner of significant changes in public transportation, a thorough study was made of the consequences of installing PRT in Morgantown to find characteristics and impacts which would be of interest to anyone considering the implementation of such a system. The study had two stages. The Pre-PRT stage, prior to the passenger service operation of the system, was completed in 1975. The Operational PRT stage was completed after the system had been placed into regular passenger service.

2.2 Organization of the Report

The remainder of this chapter is devoted to an overview of transportation in the City of Morgantown and to a brief description of the M-PRT System. Section 3 provides a brief description of the data which was collected and outlines the boundaries and characteristics of the study area. Section 4 presents comparisons of modal utilization in the PMA and PRT corridor, before and after the PRT became operational. These include such points as total travel by mode, the distribution of trips within the PMA, and the travel habits of travelers within the PMA. Section 5 compares the level of major transportation services within the PMA and looks at such features as traffic congestion, accidents, safety, noise levels and operating costs. Section 6 presents a comparison of travel behavior through the use of aggregate causal models of trip generation and distribution for both the M-PRT, the automobile and the University bus system. The models used as the basis were developed, independently, after each stage of the study to explain the magnitude of travel for each mode and for each trip purpose as a function of certain measures of transportation supply and demand for the particular zones being served. Lastly, Section 7 presents the overall conclusion reached.

2.3 An Overview of Transportation in Morgantown

Morgantown, West Virginia, is a university city with a total population of approximately 30,000 inhabitants. This figure is misleading, however, as the political boundaries of the city are rather small whereas the entire urban area, including several adjacent communities, approaches a figure closer to 60,000 inhabitants. West Virginia University (WVU) is the largest single employer in the area with some 6,000 faculty and staff on the payroll. The student body at WVU, growing steadily, totalled 17,020 at the end of the spring registration in 1977 and by fall of 1977 has reached the 18,500 mark.

All of the WVU buildings were once located in a compact area immediately adjacent to the north side of Morgantown's central business district (CBD). However, as WVU expanded new buildings, which included classrooms, research space, dormitory facilities, athletic facilities, a medical center, and a law school were located in an area some 1½ miles north of the original campus. The original group of buildings near the CBD became known as the Main (or Downtown) Campus and the new buildings, some of which are already nearly 20 years old, are located in what is known as the Evansdale Campus.

In the spring of 1975, at the time that the baseline data was collected (Pre-PRT Stage), WVU was operating a fleet of about 16 Blue Bird-style school buses, one of the largest campus transportation systems in the United States. Most of the buses were used to transport students, faculty, and staff between the Main and Evansdale Campuses, but a few of the buses were also used for shuttle service within the spacious Evansdale Campus. The total distance form one end of the Evansdale Campus to the other is also nearly one and a half miles. Use of the buses was restricted, however, and Morgantown residents who were not connected with the University were unable to use the system.

Morgantown has only two major north-south thoroughfares, University Avenue and Beechurst Avenue-Monongahela Boulevard, the latter merely changing names at one point along the corridor. These two corridors are the only viable connections between the two campuses, and also are the only direct road links between the opposite sides of town (north and south). In addition to heavy volumes of private automobile and truck traffic, these two thoroughfares carry city and county bus traffic, and have been the routes taken by the University inter-campus buses as well. However, since inauguration of M-PRT passenger service in the fall of 1975, the inter-campus bus service has been discontinued and the M-PRT now provides direct service to and from one location of the Evansdale Campus and the Main Campus; in addition to providing direct service to the CBD to and from both of the campus M-PRT stations. A portion of the University bus system still remains in operation, specifically those buses which operate along the Evansdale intra-campus route. In addition to providing shuttle service from the Medical Center, on the Medical Center Campus, to the Coliseum (Sports Arena), at the far end of the Evansdale Campus, the bus route was realigned to act as a feeder to the Engineering PRT Station.

The M-PRT is the major public transit mode in Morgantown, and unlike the University bus, it has been open to townspeople since it commenced passenger service. Both of the existing bus services, although they operate through the PRT corridor, are not competing with the PRT. The city buses reach well outside the PRT's present primary market area for their passengers, and the county buses are running from neighboring Star City. When the second phase of the PRT is completed its potential market area will expand significantly, and at that time the present city bus route alignment would compete with the PRT service. Both systems operate small Mercedes-Benz mini-buses on a maximum scheduled service freqency of ½ hour, compared to the 15 second headway of the M-PRT.

2.4 The Morgantown PRT (M-PRT)

The M-PRT is a computer controlled, fully automated, self-service transportation system which utilizes electrically powered, rubber-tired vehicles operating on a dedicated guideway. Vehicle service, which may be instituted by predetermined schedules, during peak hours, or by passenger actuation (demand mode), during off-peak hours, is non-stop between all stations, with the Main Campus station in the middle of the system being an off-line station. The system is said to belong to a generic class of systems known as the M-PRT since its inception in 1969 and will remain so named in this study.

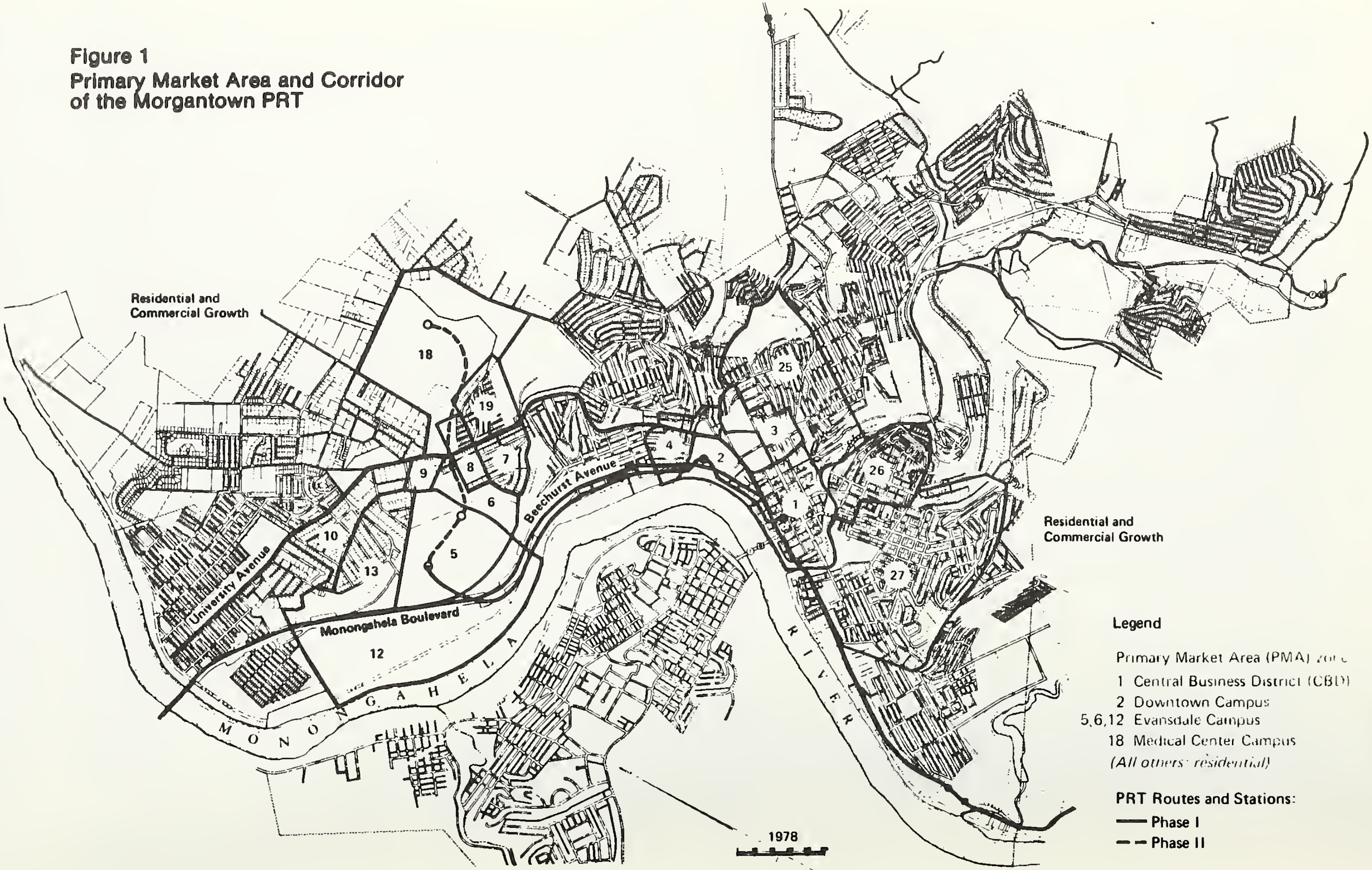
The vehicles are climate controlled with dimensions of 15.5 feet in length, 9 feet in height, and 6 feet in width, and are capable of carrying 8 seated passengers and up to as many as 12 standees during peak periods. The vehicles operate at a minimum headway of 15 seconds and at speeds up to 30 mph on 10% grades. All weather operation is provided by means of a guideway heating system to maintain the running surfaces free of ice and snow.

The present system consisting of three stations and 5.4 miles of equivalent single lane guideway with a total fleet of 45 vehicles, is only the first phase (Phase I) of a much larger system (Phase II). The three Phase I stations are at Walnut Street in the CBD, Beechurst Avenue on the Main Campus, and across from the Engineering Sciences Building on the Evansdale Campus.* The second phase of the system is currently under construction and will not be ready to carry passengers until 1979-80. The expansion of the system, under Phase II, will provide two additional stations on the Evansdale Campus plus an increase in the size of the Engineering Station, itself an off-line station. Figure 1 depicts the routing and the station location of both phases of the M-PRT. Figure 2 shows the location of the City of Morgantown with respect to its urbanized area, while bus routes are depicted in Figure 3.

---

*The Engineering Station, although operational, is only one-third completed.

Figure 1
Primary Market Area and Corridor of the Morgantown PRT



Map used by permission of City of Morgantown

Figure 2
Morgantown Urban Area

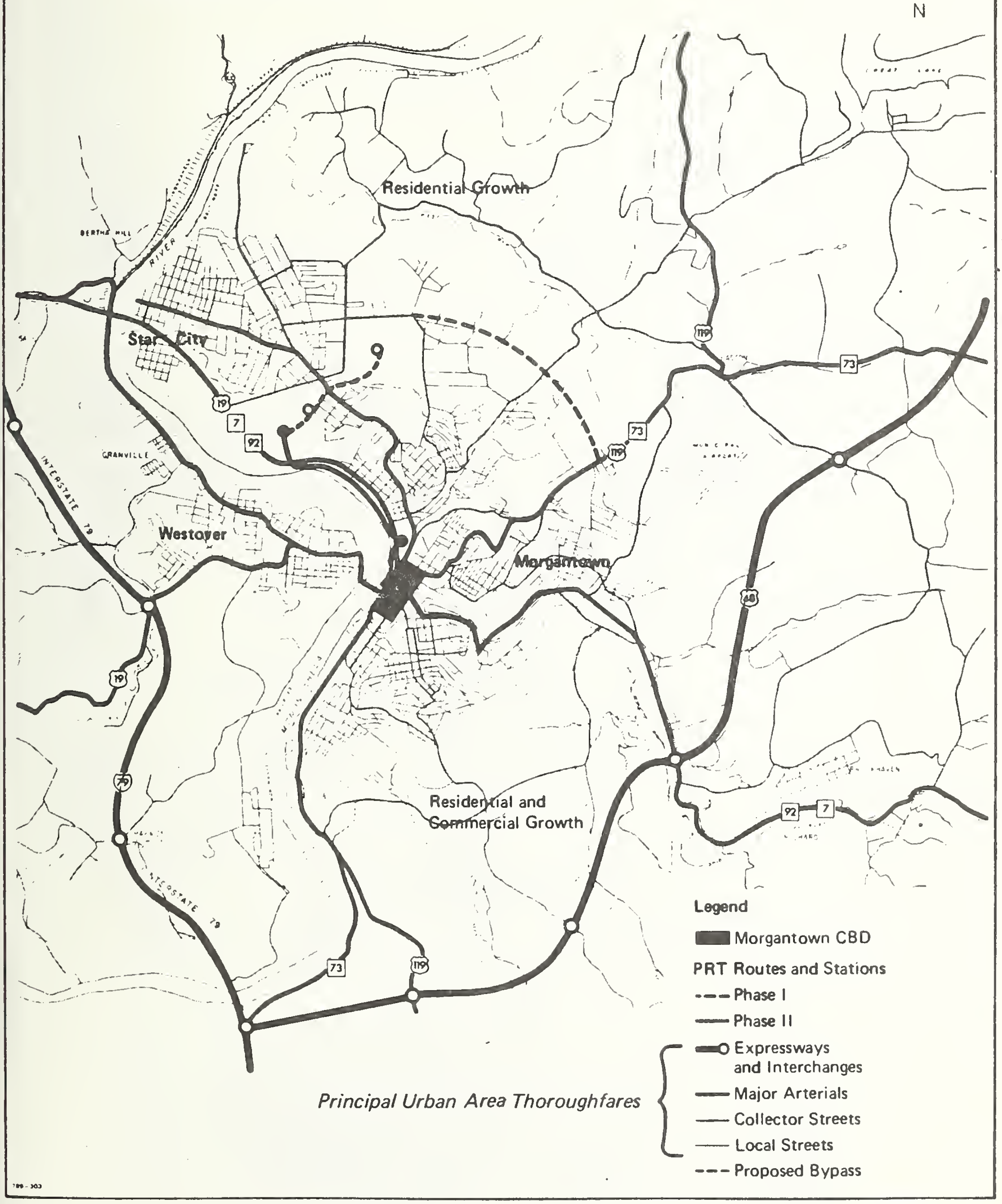
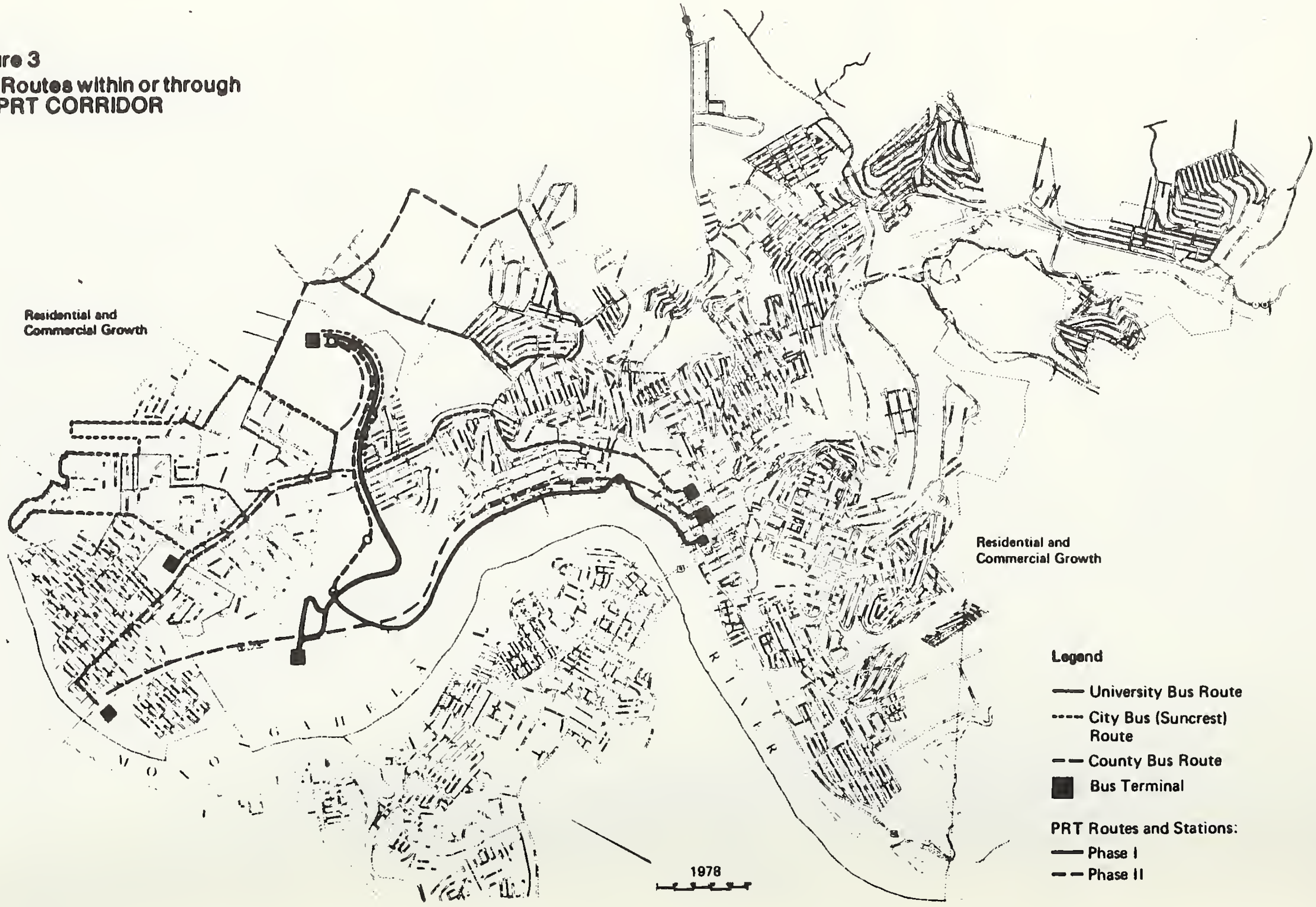


Figure 3
Bus Routes within or through the PRT CORRIDOR



Map used by permission of City of Morgantown

3. BACKGROUND

All of the data reported in this study was collected during the spring school semester of 1977, principally during the months of March and April. The following sections describe the study area and briefly outline the data which was collected to describe modal utilization, travel behavior, travel patterns, and demographic characteristics.

3.1 The Study Area

The study area of the M-PRT is defined in terms of the PRT corridor or the PRT primary market area (PMA). Following the commencement of passenger service, modal utilization impacts of the M-PRT were expected to occur along the PRT corridor. For the purposes of this report, the corridor has been defined to include the following:

1) The principal auto and bus route segments along Beechurst and University Avenues, both of which approximately parallel the PRT guideway alignment. These two avenues are highlighted in Figure 1.

2) Public parking facilities within approximately a one-quarter mile radius of a PRT station.

The magnitude of total auto traffic (ADT) along the PRT corridor is an example of the modal utilization which the study sought to measure.

The Primary Market Area (PMA) consists of 16 typical planning zones, representing a cross section of land use. The identification of zones is necessary because of the need for travel modeling and is based upon the homogenity of land use occurring within the zone. The boundaries between zones are often natural boundaries such as major corridors, ridges, streams, etc.

The PMA zones are actually a subset of a larger number of zones (46) into which the entire Morgantown area is divided. The zonal boundaries of all zones, including the PMA zones, are based on land use, topographic considerations and uniform socio-economic characteristics. The PMA zones, also illustrated in Figure 1, by definition, represent zones within approximately a ten-minute walking distance of a PRT station.

Table 3-1 describes each of the zones within the PMA, and identifies the three zones which are the locations of the M-PRT stations. The numbering of the zones is not sequential, as can be seen. Therefore, to make subsequent computer processing of the data simpler, and to be consistent with the Pre-PRT study, each of the PMA zones was given a second numerical designation which was sequential. This, too, is included in Table 3-1.

3.2 Data Collection

Measures of modes operating within the PRT corridor were based on counts of the volume of daily travel as well as estimates of average daily travel between zones within the PMA. Data was collected on travel times and speeds, operating costs and on automobile accidents within the PMA.

Travel along the PRT corridor and between PMA zones following the commencement of revenue operation of the PRT system primarily involved the use of the automobile and the PRT. (Although city, county, and university buses continued to be available, they did not really compete with the PRT service.) Several data collection techniques were utilized to record trip purposes, the choice of mode, attitudes toward alternative modes, and the socio-economic characteristics of the trip makers.

Estimates of disaggregate zonal populations were established for each of the four major categories of PMA residents. A baseline for these estimates was obtained from the 1970 U.S. census records for Morgantown, which in turn were broken into disaggregate population estimates for the PMA zones. The student population residing in each zone was estimated from WVU enrollment records for the spring semester of 1977.* The PMA residential location of University employees was projected from a sample drawn from the University Telephone Directory.

Table 3-2 is included to give an overview of the population composition of each zone in the PMA.

Full details as to techniques employed to obtain all the above data are presented in Volume II of both the Pre and Operational stage PRT studies.

---

*Only WVU Freshmen are required to live in University Dormitories.

TABLE 3-1

DESCRIPTION OF PMA ZONES

Map Zone	PRT Station Nearest to Zone	Zone Description	Special Features	Zone Designation for Analysis
1	Walnut St.	Central Business District (CBD)		1
2	Beechurst	MAIN CAMPUS OF WVU	No Housing	2
3	"	Residential	Dormitory Concentration	3
4	"	Residential		4
5	Engineering	EVANSDALE CAMPUS	No Housing	5
6	"	EVANSDALE CAMPUS	No Housing	6
7	"	Residential		7
8	"	Residential	Dormitory Concentration	8
9	"	Residential/ Light Shopping		9
10	"			9
11	"	City Park		11
12	"	EVANSDALE CAMPUS (Coliseum)		11
13	"	Residential		12
18	"	MEDICAL CENTER CAMPUS	Limited Housing	13
19	"	Residential		7
25	Walnut St.	Residential		14
26	"	Residential		15
27	"	Residential		16

TABLE 3-2

A COMPARISON OF DISAGGREGATE
POPULATION ESTIMATES FOR THE PRIMARY MARKET AREA

PMA Zone	Dorm[1] Student Pre	Dorm[1] Student Oper.[3]	Non-Dorm[1] Student Pre	Non-Dorm[1] Student Oper.	Fac/Staff Pre	Fac/Staff Oper.	Residents Pre	Residents Oper.	Total[2] Pre	Total[2] Oper.
1	0	0	967	513	35	27	860	860	1862	1400
3	950	1630	710	478	30	27	160	160	1850	2295
4	670	734	110	489	60	53	430	430	1270	1706
7	0	0	80	58	120	69	80	80	280	207
8	1733	1860		0		5	0	0	1733	1865
9	0	0		0	10	0	130	130	140	130
10	0	0	90	93	70	53	120	120	280	266
11	0	0		12	25	0	105	0	130	12
13	0	0	40	70	40	21	55	55	135	146
18	0	0	90	42	25	48	220	220	335	310
19	0	0	500	634	45	27	20	20	565	681
25	0	0	730	932	120	133	2547	2547	3397	3612
26	0	0	370	396	100	74	1253	1253	1723	1723
27	0	0	650	746	345	329	2005	2005	3000	3080
Total	3353	4224	4337	4463	1025	866	7985	7880	16,510	17,433

[1]Total Student Enrollment - Pre = 16,210
Oper = 17,020

[2]Total for the City of Morgantown - Pre = 28,872
Oper = 31,908

[3]Oper. is abbreviation for Operational Phase PRT.

4. COMPARISONS OF MODAL UTILIZATION

In reading this section, it must be remembered that by the spring semester of 1977, the PRT had replaced the major portion of the University bus (U-Bus) system which had previously run between the University's Evansdale Campus (PMA Zones 5, 6, and 8) and the Main Campus (PMA Zone 2), the latter lying immediately adjacent to the Central Business District. It is suggested in this section that any noticeable changes in modal utilization within the PMA may be at least partially attributable to the introduction of the PRT as a transportation alternative, particularly since there were no other changes in the basic transportation infrastructure within the PMA, or indeed within Morgantown. Furthermore, there were no external factors, such as land use changes, shopping center developments, or the like, which may have been at work to influence the travel habits of the PMA residents.

With the above comments in mind, the following paragraphs will compare the magnitude of auto, bus and PRT ridership estimated for both periods of the study. The section is concludes with an evaluation of traveler profiles which take into account such factors as trip purpose and reasons given for mode choice.

4.1 Total Travel Impacts

The ridership and travel estimates discussed in this section, unless otherwise noted, are estimates of travel within the PMA by residents of the PMA. These are the people and the trips originally assumed to be the most likely candidates, so to speak, for being influenced by the introduction of PRT service. While broader measures of travel through the PRT corridor are presented, and are important, the greatest investment in data was placed in the collection of information about the trips of this special subpopulation of Morgantown residents.

Total auto traffic along the PRT corridor, as a broad indication of overall transportation trends in Morgantown, increased nearly 19% between the corresponding periods of 1975 and 1977, to a total estimated 44,933 average daily vehicle trips. Although this figure includes through traffic as well as PMA trips, the limited scope of this study does not permit one to state, with any confidence, the reasons behind such a large increase. However, the overall growth of the Morgantown urbanized area is probably a substantial factor.

PMA auto trips by PMA residents, however, did not follow the same trend, as can be seen in Table 4-1. Instead these auto trips were estimated to decrease by some 17%. Aside from the PRT, there is no apparent reason for this to have occurred. Moreover, the combined total amount of average daily trip making within the PMA by residents of the PMA has remained relatively stable. What has happened is that there has been a noticeable increase, 8%, in transit's share of the total passenger trips occurring within the PMA. Additionally, it was noticed that prior to the PRT, the number of U-Bus corridor trips and the North-South PMA trips was nearly the same. Indicating that, at best, very few non-PMA residents made use of the inter-campus bus service. Following implementation of PRT service, however, approximately 15% of the corridor trips via the PRT were made by people living outside of the PMA.

The PRT is seemingly a much more attractive transportation alternative, not only when it is put up against the bus, but when it is available as an alternative to the auto as well. Reasons for this are partially discussed in Sections 4.3 and 5. However, attitudes of PMA residents toward the three principle travel modes are included in Volume I.

4.2 Comparisons of Trip Purpose

For modeling travel within the PMA (see Section 6), each trip was classified as falling into one of five categories. Each category is thought of as a trip purpose as it reflects, to a certain extent, the nature of the activities at one or both ends of the trip. Fortunately, the zones of the PMA were suitable for such an analysis as each of the zones could be described as being either predominately residential (home based), a campus, or commercial (CBD). Based on this categorization, the following trip purposes were established:

1) Campus-to-Campus
2) CBD Oriented (Zone 1 either as an origin or destination
3) Home-to-Campus
4) Campus-to-Home
5) Interzonal (involving neither the CBD nor campus zones).

The location and description of the PMA zones are presented in Figure 1 and Table 3-1.

A breakdown of travel, by trip purpose, (Table 4-2) is possible by aggregating trips from their respective origin/destination matrices (see Volume I). Additionally, the figures in Table 4-2 are only from those trips where, for a given zone of origin and destination, the auto and transit

TABLE 4-1

MAGNITUDE OF MODAL UTILIZATION (ADT)

Location/Mode	Pre-PRT	Operational PRT
PRT Corridor		
· Auto (Vehicle Trips)	37,412	44,933
· Transit (Person Trips)	7,822[a] (U-Bus)	10,294 (PRT)
Primary Market Area (PMA)		
· Auto (Person Trips)	10,371[c]	8,627
· Transit (Person Trips)	7,524[b]	8,698

Notes:

a) The estimated trips are only those trips which occurred along the North-South PRT corridor. In the case of the U-Bus, the trips included are those which were counted boarding the Towers-Campus Drive buses at Towers and the Campus Drive-Towers buses at Campus Drive.

b) Only includes those PMA trips (T_{ij}) which are designated as occurring along the North-South PRT corridor (e.g., between the Evansdale Campus and the Main Campus).

c) Auto trips taken from the PMA auto trip tables reported in Volume I of the operational stage study. (ref. appendix A of Volume I).

TABLE 4-2

COMPARISONS OF PMA MODE SPLIT
BY TRIP PURPOSE

TRIP PURPOSE	PRT SHARE OF TRAVEL BY TRIP PURPOSE WITHIN PMA							
	PRE-PRT TRIPS				OPERATIONAL PRT TRIPS			
	AUTO	U-BUS	TOTAL	SPLIT	AUTO	PRT	TOTAL	SPLIT
Campus to Campus	334	1688	2022	.83	265	2533	2798	.91
CBD Oriented	1464	334	1798	.19	1028	559	1587	.35
Campus to Home	1759	2361	4120	.57	1770	2087	3857	.54
Home to Campus	1888	2655	4117	.64	1777	2773	4550	.61
Interzonal	809	426	1235	.34	601	287	888	.32
Total	6254	7464	13292	.56	5441	8239	13680	.60

are competing for the trip at both stages of the study. For example, although one route of the U-Bus traveled between the Medical Center (Zone 18) and the Engineering Building (Zone 5), Phase I of the PRT did not extend that far; therefore, data for that zone pair is not included in the Table.

The most important trip purpose is probably the campus to campus trips, followed closely by the CBD oriented trips. In the latter case, there is an 84% change in modal split in favor of the PRT. However, it is only fair to point out, as it is in a later section as well, that the U-Bus never provided direct access to the CBD. The closest terminal was in the Main Campus (Zone 2), at least a $\frac{1}{4}$ mile walk from the CBD. Therefore, the improved accessibilitv of the CBD, along with the increased level of service offered by the PRT has had a very definite impact on trips involving the CBD.

The PRT has also had a positive impact on travel between campuses, with a 10% change in mode split. There is reason to believe that some of this change has occurred because the PRT has been able to induce trips as well as to divert them from the automobile.

4.3 Comparisons of Trip Distribution

The trip tables in Volume I present the magnitude of travel, by mode, between every zone of origin and destination within the PMA for both stages of the study. The previous paragraphs have already indicated that the total combined travel has changed following the initiation of PRT service. The following discussion investigates whether there has been a shift in trip destination within certain classes of PMA zones.

To accomplish this, correlation coefficients were calculated for the zone by zone trips. The analysis was stratified by the previously noted trip purposes, in addition to looking at all zone pairs within the PMA where the PRT replaced the bus. A further stratification in the analysis compared the following trip distribution:

- Pre-PRT Auto Trips compared to Auto Trips occurring following the inauguration of PRT service
- U-Bus trips compared to PRT trips
- The total trips occurring during the Pre-PRT stage compared to the total trips occurring following the inauguration of PRT service

- The Pre-PRT modal split (transit/total) compared to the modal split which occurred following the inauguration of the PRT service.

In general, a high (strong) correlation indicates that the distribution of trips, between designated zones, is similar for both stages of the study. A low (weak) correlation indicates a difference in the distributions and implies a change in travel behavior by the PMA residents since the PRT became operational.

The strongest correlations from the above comparison, shown in Table 4-3, are for the transit trips, across all trip purposes. The weakest correlation within this group is for the CBD oriented trips (.66). However, once again it must be pointed out that trips to the CBD using the U-Bus were required to walk from the main campus bus terminal, whereas the PRT has a station in the heart of the CBD. It is only natural, therefore, that the travel habit of CBD oriented trip makers would change.

The strongest correlations across trip purposes for all modal comparisons were for the home-oriented trips. There was also a very high correlation for the campus to campus trips by transit (.95). Therefore, while transit's share of total campus to campus trips may have increased, the distribution of these trips had not changed.

The weakest correlations are between the auto trips for both the campus to campus and CBD oriented trips, i.e., the zones most directly served by the PRT stations. It is for these trips that the PRT has apparently had the biggest impact in terms of influencing previous auto trip makers to change their travel habits. Of course, the University campuses and the CBD are the areas between which auto travel times are the worst during the working day, and where parking spaces are the most scarce. The U-Bus, prior to the PRT, was likewise caught up in the same traffic snarls as the auto; and, compared to the PRT, the U-Bus was apparently not viewed in the same light as a viable alternative to the auto as the PRT now is with regard to its convenience, comfort, etc.

4.4 Traveler Profiles

Travelers within the PMA have been divided into three distinct groups of people:

TABLE 4-3

CORRELATION OF TRIP DISTRIBUTIONS BETWEEN PRE-PRT AND OPERATIONAL PRT

Trip Purpose	Auto	Transit	Transit[1]	Split[2]
Campus to Campus Trips	-.42	.95	.98	.23
Observations: 7	p[3] = .3463	p = .0009	p = .0001	p = .6191
CBD Oriented Trips	.25	.66	.32	.62
Observations: 18	p = .3108	p = .0027	p = .1911	p = .0057
Campus to Home Trips	.68	.99	.98	.73
Observations: 22	p = .0005	p = .0001	p = .0001	p = .0001
Home to Campus Trips	.74	.99	.98	.50
Observations: 23	p = .0001	p = .0001	p = .0001	p = .0147
Interzonal Trips	.57	.74	.73	.26
Observations: 43	p = .0001	p = .0001	p = .0001	p = .0896
All PMA Trips	.65	.96	.95	.52
Observations: 113	p = .0001	p = .0001	p = .0001	p = .0001

[1]Total represents the sum of transit and auto trips

[2]Split represents the modal split (transit trips/total trips)

[3]p = the probability under the H_o:there is no correlation

1) West Virginia University Students
2) Members of the West Virginia University Faculty and Staff
3) Townspeople (residents of Morgantown who are in no way connected with the University, either as students or faculty/staff members).

The purpose in the division was based on the assumption that members of these groups are likely to have different travel habits within the PMA, particularly between the zones which were to be directly served by the PRT. However, except for the fact that University faculty/staff members work predominantly within the zones directly served by the PRT, they probably differ little from the townspeople.

General Trip Making . . . With regard to PRT trips, as compared to U-Bus trips prior to the PRT, there has been a definite change in the composition of riders. Of course, it has already been pointed out that the total average daily PRT trips have increased some 32% over the number recorded by the U-Bus in the spring of 1975. Whereas over 96% of U-Bus trips were accounted for by students, only 87% of the PRT trips were made by students, with the remaining 13% being nearly equally split between faculty/staff and townspeople. While the PRT is attracting trips from the townspeople, and possibly more trips from faculty/staff members than the bus ever did, it is necessary to remember that townspeople were not allowed to use the U-Bus prior to the PRT.

Overall, of the people surveyed in the spring of 1977, students apparently made fewer total trips/day on the average, than they did prior to the PRT (1.39 vs 1.62*). In this regard, it was pointed out in the Pre-PRT study that a large percentage of the respondents actually live in Zones 1, 2, 3, or 4, which is the main campus/CBD area, and may well find most of their needs met within walking distance of their residences. Additionally, while there is no real evidence to support the following observation, the University has reportedly striven to reduce the number of inter-campus trips through better scheduling of classes.

---

*See Table 3.10 - Pre-PRT Volume I and Table 4-1 - Operational Phase Volume I.

TABLE 4-4

COMPARISON OF TRIP PURPOSE BETWEEN THE PRE-PRT AND OPERATIONAL PRT STUDIES STRATIFIED BY MODE OF TRAVEL AND USER GROUP

AUTO TRAVEL

Trip Purpose	All Students Pre	All Students Operational	WVU Employees Pre	WVU Employees Operational	Townspeople Pre	Townspeople Operational	Total Pre	Total Operational
Returning Home	39%	44%	39%	42%	41%	33%	40%	40%
School Related	15%	29%	11%	8%	2%	3%	8%	20%
Work Related	1%	2%	18%	17%	13%	18%	9%	8%
Shopping	8%	9%	9%	5%	15%	---	12%	7%
Social/ Recreational	18%	---	12%	---	7%	11%	11%	3%
Eat Meal	1%	3%	3%	---	---	---	1%	2%
Other	18%	13%	8%	28%	22%	35%	19%	20%
Total	100% (343)	100% (370)	100% (153)	100% (36)	100% (549)	100% (169)	100% (1054)	100% (575)

TRANSIT TRAVEL (Pre-Bus, Phase I-PRT)

Trip Purpose	All Students Pre	All Students Operational	WVU Employees Pre	WVU Employees Operational	Townspeople Pre	Townspeople Operational	Total Pre	Total Operational
Returning Home	32%	24%	36%	37%	23%	14%	33%	24%
School Related	53%	64%	43%	6%	45%	10%	52%	57%
Work Related	2%	---	19%	26%	16%	---	3%	2%
Shopping	1%	3%	1%	---	3%	7%	1%	3%
Social/ Recreational	3%	5%	2%	9%	3%	45%	3%	8%
Eat Meal	2%	---	2%	---	---	---	2%	---
Other	7%	4%	7%	22%	10%	15%	6%	6%
Total	100% (1669)	100% (720)	100% (197)	100% (50)	100% (31)	100% (58)	100% (1897)	100% (828)

Faculty/staff members surveyed in the spring of 1977 reported nearly the same number of trips/day, on the average, as they did in the spring of 1975 (2.12 vs 2.15), while the townspeople reported an increase (1.92 vs 1.54). However, it is doubtful that the PRT has had any effect on the townspeople trips thus reported.

Trip Purpose . . . It was hypothesized, prior to the operation of the PRT, that because of its higher level of "personal" service, the PRT would induce a greater number of discretionary trips, namely trips for such purposes as shopping, social, recreational, eating meals, etc. Statistics reflecting what has actually occurred are displayed in Table 4-4.

For faculty/staff members, the PRT apparently has been an inducement to additional trips for discretionary purposes, as 31% of their PRT trips were made for these reasons, compared to only 12%* two years before. Moreover, the same group, who prior to the PRT recorded 32% of the auto trips for discretionary purposes, once the PRT was opened, recorded only 21% of their auto trips for purpose of shopping, eating, recreation, etc. Faculty/staff members have apparently found the PRT mode more desirable for these kinds of trips than either the U-BUS before it, or presumably even the auto.

Townspeople also recorded that a large percentage of their PRT trips were made for the same purposes. However, comparing this behavior to either U-Bus trips or auto trips is not nearly as significant as it was for faculty/staff. In the first instance, townspeople, as mentioned previously, were not normally permitted to ride the U-Bus.

Students are apparently more locked into the purposes for which they travel, especially when one compares U-Bus trips against the PRT trips. There was, however, a noticeable decrease in the use of the auto for discretionary trips.

Mode Choice . . . The only striking difference recorded between the two studies being compared, so far as the reasons for "choice of mode" is concerned, involves the reason labeled "other", as shown in Table 4-5. It is possible

---

*Derived from Pre-PRT On-Board U-Bus Survey.

that the characteristics of the PRT were underspecified, and that there is some other desirable trait of the system which was not listed as an option for the respondents to check.

Overall the evidence in Table 4-5 does not permit conclusions about mode choice decisions. For example, there are believed to be inconsistent responses to survey questions dealing with the implied convenience of the PRT. On the one hand there was a drop between both stages of the study, and across all user groups, in the frequency with which convenience is offered as a reason for choosing transit. In other words, the PRT is reportedly less convenient than the U - Bus. On the other hand, from the responses to a separate question, which required that respondents rank the modal alternatives with regard to their convenience, the PRT was ranked higher than the bus. Furthermore, it is believed that if the PRT is indeed less convenient than the bus, as implied from the mode choice responses, than one would expect this to show up in the ridership figures. Instead, the PRT carried a far greater number of trips in the corridor than the U-Bus ever did; and it did, in fact, offer an overall level of service which was much improved over the buses.

One last point needs to be raised in this issue. The drop in the percent of respondents who chose transit (PRT) because of its convenience is made up chiefly by the increased number who reported they had no choice, particularly among the students. While this is probably a valid claim for many of the residents, the increase between 1975 and 1977 is not believed to be an accurate reflection of fact. For example, 55 percent of the people surveyed prior to the PRT reported that they had an automobile available for use, while in the spring of 1977, almost the same number (56%) reported that they had an auto available.

The general mood or attitude towards the PRT, at the time of the second study, was highly sensitized. At the time of the second study, in the spring of 1977, on the second phase of the PRT* had not begun construction; there was some uncertainty as to whether it would ever be built; the first phase did not serve the entire University, much

* Phase II gained final approval and began construction in the Summer of 1977.

TABLE 4-5

COMPARISON OF REASONS FOR MODE CHOICE BETWEEN THE PRE-PRT AND OPERATIONAL PRT STUDIES STRATIFIED BY MODE OF TRAVEL AND USER GROUP

Reason	Students		WVU Employees		Townspeople		Total	
	Pre	Operational	Pre	Operational	Pre	Operational	Pre	Operational
AUTO TRAVEL								
Convenience	65%	51%	70%	58%	37%	39%	50%	49%
Low Cost	4%	2%	2%	5%	45%	1%	26%	2%
Speed	5%	10%	6%	7%	2%	3%	4%	8%
Safety	---	34%	---	---	1%	---	1%	25%
No Other Transportation	25%	---	---	28%	13%	53%	12%	12%
Other	1%	3%	22%	2%	2%	4%	7%	4%
Total	100% (345)	100% (1203)	100% (478)	100% (84)	100% (1069)	100% (274)	100% (1892)	100% (1354)
TRANSIT TRAVEL (Pre-Bus, Phase I-PRT)								
Convenience	48%	21%	44%	37%	45%	34%	47%	22%
Low Cost	6%	2%	7%	5%	10%	7%	6%	2%
Speed	2%	3%	2%	4%	3%	2%	2%	3%
Safety	1%	1.1%	2%	25%	---	---	1%	2%
No Other Transportation	40%	64%	53%	---	36%	10%	39%	59%
Other	3%	10%	10%	29%	6%	47%	5%	12%
Total	100% (1624)	100% (1561)	100% (197)	100% (83)	100% (31)	100% (58)	100% (1852)	100% (1702)

less the large residential sections of Morgantown and the townspeople; there was heated student debate over the price to be charged for a flat semester fare card; press coverage of the PRT up until that point had been extensive, often anti-Morgantown PRT, and had to have had an influence on Morgantown residents. This was all occurring despite the PRT's achieved high level of performance. Unfortunately, it is also believed that the PRT's earlier performance records (see Volume I -- Operational PRT Travel Analysis) influenced people's attitudes regarding its reliability and its convenience.

5. THE LEVEL OF TRANSPORTATION SERVICES

This section will investigate the level of service provided by the transportation alternatives in Morgantown and the changes which have occurred between 1975 and 1977.

With regard to auto travel, the overall network of streets and roads has not changed within the PMA or along the PRT corridor since 1975. Moreover, the auto network within all of Morgantown has remained unchanged. Auto traffic within Morgantown, especially along the PRT corridor, was severe before the PRT and it has remained severe since the PRT became operational. Section 5.2 documents this fact and also discusses the accident history of the study area.

Clearly public transportation alternatives have changed dramatically. The University Bus System (U-Bus) which is the baseline against which the M-PRT is compared, was only available to University students and faculty/staff members. The frequency of U-Bus service during the normal working day was 5 minutes along the PRT corridor. Evening and weekend service increased to a frequency of 30 minutes along the same route.

The M-PRT operated with a scheduled headway as frequent as 15 seconds and it was available to all who wished to ride, including the "townspeople" of Morgantown (individuals not connected with the University). Countering this obvious improvement in service, at least initially, was the PRT's frequent failure rate relative to the U-Bus. However, by the spring of 1977, the PRT's dependability* had stabilized at around 97 percent.

The level of service of the remaining modes of public transportation in Morgantown (City and County Buses) had also not changed during the time frame being investigated, at least not within the PMA. The routes taken by the buses had changed outside the PMA, but these changes were not as a consequence of the PRT, nor did they have any measurable effect on the PRT. The scope of both these bus services was already presented in Section 2.2.

---

*Reference: Volume I, page 30.

5.1 Level of Service Comparisons

The level of service of a transportation system is a complex issue and probably one area of transportation studies where opinions differ as to what is included under this title. The following characteristics of a system's level of service are, nonetheless, a few of the commonly used measures:

- A system's REACH, defined by the total population which is immediately served by the system (e.g., within 1/4 mile radius of each station).

- A system's COVERAGE, defined as the "reach" population taken as a percent of the total population of the area (city).

- A system's PENETRATION, defined as the average daily ridership, taken as a percent of the most likely potential market ("reach").

- A system's MOBILITY, defined as the product of the number of trips, their respective trip lengths, and their speed of travel.

Table 5-1 presents a comparison of the above measures for the University Bus System (Pre-Phase I PRT) and the Operational Phase PRT. System ridership has noticeably increased and was discussed more fully in Section 4. However, this needs to be pointed out again as it obviously has a bearing on the level of service results. Transit MOBILITY, for example, has increased, while there has been a corresponding decrease in auto mobility within the PMA. Ridership clearly contributes to this change. The other contributor to this shift in mobility has been a change in travel times, generally in favor of transit, as documented in Table 5-2. M-PRT travel time is generally less than the U-Bus because of grade separation. However, auto travel times have become considerably worse, making the overall change in the relative advantage of transit travel time to auto travel (T/A in Table 5-2) much greater than the change in transit travel time alone.

The selected travel times reported in Table 5-2 are a composite of walking time, waiting time, and vehicle travel time. In most cases, it is the vehicle travel time which has contributed to the advantage of transit. This point is partially exemplified by Table 5-3 which compares the auto travel speeds along the principal auto corridors. Additionally, the time required to find a

TABLE 5-1

A COMPARISON OF SELECTED LEVEL OF SERVICE MEASURES

	Pre-Phase I (U-Bus)	Phase I (PRT)
1. Ridership (Avg. Daily)	7,822	10,294
2. PMA Population	16,570	17,433
3. Morgantown Population (including students)	45,082	45,892
4. Reach (2)	16,570	17,433
5. Coverage (2 ÷ 3)	37%	38%
6. Penetration (1 ÷ 4)	47%	59%
7. Mobility (# trips x Length[a] x speed[b])	118,993	138,150
(PMA Auto Mobility)	(175,628)	(143,817)
8. Maximum Capacity in Corridor (Passenger/hr)	2,800	9,600
9. Maximum Load Factor	1.4	1.5
10. Service Frequency	5 min	15 sec

NOTES: a) trip length expressed in miles.

b) average trip speed expressed in miles/hour.

TABLE 5-2

A COMPARISON OF TOTAL TRAVEL TIME (MINUTES)
BETWEEN THE PRINCIPAL PMA ZONES

Zones*	Pre Bus(T)	Operational PRT(T)	% Δ	Pre Auto(A)	Operational Auto(A)	% Δ	Pre T/A	Operational T/A	%Δ
5-2	15	9.8	-35	16.3	26	+60	.92	.38	-59
5-1	20	11.7	-42	18.6	28.6	+54	1.08	.41	-62
1-5	16	10.4	-35	15.6	16.8	+8	1.03	.62	-40
2-5	9	11.2	+24	13.3	14.2	+7	.68	.79	+16
8-2	17	18.0	+6	13	22.3	+72	1.31	.81	-38
8-1	22	17.3	-21	15	24.6	+64	1.47	.70	-52
1-8	23	17.0	-26	10	12.5	+26	2.30	1.36	-41
2-8	16	17.8	+11	8	12.1	+51	2.0	1.47	-26

*1 - CBD
2 - Main Campus
5 - Engineering/Creative Art Center (Evansdale Center)
8 - Towers Dormitory Complex (Evansdale Campus).

TABLE 5-3

COMPARISON OF AUTO TRAVEL SPEEDS IN PRT CORRDIOR - TRAVEL TIME (MINUTES)

ROUTE	UNIVERSITY AVENUE				BEECHURST AVENUE			
HOUR	Main Campus -Towers NORTH-BOUND		Towers- Main Campus SOUTH-BOUND		Walnut-Coliseum NORTH-BOUND		Coliseum-Walnut SOUTH-BOUND	
	1975	1977	1975	1977	1975	1977	1975	1977
8:00 am	--	5.33	6.50	6.33	5.50	6.10	6.25	6.40
9:00 am	5.50	5.20	7.50	--	6.50	5.50	6.50	6.00
10:00 am	--	6.90	--	10.00	--	--	--	6.20
11:00 am	4.75	9.70*	11.25*	--	10.50*	5.30	7.50	5.30
12:00 pm	6.75*	6.50	--	15.1*	--	10.00*	--	8.00
1:00 pm	--	--	--	--	--	6.60	--	8.00
2:00 pm	4.75	8.60	6.75	9.02	--	6.00	8.75	7.00
3:00 pm	4.08	9.00	8.50	9.30	6.50	5.10	6.50	15.50
4:00 pm	5.75	5.80	9.50	9.80	7.25	7.50	10.75*	16.00
5:00 pm	--	7.10	5.50	--	6.75	--	--	18.05*
AVERAGE TIME (MINUTES)	5.26	7.13	7.92	9.93	7.17	6.51	7.71	9.75
DISTANCE (MILES)	1.5	1.5	1.5	1.5	2.1	2.1	2.1	2.1
AVERAGE SPEED (MPM)	17.11	12.62	11.36	9.06	17.57	19.35	16.34	12.92
MINIMUM SPEED (MPM)	13.33	9.28	8.00	5.96	12.00	12.60	11.72	6.98

*Travel Time for Slowest Trip

parking place, once a car arrives in the vicinity of its destination (principally in the CBD and main campus), has also increased between 1975 and 1977. Specifically, the average time to park in the downtown/main campus area increased from 3.85 minutes to 12.6 minutes, respectively. All of these increases are due to an overall increase in auto traffic (see Section 4) through the PMA and along the PRT corridor which has been generated outside the PMA, presumably caused by the growth of the greater Morgantown urban area.

For those trips where travel time has not been totally in favor of transit, it is due to the fact that the walking or connecting vehicle time has increased significantly. In these cases, it must be pointed out that this study is focusing on Phase I of a two phase M-PRT system, and trips which will eventually use Phase II PRT stations are presently made to either walk much further to a Phase I station or to use an additional mode (e.g., Evansdale Shuttle Bus).

One further point on the travel times, which relates to the influence of walking time, is the fact that the University Bus (Pre-PRT) did not have a stop in the CBD, which the M-PRT has. Therefore, transit trips destined for the CBD, from the Evansdale area, were required to walk the remaining distance from the Main Campus to the CBD prior to the M-PRT.

Referring again to Table 5-1, and more specifically to PENETRATION as a measure of each system's level of service, one observes a noticeable increase in system penetration following the opening of M-PRT operation. It is only fair to point out in this instance, since the numerator in the penetration ratio is system ridership, that the University Bus was generally unavailable to the members of the Morgantown community who were not connected with the University. Therefore, while the level of transit service has indeed increased substantially, it has done so partly because the service has been made available to the entire community.

Lastly, one notes from Table 5-1 that both maximum system capacity (passenger/hour) and service frequency have improved significantly. While the maximum capacity figures for the M-PRT is based on the fastest schedule which can be run on the Phase I system, (i.e., most vehicles and greatest sustainable dispatch rate), it must be appreciated that this level of service was seldom in operation, but overall the increased level of service offered by the M-PRT was partially observed in a modest reduction in perceived average passenger waiting times at transit stops (stations), from 3.7 minutes for the bus, to 3.1 minutes for the M-PRT.

5.2 Traffic Congestion and Auto Accidents

It would be very difficult* to derive any evidence from the data which was collected to support an hypothesis that the M-PRT may have had a positive impact on traffic congestion within its corridor. This is due to the fact that the major arterials which have been defined as the corridor are the only direct links between both sides of the city, and perhaps more importantly the only practical links between the CBD/Main Campus and what probably is the fastest growing residential area of town, to the North of the Evansdale Campus.

The evidence in Table 5-4 supports the above claim, by exhibiting a combined overall growth in average daily traffic within the corridor of 20.1%.

	Pre-PRT ADT	Operational Phase ADT	%Δ
University Avenue			
North Bound	6,041	7,487	+24
South Bound	6,836	6,735	-1
Beechurst Avenue			
North Bound	12,818	19,416	+51
South Bound	11,717	11,295	-4
Total ADT	37,412	44,933	+20.1

Despite the overall increase in auto traffic through the corridor, the distribution of traffic, by hour of day, has not changed significantly, nor has the introduction of the M-PRT greatly changed trip making habits, so far as the time trips are made is concerned. This latter fact is partially displayed in Table 5-5 where the change in transit's share of traffic, by hour of day, is recorded. The most noticeable change taking place is not so much a shift between hours of the day, as it is the simple overall increase in transit trip making in the corridor as a percent of total trips, regardless of the time of day. The biggest exceptions to this generalization are during the hours of 9-10 a.m. and 5-6 p.m., and 7-8 p.m. To suggest reasons for these more noticeable shifts,

*By discontinuing U-Bus service to the Main Campus, 10-12 buses were taken out of service along the PRT corridor.

TABLE 5-4

AVERAGE DAILY WEEKDAY TRAFFIC IN PRT CORRIDOR

	UNIVERSITY AVENUE						BEECHURST AVENUE					
	N - BOUND		S - BOUND		TOTAL		N - BOUND		S - BOUND		TOTAL	
HOUR	1975	1977	1975	1977	1975	1977	1975	1977	1975	1977	1975	1977
12-1	113	189	131	169	244	358	109	146	148	98	257	244
1-2	60	105	87	137	147	242	55	86	73	63	128	149
2-3	21	52	37	57	58	109	29	43	48	28	77	71
3-4	16	23	15	29	31	52	19	37	21	27	40	64
4-5	9	27	13	12	22	39	18	64	22	49	40	113
5-6	21	85	43	24	64	109	57	299	50	176	107	475
6-7	123	250	114	100	237	350	351	745	237	498	588	1243
7-8	296	394	334	276	630	670	655	1085	728	717	1383	1802
8-9	381	404	369	375	750	779	796	1146	723	619	1519	1765
9-10	284	378	329	335	613	713	630	1110	597	572	1227	1682
10-11	278	362	319	362	597	724	639	1101	613	628	1252	1729
11-12	299	389	339	382	638	771	730	1156	662	709	1392	1865
12-1	335	391	414	391	749	781	904	1220	783	721	1687	1941
1-2	335	410	395	383	730	793	859	1211	719	717	1578	1928
2-3	376	414	430	388	806	802	925	1265	741	758	1666	2023
3-4	363	422	440	410	803	832	1023	1377	886	766	1909	2143
4-5	367	413	469	404	836	817	989	1381	1016	775	2005	2156
5-6	385	417	432	394	817	811	899	1294	789	674	1688	1968
6-7	394	453	444	410	838	863	811	1169	653	685	1464	1854
7-8	384	436	404	415	788	851	672	1050	603	610	1275	1660
8-9	344	414	389	357	733	771	549	823	569	496	1118	1319
9-10	347	407	347	334	694	741	478	739	470	386	948	1125
10-11	270	331	286	287	556	618	368	491	326	300	694	791
11-12	231	321	246	305	477	626	243	378	232	223	475	601
TOTAL	6032	7487	6826	6735	12858	14222	12808	19416	11709	11295	24517	30711

TABLE 5-5

Δ COMPARISON OF PRT CORRIDOR TRAFFIC PATTERNS BY TIME OF DAY

	Transit Share		
	Pre-Phase I Bus/Auto Trips	Operational PRT/Auto Trips	Δ
8-9 am	0.30	0.27	-0.03
9-10 am	0.55	0.38	-0.17
10-11 am	0.54	0.45	-0.09
11-12 pm	0.37	0.39	+0.02
12-1 pm	0.43	0.44	+0.01
1-2 pm	0.42	0.46	+0.04
2-3 pm	0.30	0.31	+0.01
3-4 pm	0.30	0.29	-0.01
4-5 pm	0.19	0.20	+0.01
5-6 pm	0.07	0.10	+0.03
6-7 pm	0.06	0.07	+0.01
7-8 pm	-	0.07	+0.07

particularly the negative shift between 9-10 a.m., would only be speculation at this point, and is open to a variety of interpretations.

Despite the increases in auto traffic through the corridor, the level of service for University and Beechurst Avenues prior to the M-PRT generally was not any better. For the average speeds of these urban/suburban arterials, which are reported elsewhere in this report, the levels of service, both in 1975 and 1977, may be classified essentially as "unstable flow" with "intolerable delays", to totally "jammed".* The reasons for the congestion, since the volume to capacity ratios are all quite low, are due mainly to pedestrian interference and intersection bottlenecks: both streets run either through or immediately adjacent to the Main Campus and converge, at the same point, at the edge of the CBD (see Figure 1).

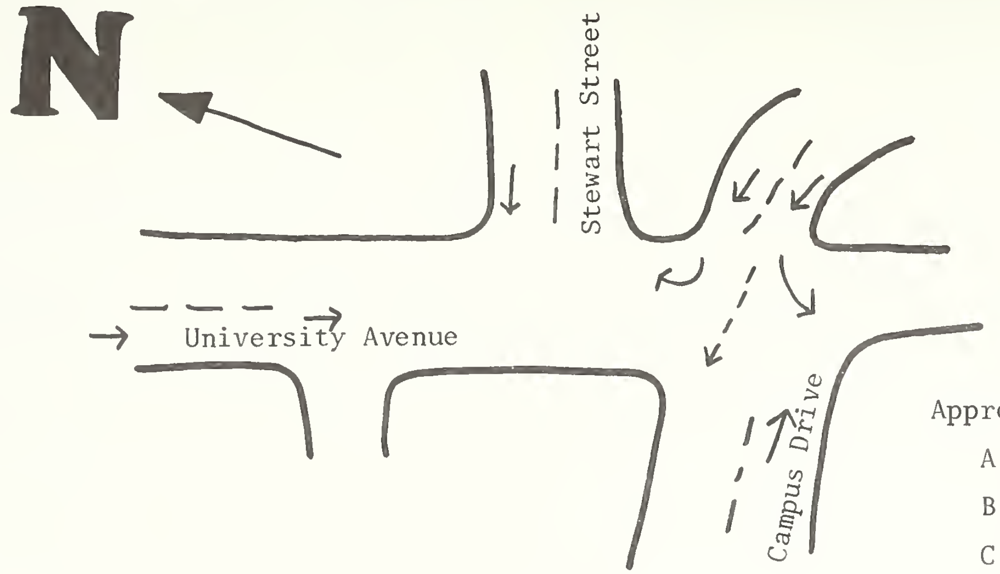
One of the major intersections in the study area was singled out during the collection of baseline data as one which benefits from the inauguration of PRT service. The intersection had been chosen because of its long standing tradition as one of the chief bottlenecks to travel between the Evansdale Campus (southbound) and the Main Campus and the CBD. The intersection, depicted in Figure 4, occurs in PMA zone 4. One approach to the intersection (Approach A), southbound along University Avenue, was the route taken in 1975 by the University inter-campus buses: the buses turned right at the intersection onto Campus Drive, the latter serving as the Main Campus terminus. The inter-campus buses, running on an already heavily congested roadway, have since been replaced by PRT service, and it is for this reason that it was thought that a change in intersection level of service might be observed. Unfortunately, while the peak-hour traffic along this approach has dropped slightly, the level of service has remained very close to the capacity of the intersection (E).**

Standard police accident records provided the data which has been composed into Tables V-6, V-7, and V-8. Unfortunately, because traffic within the PMA is also influenced by external trips, it would be very difficult to conclude that any observed changes in accident statistics would be related to the M-PRT. For example, the total number of accidents in the PMA has increased 88% between the corresponding 18 months since the PRT has been operational.

---

*Highway Capacity Manual, Highway Research Board, Special Report 87, 1965 (pp. 318-323).

**Highway Capacity Manual, Highway Research Board, Special Report 87, 1965, (pp. 126-146).



Approach	(Seconds) Green	Amber
A	45	5
B	25	5
C	25	5

Cycle Length = 110 sec.

FIGURE 4

STREET INTERSECTION
USED IN DETAILED TRAFFIC ANALYSIS

TABLE 5-6

TRAFFIC ACCIDENTS WITHIN PMA

	Pre-PRT			Operational Phase			
	Jan. 1 Dec. 31 1974	Jan. 1 June 30 1975	Total	Jan. 1 Dec. 31 1976	Jan. 1 June 30 1977	Total	% Δ Last Six Months
Total No. of Accidents	395	225	620	808	358	1165	
Total No. with Injury	80	54	134	112	25	137	
% with Injury	20.2%	24%	22%	13.9%	7%	12%	-45%
Total Cost of Damage	$186,835	$143,858	$330,693	$404,028	$223,372	$627,400	
Average Cost per Accident	$473	$639	$533	$500	$624	$538	+1%

TABLE 5-7

NUMBER OF TRAFFIC ACCIDENTS BY SELECTED INTERSECTIONS AND ZONES WITHIN THE PMA

	Pre-PRT Jan. 1 June 30 1975	Operational Phase Jan. 1 June 30 1977	%Δ Last Six Months
CBD (Zone 1)	109	107	-2%
Main Campus (Zone 2)	15	9	-5%
Engineering (Zone 5)	27	7	-59%
Towers (Zone 8)	4	5	+25%
Total	145	128	-12%
High Street-Walnut Street (CBD)	4	5	+25%
University Ave. & Beechurst Ave. (CBD)	4	4	0
University Ave. & Campus Drive (Main)	2	0	-100%
University Ave. & Stadium Bridge (Main)	4	0	-100%
University Ave. & College Ave. (Main)	2	2	0
Monongahela Blvd. & Patterson Drive (Evansdale)	8	7	-13%
Patterson Drive & Fine Arts Dr. (Evansdale)	3	1	-67%
University Ave. & Oakland St. (Evansdale)	3	1	-67%
Total	30	20	-33%

TABLE 5-8

TRENDS IN ACCIDENTS BY SELECTED INTERSECTIONS AND ZONES WITHIN THE PMA

	1972	1973	1974	1975	1976	1977*
High Street & Walnut Street (CBD)	12	17	4	10	12	10
University Ave. & Beechurst Ave. (CBD)	4	3	3	10	9	8
University Ave. & Campus Drive (Main)	4	8	7	4	5	0
University Ave. & Stadium Bridge (Main)	5	4	1	5	1	0
University Ave. & College Ave. (Main)	9	8	8	3	5	4
Monongahela Blvd. & Patterson Drive (Evansdale)	15	20	25	20	26	7
Patterson & Fine Arts Drive (Evansdale)	4	0	1	4	1	1
University Ave. & Oakland Street (Evansdale)	12	18	8	10	13	2
Total	65	78	57	66	72	32
CBD (Zone 1)	288	283	119	274	322	214
Main Campus (Zone 2)	43	33	25	31	29	18
Engineering (Zone 5)	26	28	28	37	28	14
Towers (Zone 8)	16	20	11	13	24	10
Total	373	364	183	355	403	256

*Estimate based on twice the number for the first six months.

The only positive trend is in the reduction of the percent of accidents which resulted in injury. With this background one can investigate the changes occurring in zones/intersections most likely to be impacted by the PRT. This data is summarized in Table 5-7.

The data documented in Table 5-7 exhibits large percentage changes, mostly decreases in accidents, for corresponding six month periods (spring semesters). Although the percentage changes are large the absolute decreases are small, usually only 1 or 2 accidents. Interestingly enough, the increase in accidents in Zone 8 is partially explained by the fact that there is no Phase I PRT station in that zone, while there are stations in the other three zones. In Phase II of the PRT there will be a station located immediately adjacent to the Towers dormitory complex in Zone 8.

The total trend in accidents in the same selected intersections and zones (Table 5-8) is consistent with conditions known to exist at the respective times. For example, one observes a marked decrease in 1974, which corresponds to the days immediately following the Arab oil embargo. Similarly, a rather large increase is seen to occur in 1976, which corresponds to the severe winter of 1976. Overall, caution is advised in drawing any hard conclusions regarding the M-PRTs impact on accidents within the PMA.

5.3 Transit System Safety, Crime and Provisions for the Elderly and Handicapped

A separate report discusses the safety of the PRT and incidences of misbehavior by system patrons.* Overall, the safety record of the PRT is unblemished with regard to accidents involving PRT vehicles or system patrons. This was to be expected, given the intense effort devoted to system safety during the PRT's design and testing stages. By comparison, the U-Bus system has also recorded an excellent safety record.

The PRT is new, and people in general are tempted to test the limits of something new. When acts of misbehavior occurred, and then only infrequently, offenders were identified by the system's surveillance systems and offenders

* Durant, P., and Ward, R., "The Inspection of an AGT System Safety Record: The Status of the Morgantown Personal Rapid Transit System", College of Engineering, West Virginia University, Morgantown, WV 1978.

deal with by the proper authorities. The referenced report documents the few incidences of passenger misbehavior (five events), which occurred during the period October, 1975, through April, 1978. Incidences of misbehavior or criminal activity on the buses were never reported to be a problem when it was in operation either, and therefore, no significant changes can be reported in this regard.

Elderly and Handicapped provisions were only partially implemented in Phase I of the PRT. For example, although elevators in the station were deferred to Phase II (Phase II is a Capital Grant Project), the PRT vehicles are already capable of accomodating a wheel chair. The U-Bus, in contrast, had no special feature for the Elderly and Handicapped. The buses were conventional Blue Bird-style school buses with normal curb side low level loading doors. Other than station access ramps, elevators, and special arrangements for handling the fares and destination selections of ambulatory passengers, no other special features of the PRT can be noted.

5.4 Transit System Noise Impacts

A separate study, which was funded by the Environmental Protection Agency, was concerned with the possible impact which the PRT might have on noise levels along the PRT corridor. While a final report has not been published, a major portion of the findings have been included in a research thesis.* Therefore, the intent of this section is to briefly summarize the results.

The main purpose of the noise investigation was to "experimentally examine the change of community noise level due to any change in traffic volume after the commencement of the Phase I PRT System". To accomplish this, data was collected at selected sites within the PMA both before the PRT became operational and after it began to carry passengers. However, the second period occurred prior to the second stage of this impact study and the U-Bus system had not yet been completely replaced, and a reduced service (33%) was still running in parallel with the PRT, as a back-up.

*Hoang, H.T., "Assessment of the Personal Rapid Transit (PRT) System Phase I Operation on Morgantown Communigy Noise Level", Masters Thesis, Mechanical Engineering Department, West Virginia University, Morgantown, WV, 1977.

The monitoring sites, six (6) in all, were selected according to the following criteria:

1. Sensitivity to the inter-campus bus system,
2. Exposure to different traffic flows,
3. Encompassment of different types of communities, and,
4. Inclusion of different roadway features.

The results summarized in this section are only for two of the sites; one along side each of the roadways (University and Monongahela/Beechurst Avenues) identified in this study as the PRT corridor. The characteristics of the site are given below:

Site	Location Specification	Land Use	Speed Limit
A. University Avenue (PMA Zone 7)	Local Traffic/ 2 lane street/ slight grade	Residential	25 mph
B. Monongahela Boulevard (PMA Zone 5)	Express, local & through traffic/ 4 lane highway/ steep grade	Undeveloped	50 mph

The data was collected by taking "continuous 24-hour outdoor sound recordings for seven days". For Site A, the microphone unit was set up in the backyard of a home, located in a high density single-family dwelling area. For Site B, the microphone unit was located at the edge of the hillside trees behind the University's Engineering Sciences Building.

It was concluded in the noise study that the replacement of the University Inter-campus buses by the PRT had accounted for a decrease in community noise level. It was recognized, however, that the "after" measurement period was not the most desirable because the inter-campus bus volume had been reduced by only 33% at that time. The data in Figure 5 and Figure 6, reproduced from the referenced study, present an overview of the findings. The variable, L'_d in the figures represents the "academic day energy equivalent sound level obtained by time averaging the instantaneous A-weighted sound energy occurring over the entire day time period", from 8 a.m. to 5 p.m. The variables $\overline{V}_T$ and $\overline{V}_B$ represent the average hourly total traffic and bus traffic, respectively, for the same daytime period.

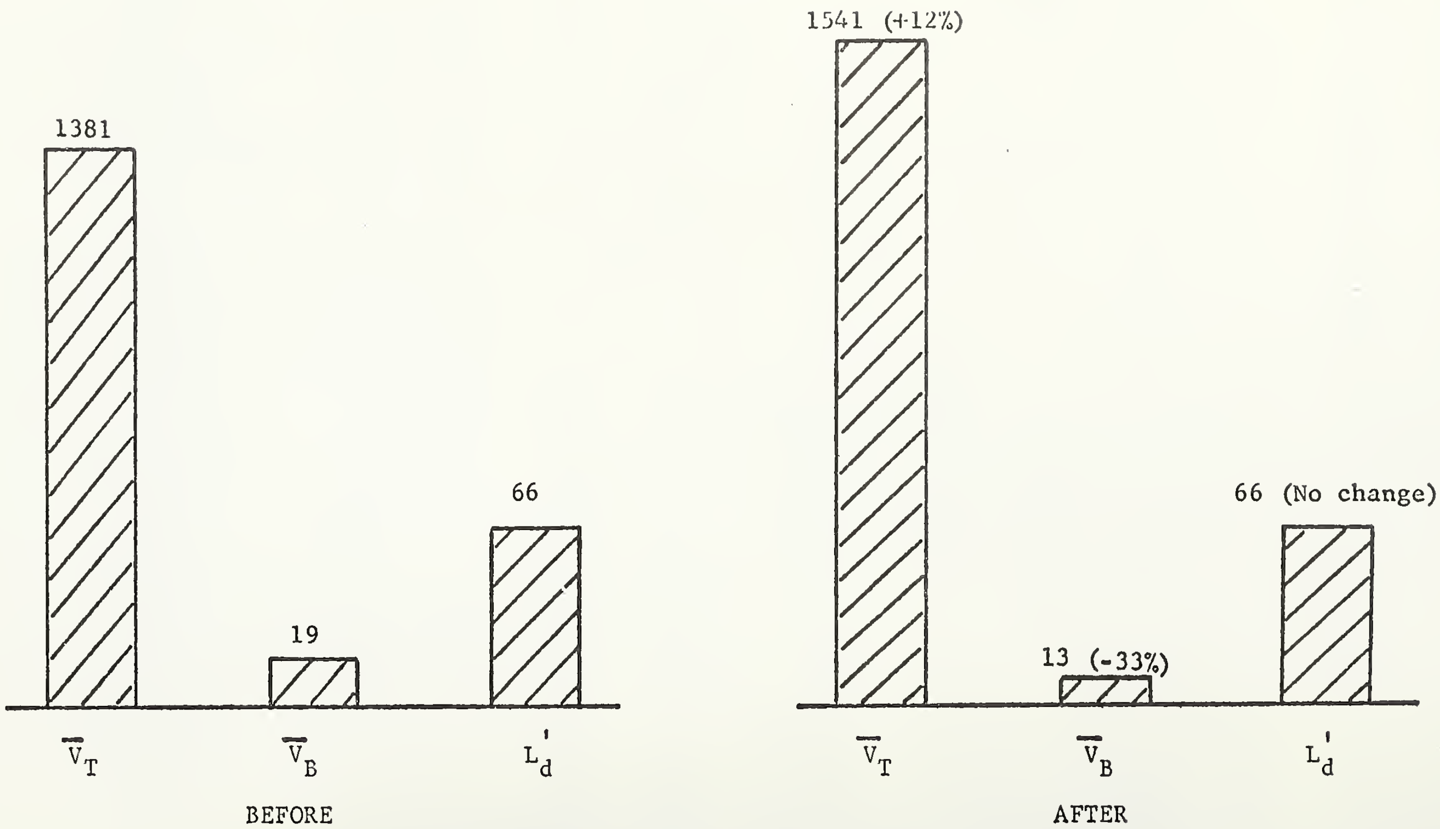


FIGURE 5

COMPARISON OF AVERAGE WEEKDAY $\overline{V}_T$, $\overline{V}_B$ AND L'_d BEFORE AND AFTER PRT OPERATION AT SITE A

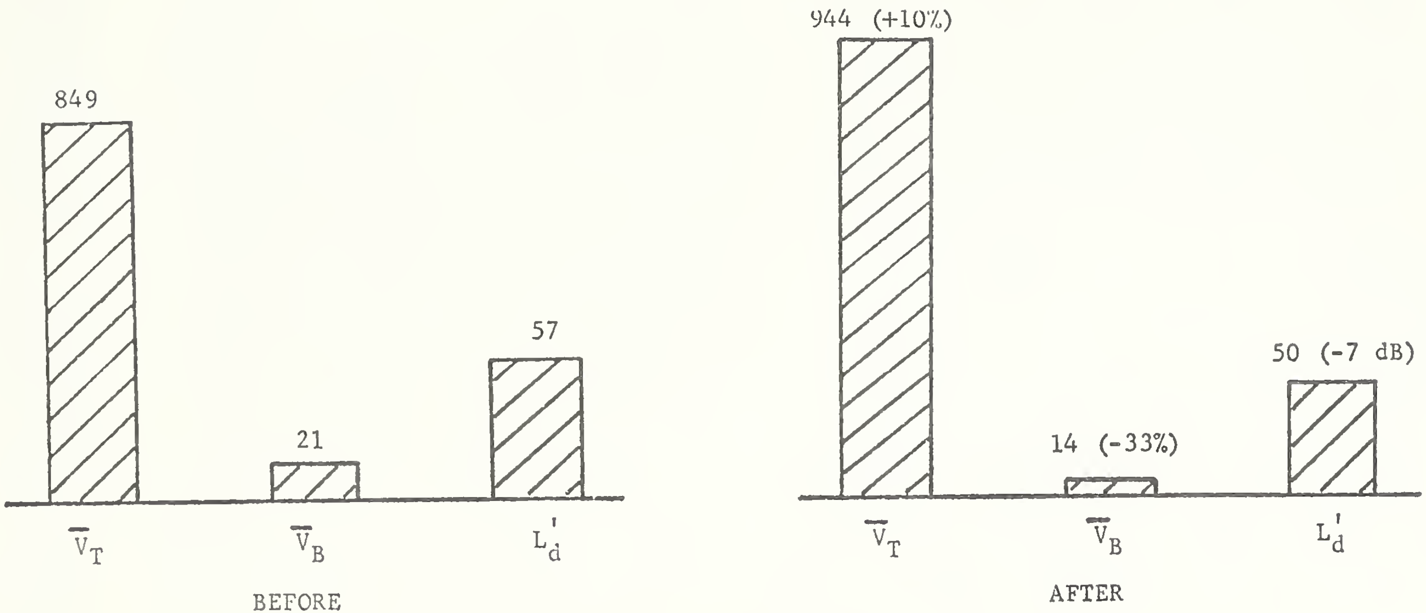


FIGURE 6

COMPARISON OF AVERAGE WEEKDAY $\overline{V}_T$, $\overline{V}_B$ AND L'_d BEFORE AND AFTER PRT OPERATION AT SITE B

5.5 PRT Operating Costs

For the second stage of this study, it was reported that the M-PRT annual operation and maintenance costs (July, 1976 - June, 1977) totaled $1,297,178 (see Volume I-Travel Analysis). This is seemingly a large increase over the University Bus System which it partly replaced. The annual operation and maintenance cost for the U-Bus, reported at the time of the Pre-PRT stage (July, 1974 - June, 1975) was $230,846. Neither of these figures include an annualized capital recovery cost.

The above amounts correspond to an estimated average cost per vehicle mile per passenger trip for the Pre-PRT U-Bus of $1.62/14¢* and for the PRT, $2.06/70¢. While being a fairly dramatic comparison, it is not really believed to be a very meaningful one for a variety of reasons; not the least of which is the fact that the Phase I M-PRT has not yet reached its full potential of ridership, and will not until Phase II is completed and in operation, sometime in 1980-81. It must be remembered that the U-Bus provided service to the entire campus (including the Medical Center), while the M-PRT terminated its service at the Engineering Station on the Evansdale Campus.

It must also be realized that the level of service provided by the M-PRT is far greater than the U-Bus ever was (see Section 5). For example, one could, with a bit of data manipulation, project a significant savings, in terms of traveler's time saved, due to the faster trip times of the PRT. As an illustration of this point, the PRT takes 5.1 minutes to travel the main route from Evansdale (Engineering Station) to the Main Campus (Beechurst Station). The U-Bus, for the comparable trip, was recorded as averaging 6.77 minutes during the study period, with a maximum trip time of 17 minutes. Data collected at other times showed some U-Bus travel times well over 30 minutes due to severe traffic congestion, an occurrence not uncommon along University Avenue. The PRT, by comparison, has a fixed travel time due to grade separation, and its performance record has already been shown to be high (see Volume I). Moreover, based on the survey of travel times and speeds, should the U-Bus have made the run to the Main Campus in the spring of 1977, its average speed would have decreased by some 20% from what it was in 1975, making the above comparison even worse for the U-Bus.

---

*A yearly bus ridership figure is not kept by WVU. The Pre-PRT average weekday survey of 10,252 was factored up to a yearly estimated number of 1,663,272 passenger trips.

The savings in reported waiting time, due to the PRT, was not nearly as great as the savings in travel time. The average wait for the U-Bus was 3.64 minutes during the Pre-PRT study period, while PRT riders reported an average of 3.11 minutes. Nevertheless, travelers by bus had to plan to be at the bus stop, while PRT travelers really did not have to plan as much for a service running on a 15-second headway.

To illustrate the above point concerning travel time savings any further requires that some extrapolations be done; but it is probably worth the exercise so as to leave the reader with some impression about the magnitude of the benefits brought on by the PRT. To do this, we will only consider the trips made from the Engineering Station to the Beechurst Station, which are assumed to represent 42% (see Volume I - 4,354 ÷ 10,294) of the total yearly PRT trips, or 785,316 trips (42% x 1,856,694). The savings in time is the difference between the PRT travel time (5.1 minutes) and the U-Bus travel time (6.77 x 120% = 8.12 minutes), if the latter had been run in 1977. Based on these figures, the savings in passenger hours for the one link only is estimated to be on the order of 39,500 hours annually.

An additional point is that the U-Bus was often operating at or close to its capacity during the day, based on the service it could provide with the available fleet. A minimum of ten buses, with an average seating capacity of 50 (legel maximum load factor of 1.4), were required to provide continued round trip service, on a 5-minute scheduled headway (which in reality was often exceeded), between Evansdale and the Main Campus. The theoretical maximum hauling capacity on this route was:

10	buses
4	trips/hour
x 50	passengers/trip
2,000	passengers/hour
1.4	load factor
2,800	passenger/hour .

The M-PRT, on the other hand, based on its fastest schedule and its present fleet was capable of the following:

320 trips/hour (using 28 vehicles between Engineering and Beechurst - not even considering Walnut Street which is an additional 160 trips)

x 8 passengers/trip

2,520 seated passengers/hour

x 2.63 design load factor (13 standees)

6,732 passengers/hour.

Another way to look at the economic potential of the M-PRT is to project the average cost per passenger trip, assuming the system is operating at capacity. For the period of time in question (July, 1976 - June, 1977) the estimate is handled in the following way:

$$\text{Total Capacity Passenger Trip} = \frac{\text{Total Annual Vehicle Miles} \times \text{Maximum Passenger/Vehicle}}{\text{Average Trip Length (miles)}} =$$

$$\frac{629{,}157 \times 21}{1.6} = 8{,}257{,}686.$$

Assuming this figure, the average cost per capacity-passenger trip becomes

$$\frac{\$1{,}297{,}178}{8{,}257{,}686} = 16¢.$$

The average cost per passenger mile, on this basis, becomes 10¢.

Trends in the M-PRT operating cost are displayed in Table 5-9. Overall, the average unit cost, per passenger trip, is steadily decreasing as ridership steadily increases (see Volume I - Travel Analysis). However, several explanations are required by the figures in Table 5-9. In the first instance, the total annual O&M cost for the period covering October, 1975 through June, 1976, included an additional $2,750,824 allocation for the system supplier's support during the initial operation. Additionally, the figures for fiscal year 1976-77 and 1977-78 include allocations for support of Phase II plus some temporary stop gap measures to correct certain equipment problems. All of the problems are expected to be permanently corrected as part of the upgrading of the system to the Phase II level.

TABLE 5-9

TRENDS IN M-PRT OPERATING COSTS

	Oct-75 June-76	July-76 June-77	July-77 June-78
Total Annual O&M Cost	$3,166,066	$1,297,178	$1,257,397
Total Vehicle Miles	401,542	629,157	529,732
Average Cost Per Vehicle Mile	$7.88	$2.06	$2.37
Total Passenger Trips	607,452	1,856,694	2,011,488
Average Cost Per Passenger Trip	$5.21	$ .70	$ .62
Average Cost Per Capacity Passenger-Trip	$ .59	$ .16	$ .18
Average Cost Per Capacity Passenger-Mile		$ .10	$ .11

With the Phase II expansion, the annual fleet mileage is expected to increase initially to around 1.5 million miles from the current 530 thousand miles, with a much greater than proportional increase in ridership. The operating costs are projected to be approximately $1.9 to $2 million annually, which is a figure based on the experience of operating the M-PRT at its current level for nearly 3 years. Therefore, if these estimates are realistic, one can expect a cost of some $1.26 per vehicle mile, and a cost per passenger no greater than it was at the end of Phase I (62¢).

The Phase I staff levels for the M-PRT, for the last fiscal year, are depicted in Figure 7 and total 60 personnel, including secretarial positions. In certain areas, the staff personnel figures are higher than were originally estimated for the system during the planning stages. The operations staff, at 15, is one more than originally anticipated, as it became apparent that a System Programmer was required. The most sizeable increase, over what was originally anticipated, was in the maintenance staff. The original estimate was for 22 people; the Phase I maintenance roster finally totaled 36 personnel. The system engineering staff is the other area where there was a build-up to the total five person department.

Although some purchasing support is available to the M-PRT operation from the University, most of the work is handled by the referenced PRT personnel because of the unique nature of PRT service, and the need, at times, to expedite normal state purchasing channels. The only other service provided by the University is the availability of its security force.

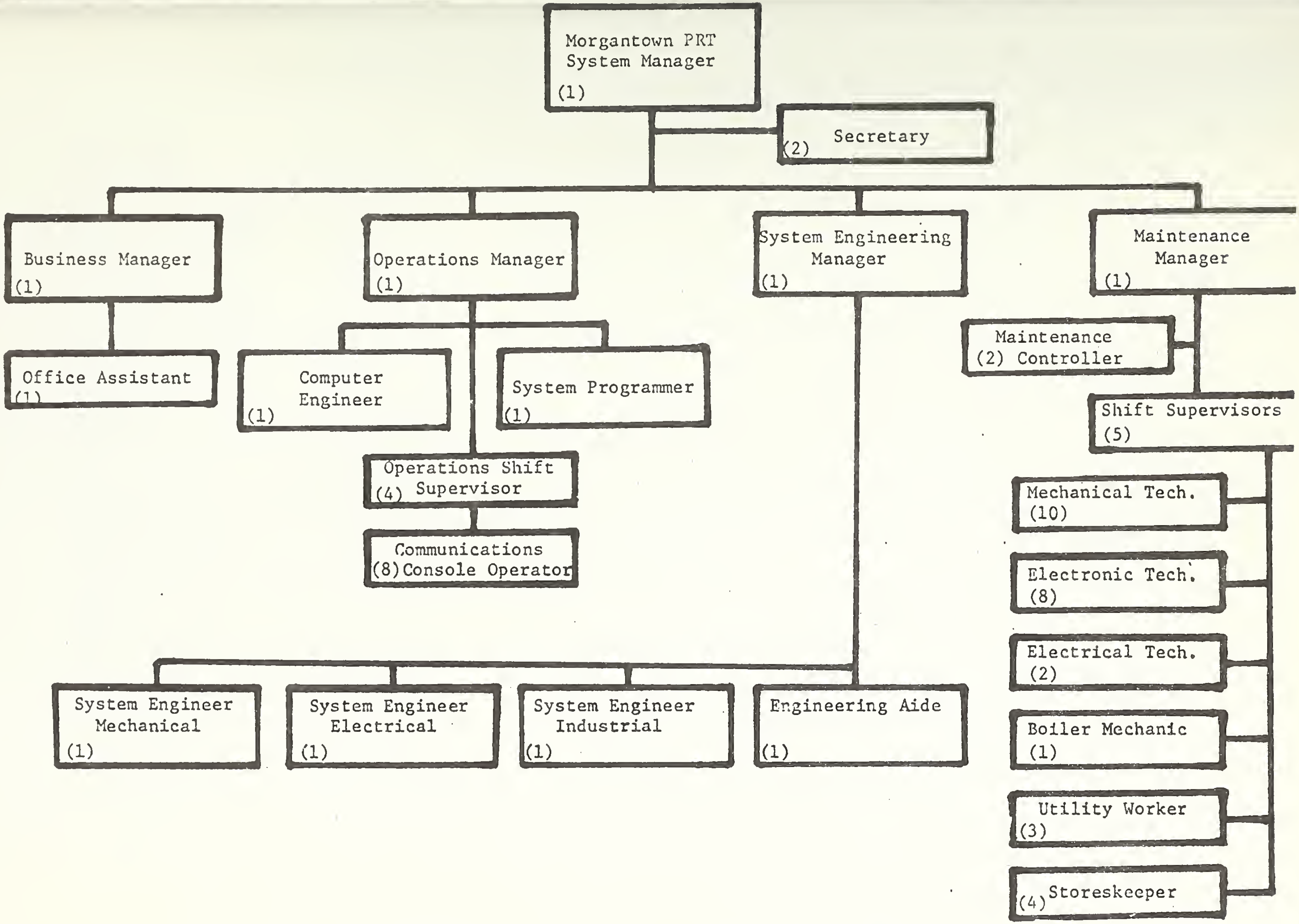


FIGURE 7. M-PRT ORGANIZATIONAL CHART

6. INTERPRETATIONS OF AGGREGATE, CAUSAL MODELS OF TRIP MAKING

During both stages of the impact study (Pre-PRT and Operational-Phase I PRT), interzonal travel (trip distribution) models were calibrated. The purpose of the models was to seek explanations for the variations in interzonal traffic flows (T_{ijk}), by mode, in a selected group of independent variables. The selected variables for the models, defined in Table 6-1, were identified as being either supply (S) characteristics of the transportation alternatives, e.g., travel time and travel cost, or factors (zonal characteristics) which are behind transportation demand (D) to begin with; e.g., the population of the origin and destination zones.

At the onset of this study, it was suggested that if data for the independent variables (S, D) from the Operational Phase study were to be used in the Pre-PRT models, then the Pre-PRT models would yield an estimate of the interzonal traffic flows to be expected during the period of time when the PRT was to be operational. If the expected traffic flows generated in this manner did not correspond to the interzonal traffic flows actually observed to be taking place once the PRT was operational, then it was originally speculated that one reason for the apparent inadequacy of the Pre-models would be due to a shift in travelers' attitudes toward the alternate transportation modes.

This section of the report investigates the above question, and discusses the adequacy of the various interzonal travel models which were developed. Simple linear trip generation models were not investigated during the operational stage because of the poor results achieved with such models during the Pre-PRT study; and therefore discussion of same is not included in this section.

6.1 Comparisons of Expected and Observed Trips for the Phase I PRT Stage

The Pre-PRT models are summarized in Volume I, Appendix C. With the exception of the interzonal trip models and the model of CBD oriented bus trips, all of the remaining Pre-PRT models display a fairly good fit to the Pre-PRT data (lowest R^2 = .887). For these models, at least 88 percent of the variation in the estimated trips are explained by the specific model formulation.

TABLE 6-1

DEFINITION OF INDEPENDENT VARIABLES
EMPLOYED IN THE MODELS

Variable Name	Definition of Variables Characterizing PMA Zones
P_1	Total residential population of origin zone
P_2	Total residential population of destination zone
S_1	Residential population of students in origin zone
S_2	Residential population of students in destination zone
FA_1	Total floor area of campus buildings in origin zone
FA_2	Total floor area of campus buildings in destination zone
CL_1	Number of student classes scheduled at campus of origin
CL_2	Number of student classes scheduled at campus of destination
C_1	Number of class changes occurring in campus of origin
C_2	Number of class Changes occurring in campus of destination
E_1	Number of people employed at origin zone
E_2	Number of people employed at destination zone

TABLE 6-1 (Cont'd)

DEFINITION OF INDEPENDENT VARIABLES
EMPLOYED IN THE MODELS

Variable Name	Definition of Variables Used to Characterize Transportation Supply
AC	Total cost of an auto trip between specific zone pairs
PC	Total cost of a PRT trip between specific zone pairs
RPC	The ratio of the cost of a trip by PRT (PC) to the cost of the same trip by auto (AC) for specific zone pairs
RAC	The ratio of the cost of a trip by auto (AC) to the cost of the same trip by PRT (PC) for specific zone pairs

By using the appropriate models developed during the Pre-PRT stage, and values for the independent variables estimated during the Operational stage, expected trips for Phase I PRT conditions were generated for each trip purpose and for each mode. Given the origins and destinations of the expected trips thus generated, along with the observed origins and destinations of trips recorded during the operational stage study, it was possible to calculate a χ^2 statistic for each mode of travel and for each trip purpose relative to the distribution of trips within the PMA. Therefore, expected auto trips were compared to observed auto trips, and expected PRT trips (transit) were compared to observed PRT trips. The resulting χ^2 statistic allows one to assess whether or not there is a statistically significant difference in the distributions of the trips. The results of this analysis are summarized in Table 6-2. In every case one is led to the conclusion that there is a difference in the observed and expected distribution of trips. Zone for zone the differences between the observed and expected trips are much greater for the transit trips than they are for the auto trips, pointing to a marked change in travel patterns between the Pre and Operational stages, for the trips which used transit.

This analysis indicates that the Pre-PRT models are not sufficient to explain what has happened to trip making within the PMA during the Operational stage of the PRT. The original hypothesis, stated at the beginning of this section, was that the cause may well be a change in attitude regarding the available transit mode. While evidence presented in Volume I and Sections 4 and 5 of this report tend to support this hypothesis, it is believed that the attitude of PMA residents certainly should not be construed as the only explanation for the inadequacy of the Pre-PRT models to predict operational stage conditions. In keeping with this opinion, a closer look at the models, as well as a partial critique of the models, is presented in the remaining sections.

6.2 Recalibration of the Pre-PRT Models

Before attempting to calibrate a totally new formulation for each of the models, using Operational PRT data, it was felt that a recalibration of the Pre-PRT formulations, using Phase I PRT data, might provide some meaningful insights with regard to understanding the inadequacies of the original (Pre-PRT) models in predicting Operational stage travel. Specifically, it was thought that the recalibrated models would demonstrate that the independent variables (S, D) chosen for the Pre-PRT models simply were not sufficient, combined as they were, to explain the operational stage conditions.

TABLE 6-2

GOODNESS OF FIT TESTS BETWEEN THE DISTRIBUTIONS OF EXPECTED OBSERVED TRIPS, BY MODE, IN THE PMA DURING THE OPERATIONAL PRT STAGE

Trip Purpose	χ^2_{calc}	d.f.	Significant Difference (α = .005) (noted by *)
Campus to Campus			
Auto Trips	2050	6	*
Transit Trips	19898	6	*
CBD Oriented			
Auto Trips	522	17	*
Transit Trips	9972	17	*
Campus to Home			
Auto Trips	2906	21	*
Transit Trips	12704	21	*
Home to Campus			
Auto Trips	5136	22	*
Transit Trips	21972	22	*
Interzonal			
Auto Trips	3341	43	*
Transit Trips	3935	43	*

Table 6-3 summarizes the results of the recalibration effort. By comparing the coefficients of determination (R^2) in Table 6-3, excluding the interzonal trips, one can see that the recalibrated Pre-PRT models still provide a reasonable fit to the operational data. In the case of the auto, the Pre-PRT formulation fits better to the operational data than it did to the Pre-PRT data. On the surface, it appears that the concerns expressed in the above paragraph were unvalid.

Differences in the Calibration Coefficients

However, not withstanding the results in Table 6-3, the coefficients of the recalibrated independent variables (see Appendix B) show some definite differences when compared to their counterparts in the Pre-PRT calibrations (see Volume I, Appendix C). What this is believed to mean is that the relationship which some of these variables had with travel behavior has changed since the PRT began service. This could be partly due to the modifying influence of travelers' attitudes, as originally assumed, or it could be partly due to data inadequacies. If there is some truth in the latter suggestion, then one might expect that the differences in the expected and observed traveler behavior (trips between zones) might be explained as a function of the differences in the Pre and Operational stage values estimated for the independent variables. To investigate this particular aspect of the problem, simple linear regression models were set up as a means to obtaining an analysis of variance. Table 6-4 summarizes the results.

A large percentage of the variation between the expected and observed trips made between campuses is explained by the differences in the estimates made for the independent variables during the Pre and Operational stage studies. In this case, particular attention must be drawn to the possibility of inaccuracies in the estimating procedures for classes scheduled, class changes, and the employment population, even though they are not significant contributors (except for E_1) to the variations observed in the other trip purposes.

Except for the fact that campus PRT trips have increased 50% over the bus trips, one is tempted to say that attitude plays less of a role in influencing aggregate trips between campuses than it does for the other trip purposes. This could well be true because of the nature of campus to campus trips, and the fact that there is less choice in the mode of travel between campuses than there is for the other trip

COMPARISON OF THE RESULTS WHEN THE PRE-PRT MODEL FORMULATION WAS CALIBRATED WITH BOTH PRE-PRT AND OPERATIONAL PRT DATA

Trip Purpose	Variables in PRT-PRT Models (See Volume I, Appendix C)				R^2 Pre-PRT Calibration (Pre-PRT Data)	R^2 Operational PRT Calibration (Operational PRT Data)
Campus to Campus						
Auto Trips	C_1	CL_1	E_1		.985	.992
PRT Trips	CL_1	FA_1	E_1	CL_2	.994	.871
CBD Oriented						
Auto Trips	E_1	E_2			.887	.955
PRT Trips	E_2	RBC			.598	.583
Campus to Home						
Auto Trips	FA_1	P_2	RAC		.92	.952
PRT Trips	S_1	CL_2	BX	RBC	.958	.805
Home to Campus						
Auto Trips	P_1	C_2	FA_2	E_2	.916	.922
PRT Trips	S_1	CL_2	BC	RBC	.894	.792
Interzonal						
Auto Trips	P_1	P_2	AC		.494	.556
PRT Trips	P_1	P_2	BX		.412	.324

TABLE 6-4

ANALYSIS OF VARIANCE PERFORMED ON THE DIFFERENCE BETWEEN THE EXPECTED AND OBSERVED TRIPS FOR THE OPERATIONAL PRT BASED ON THE PRE-PRT MODEL FORMULATIONS

Trip Purpose	Mode	Variables	F	Significance ($\alpha = .05$) Noted by *	R^2
Campus to Campus	Auto	C_1	338.25	*	.99
		CL_1	30.03	*	
		E_1	26.75	*	
	PRT	CL_1	.53		.94
		FA_1	2.14		
		E_1	23.31	*	
		CL_2	.33		
CBD Oriented	Auto	E_1	.42		.07
		E_2	.87		
	PRT	E_2	1.22		.35
		RPC	6.64	*	
Home to Campus	Auto	P_1	4.28		.43
		C_2	.97		
		FA_2	.23		
		E_2	2.60		
	PRT	S_1	.37		.29
		CL_2	.02		
		PC	2.06		
		RPC	1.86		

TABLE 6-4 (Cont'd)

ANALYSIS OF VARIANCE PERFORMED ON THE DIFFERENCE BETWEEN THE EXPECTED AND OBSERVED TRIPS FOR THE OPERATIONAL PRT BASED ON THE PRE-PRT MODEL FORMULATIONS

Trip Purpose	Mode	Variables	F	Significance (α = .05) Noted by *	R^2
Campus to Home	Auto	FA_1	2.96		.24
		P_2	2.39		
		RAC	0		
	PRT	FA_1	7.96	*	.40
		P_2	.65		
		PC	2.25		
		RPC	5.79	*	
Interzonal	Auto	P_1	10.54	*	.36
		P_2	4.17	*	
		AC	.24		
	PRT	P_1	9.8	*	.26
		P_2	4.56	*	
		PC	5.04	*	

purposes. Moreover, the percent of variation explained for the other trip purposes, by the differences in the estimated values of the independent variables, is relatively low (maximum R^2 = .43), implying that attitudes could have had a more decided effect on these trip purposes.

For three of the PRT models shown in Table 6-4, one or the other of the following cost related variables had a significant effect on the differences between the expected and the observed PRT trips: 1) differences between the PRT travel costs and the U-Bus travel costs; 2) differences between the ratios of the PRT's travel cost to auto cost; 3) U-Bus travel cost to auto cost. Of all the variables used in the models, travel cost and the relative ratio of travel costs are the only two which it can be said may be linked to travelers' attitudes regarding the most desirable transportation alternative to choose for a given trip.

6.3 Travel Costs in the Operational Stage Models

Travel cost and/or the relative ratio of travel cost became a significant factor in almost every one of the Operational stage models (see Appendix B). The importance of this is viewed as the apparent increased sensitivity of travelers within the PMA (following implementation of the PRT) to the travel costs of the alternative modes. It was shown in Section 5 (Level of Service) how, in most cases, transit's advantage over the auto has increased by a substantial margin since the PRT became operational. Part of this has been due to the improved trip time of the PRT over the bus, but part is also due to the worsening auto congestion within the corridor, and to the ever increasing scarcity of parking on the campuses, in the CBD, and in many of the residential zones adjacent to the Main Campus and CBD.

7. SUMMARY AND CONCLUSION

The purpose of this document was to investigate and report on the possible impacts of installing the PRT, an automated guideway transit system, in Morgantown, West Virginia. Overall, it is believed that many of the findings have demonstrated that the PRT has had an influential role in changing the travel habits of a substantial number of travelers.

While auto traffic along the two major arterial thoroughfares (both of which are included in the PRT's corridor) has experienced a large increase over the two year study period (Spring, 1975 - Spring, 1977), residents of areas directly served by the PRT, its primary market area (PMA), have used an auto for their trips within the PMA less often then they did prior to the PRT. As an alternative, they have apparently adopted the PRT's service. Moreover, compared to the bus system which it replaced, the PRT is carrying more than the buses' previous share of total trips. The increases in transit travel (by PRT) is assumed to be at least partly due to favorable attitudes towards PRT service as it cannot be completely accounted for in any increases either in Morgantown's population or University student enrollment.

There are, however, several factors which partially mitigate the PRT's apparent impact. The first is that the PRT extends into the heart of Morgantown's central business district, a service which was never offered by the previous bus system. Travelers using the bus system, with a final destination in the CBD, were required to walk on the average of 1/2 miles after disembarking from the bus.

A second factor is that while travel by the PRT is much faster than by the bus, travel time by auto decayed significantly, giving the PRT more of an advantage over the auto than the bus had.

A final factor is that the PRT was offered as a full public service system, and as such persons who were not related to the University (townspeople) were permitted, in fact encouraged, to ride the PRT. In this case, townspeople were believed to be the least captive users of the system and accounted for a substantial (6%) number of the total trips. The mitigating facts in this example is that the previous University's bus system was not available to the townspeople. However, there is another interpretation of the PRT's implied desirability as a transportation alternative for the townspeople; and that is that it had to overcome the fact that, for the townspeople, the system has been said "to go from somewhere (CBD and Main Campus) to nowhere (Engineering Station) and from nowhere to somehwere". In other words, it was generally viewed as offering an incomplete service in its Phase I state. Townspeople using the Engineering Station had to either change modes (auto), or walk more than a quarter of a mile to or from their destination or origin, respectively. Station side parking was not available at the Engineering Station and city or county bus service did not feed the Phase I PRT. Despite these circumstances, the PRT was still viewed as a viable and attractive transportation alternative; a result which was not expected until the completion of an expansion to the system (Phase II).

The reason behind the townspeople's apparent attraction to the PRT was noted principally as its convenience. An even larger number indicated a reason "other" than its convenience, cost to use, speed, safety, or the fact that they may have had no choice. At this point, one can only speculate as to what service characteristics of the PRT fill this gap.

Moreso for non-students than other travelers, the purposes behind the PRT trips were seen to change compared to conditions prior to the PRT. For example, discretionary trips, such as for shopping or recreation, had increased relative to the other purposes, and it is likely that the service of the PRT induced as well as diverted trips for these purposes, particularly since the PRT ran into the CBD.

Implications of the PRT's impact to other cities must be viewed with caution, even though it has had a favorable travel impact in Morgantown. For one thing, the conditions and the environment surrounding the installation in Morgantown are so unique that it is unlikely that conditions resembling those in Morgantown will be seen in many other areas, least of all the present candidates for DPM installations.*

Notwithstanding the last remarks, there are several points which are viewed as extremely relative to potential installations of similar systems. For instance, it is speculated that early exposure to the system, by regular

---

*Mitre Corporation, "Review of Downtown People Mover Proposals" Preliminary Market Implications for Downtown Applications of Automated Guideway Transit," Report No. UMTA-IT-06-0176-77-1, December, 1977.

patrons, during its debugging period, may have greatly influenced their attitudes regarding the system, and possibly their willingness to use it, at least with some regularity. This phenomena is also believed to have confounded the issues to the point where interpretation of the data pertaining to mode choice decisions leaves something to be desired.

It has been argued, mainly by critics of the PRT project, that such an experimental system should never have been deployed in an urban setting. However, it must be recognized that there was a definite positive side to the system being installed in a real life environment. For one example, it certainly put direction to a program of automated guideway transit system research which until that time had been mostly confined to laboratory research. Perhaps more importantly, however, many of the system's problems and bugs may not have been exposed, at least not as quickly, without having subjected the system to the wear and tear of regular passenger service. There are two lessons in all of this but the final conclusion must be drawn by the reader.

Another point of some importance, particularly to other potential installations, concerns the matter of the safety of automated systems. Concern was expressed in the late sixties and the early seventies about people's willingness to travel in relatively small, unmanned vehicles, which are traveling in environments and at speeds which are outside the scope of the amusement park ride. A separate study conducted in Morgantown* indicated that the features of the PRT that concerned Morgantown residents the most, before it was operational, was its safety. Results of the study at hand have clearly shown a total reversal of this concern. The M-PRT has had a perfect safety record, and there is no evidence to suggest that people are hesitant or unwilling to ride a totally automated system. Systems with a different "track record", however, may experience a much different public reaction.

Although land use changes are not included in this report of the PRT's impact, certain major decisions concerning new facilities have been made and identified the PRT as one of the chief reasons for the locations of the new facilities. Specifically, during 1977 the

---

*Trent, R.B., and Redwine, C.N., "Public Acceptance of New Mass Transit System," ASCE Journal of the Urban Planning and Development Division, pp. 225-234, August, 1976.

University announced that both a new 300,000 volume research library and a 55,000 seat football stadium will be located at sites close to PRT stations. The library is to be adjacent to the Engineering Building and the stadium is to be located on the Medical Center Campus on a site close to one of the Phase II Stations.

One of the largest impacts of the PRT project as a whole was the fact that Morgantown became a tourist attraction, not only for the scientifically oriented, but also for the average "person in the street". Since 1972, groups of up to two full bus loads at a time. consisting of transportation experts and engineers, have made on-site visits. These visitors have come from most of the developed countries in the world. The frequency of these visits was often three out of five working days a week, and on occasion, every day. For a town the size of Morgantown, this was significant. In fact, the University was forced to set up a special tour office, and hired one full time tour leader to take the burden off the project office.

The other noticeable phenomenon, although not officially documented as a part of this study, is that it is not uncommon to find the system used almost as an amusement ride, even nearly two years after it opened.

If the PRT has indeed had a positive impact on Morgantown, and it is believed that it has, then the results of implementing Phase II must be anticipated with even greater interest than Phase I. It is perhaps a bit unusual, but yet very appropriate to conclude with an article which appeared in July 1, 1978, issue of the Morgantown Post (the evening newspaper). The article appeared just as this report was going to press, and on the eve of Phase I being shutdown for over a year so that it could be tied in with Phase II:

> "If you park on a yellow line, in front of a driveway or fire hydrant, or block a driveway next month, your car might be missing when you return to it.
>
> City Manager George DeFrence and towing firms met yesterday to discuss the planned illegal parking crackdown to begin August 27.
>
> DeFrence asked towing firm operators about storage capacity in

"an effort to determine whether there is space for cars towed in a crackdown effort.

DeFrence said letters were being mailed in packets to West Virginia University students warning them and their parents of the parking problems in Morgantown and the planned crackdown. He said that since the Personal Rapid Transit (PRT) is closing soon, more students may be tempted to bring cars.

Police Chief Bennie Palmer said his department plans to "brighten" the yellow curb lines designating where parking is prohibited.

DeFrence said that towing may level off after the initial crackdown because motorists will know the city plans to tow illegally parked cars.

City Council last week voted for a crackdown on illegal parking."

APPENDIX A

ORIGIN/DESTINATION MATRICES

TABLE A-1

PRE-PRT PMA AUTO TRIP MATRIX BY RESIDENTS OF THE PMA

ZONE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	TOTAL
1	0	14	35	87	57	16	387	167	37	126	8	3	30	248	181	197	1593
2	64	0	184	12	14	20	139	309	5	26	29	27	7	129	21	110	1096
3	35	202	0	4	5	10	10	149	10	0	55	0	7	0	0	20	507
4	109	12	4	0	8	17	4	31	0	0	20	0	12	31	11	48	307
5	81	200	5	12	0	2	5	0	0	7	6	0	14	114	39	156	641
6	13	40	5	37	2	0	9	0	0	0	0	10	6	5	12	139	278
7	164	154	5	4	5	10	0	5	5	0	15	0	25	0	0	26	418
8	186	267	88	27	0	0	5	0	15	0	23	8	15	0	59	99	792
9	42	9	0	4	0	0	5	8	0	36	0	19	19	61	0	30	233
10	52	21	0	0	9	5	0	0	27	0	7	3	22	0	27	0	173
11	11	30	49	12	12	0	10	30	0	2	0	0	5	10	61	17	249
12	0	25	0	20	0	10	0	0	19	0	10	0	0	0	0	0	84
13	83	24	15	12	9	6	20	23	19	21	3	0	0	253	186	136	810
14	349	36	17	31	210	8	0	11	61	0	10	0	313	0	0	61	1107
15	248	78	55	11	15	12	3	59	27	27	60	0	192	0	0	58	845
16	251	140	20	56	269	139	26	28	15	0	61	0	145	61	27	0	1238
TOTAL	1688	1252	482	329	615	255	623	820	240	245	307	70	812	912	624	1097	10371

TABLE A-2

PHASE I - PRT PMA AUTO TRIP MATRIX BY RESIDENTS OF THE PMA

ZONE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	TOTAL
1	0	43	40	81	36	36	36	115	125	48	38	10	81	390	22	164	1265
2	39	0	0	26	33	54	141	307	14	25	50	8	51	91	22	76	937
3	38	0	0	6	58	59	56	63	47	13	97	0	20	0	0	44	501
4	88	94	20	0	81	124	0	20	34	13	72	0	47	20	14	0	627
5	54	27	58	108	0	10	11	0	0	24	11	11	6	100	6	54	480
6	37	26	47	124	0	0	11	0	0	0	0	0	40	31	12	41	369
7	56	160	62	14	32	21	0	0	0	0	36	0	11	0	0	33	425
8	120	313	89	26	0	0	26	0	7	0	0	0	9	20	0	42	652
9	3	20	33	14	0	0	0	7	0	0	0	8	0	0	0	0	85
10	40	19	13	13	24	24	0	0	6	0	0	0	24	0	0	0	163
11	43	6	44	12	0	0	11	0	0	0	0	0	19	14	172	55	376
12	8	11	0	0	11	0	0	0	0	0	0	0	0	0	0	0	30
13	132	24	73	75	10	30	36	7	8	0	19	0	0	124	113	85	736
14	30	205	0	61	110	22	26	26	0	0	0	0	137	0	0	33	650
15	72	50	6	27	6	12	10	0	0	0	65	0	159	0	0	0	407
16	237	153	21	0	129	41	33	7	0	0	28	0	119	134	22	0	924
TOTAL	997	1151	506	587	530	433	397	552	241	123	416	37	723	924	383	627	8627

TABLE A-3

PRE-PRT UNIVERSITY BUS TRIP MATRIX BY RESIDENTS OF THE PMA

ZONE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	TOTAL
1	0	0	0	0	42	50	0	91	0	0	5	0	7	0	0	0	195
2	0	0	0	0	573	245	105	1612	52	4	52	4	48	0	0	0	2695
3	0	0	0	0	197	94	0	83	0	0	8	0	6	0	0	0	388
4	0	0	0	0	100	81	0	48	0	0	8	0	6	0	0	0	243
5	56	553	172	105	0	278	114	144	61	0	212	0	195	41	61	50	2042
6	0	22	40	47	65	0	0	0	0	0	25	0	45	10	10	15	279
7	15	123	0	0	0	124	0	0	0	0	15	0	30	0	0	0	307
8	11	1867	52	30	200	0	0	0	30	0	160	0	177	21	6	3	2557
9	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	5
10	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
11	8	86	65	19	42	2	15	25	10	0	0	0	35	12	15	10	344
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	41	195	48	47	25	35	35	180	30	0	25	2	0	10	15	10	698
14	0	0	0	0	20	20	22	0	0	0	2	0	0	0	[illegible]	0	64
15	0	0	0	0	7	12	0	5	5	0	0	0	2	0	0	0	31
16	0	0	0	0	0	9	0	0	3	0	0	0	0	0	0	0	12
TOTAL	131	2852	377	248	1271	950	291	2188	191	4	512	6	553	94	[illegible]	98	[illegible]

A-3

TABLE A-4

PRT PMA TRIP MATRIX BY RESIDENTS OF THE PMA

ZONE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	TOTAL
1	0	10	0	20	132	36	0	84	0	0	0	24	48	0	0	0	354
2	70	0	0	0	852	180	12	1344	0	0	0	72	276	0	28	28	2862
3	7	0	0	0	180	12	12	48	0	0	48	24	48	0	0	0	379
4	7	0	0	0	204	132	0	48	12	0	0	0	48	0	0	7	458
5	90	1078	238	168	0	0	0	0	0	0	0	0	0	27	59	54	1714
6	18	126	0	42	0	0	0	0	0	0	0	0	0	18	0	9	213
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	63	1708	14	28	0	0	0	0	0	0	0	0	0	0	0	0	1813
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
11	14	82	42	0	0	0	0	0	0	0	0	0	0	0	0	0	140
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	18	224	42	28	0	0	0	0	0	0	0	0	0	0	9	18	339
14	0	10	0	0	108	12	0	0	0	0	0	0	12	0	0	0	142
15	0	5	5	0	96	24	0	12	0	0	0	0	12	0	0	0	154
16	0	20	0	0	72	24	0	0	0	0	0	0	0	0	0	0	116
TOTAL	287	3279	341	286	1644	420	24	1536	12	0	48	120	444	45	96	116	8698

APPENDIX B

TRIP DISTRIBUTION MODELS

TABLE B-1

SUMMARY OF TRAVEL MODELS WHEN THE PRE-PRT FORMULATION WAS CALIBRATED WITH OPERATIONAL STAGE DATA

Trip Purpose	Mode (k)	Model Description					R^2
Campus to Campus	Auto	$T_{ijk} =$	$C_1^{-.826}$	$CL_1^{.4875}$	$E_1^{-.0774}$		.992
		F	567.13	97.41	.03		
		t	-.5	1.13	-.17		
		p	.0001	.0006	.8699		
	PRT	$T_{ijk} =$	$CL_1^{2.755}$	$FA_1^{-13.819}$	$E_1^{-4.862}$	$CL_2^{.1103}$	.871
		F	22.97	.1	3.91	.07	
		t	1.4	-1.79	1.81	.27	
		p	.0093	.771	.819	.798	
CBD Oriented	Auto	$T_{ijk} =$	$E_1^{.342}$	$E_2^{.278}$			.955
		F	403.45	19.59			
		t	5.44	4.43			
		p	.0001	.0003			
	PRT	$T_{ijk} =$	$E_2^{.312}$	$RPC^{-3.01}$			.583
		F	27.88	.08			
		t	1.98	-.28			
		p	.0001	.732			

TABLE B-1 (Continued)

Trip Purpose	Mode (k)	Model Description					R^2
Home to Campus	Auto	T_{ijk} =	$P_1^{.234}$	$C_2^{-.002}$	$FA_2^{-.093}$	$E_2^{.392}$	.992
		F	256.87	.00	3.09	.28	
		t	1.37	.02	-.07	.53	
		p	.0001	.9993	.0927	.6019	
	PRT	T_{ijk} =	$S_1^{.860}$	$CL_2^{.874}$	$PC^{-2.099}$	$RPC^{.812}$	.792
		F	74.47	1.22	8.02	-.28	
		t	2.42	1.85	-2.47	.53	
		p	.0001	.2828	.01	.602	
Campus to Home	Auto	T_{ijk} =	$FA_1^{.354}$	$P_2^{.357}$	$RAC^{.277}$		.805
		F	413.54	7.34	.34		
		t	1.31	2.70	.58		
		p	.0001	.0131	.5674		
	PRT	T_{ijk} =	$FA_1^{2.521}$	$P_2^{2.093}$	$PC^{4.618}$	$RPC^{-.796}$	.815
		F	71.74	.03	15.31	1.06	
		t	4.02	3.48	-3.79	-1.03	
		p	.0001	-.8583	.0009	.313	

TABLE B-1 (Continued)

Trip Purpose	Mode (k)	Model Description				R^2
Interzonal	Auto	$T_{ijk} =$	$P_1^{.476}$	$P_2^{.185}$	$AC^{-1.108}$	.556
		F	45.01	.98	7.83	
		t	2.76	2.78	-2.80	
		p	.0001	.327	.008	
	PRT	$T_{ijk} =$	$P_1^{.467}$	$P_2^{.475}$	$PC^{-1.196}$	.324
		F	12.26	.53	7.75	
		t	2.58	2.76	-2.80	
		p	.0011	.469	.008	

TABLE B-2

SUMMARY OF CALIBRATED TRAVEL MODELS FOR THE OPERATIONAL PRT STAGE

Trip Purpose	Mode(k)	Model Description					R^2
Campus to Campus	Auto	T_{ijk} =	$CL_1^{-.817}$	$FL_1^{-2.698}$	$E_1^{1.032}$	$RAC^{-.445}$	.999
		F	65.4	40.3	46.7	27.4	
		t	8.09	-6.35	6.83	-5.24	
		p	.001	.003	.002	.006	
	PRT	T_{ijk} =	$F_1^{4.627}$	$CL_2^{1.86}$	$RPC^{-7.04}$		.937
		F	13.48	15.88	14.7		
		t	3.67	3.98	-3.83		
		p	.014	.011	.012		
CBD Oriented	Auto	T_{ijk} =	$E_1^{.342}$	$E_2^{.278}$			.954
		F	29.63	19.59			
		t	5.44	4.43			
		p	.000	.000			
	PRT	T_{ijk} =	$E_1^{.2686}$	$RPC^{-.8512}$			.649
		F	8.42	1.83			
		t	2.9	-1.35			
		p	.009	.191			

TABLE B-2 (Continued)

Trip Purpose	Mode(k)	Model Description					R^2
Home to Campus	Auto	T_{ijk} =	$S_1^{.469}$	$FA_2^{1.287}$	$AC^{-.788}$		.93
		F	5.75	3.26	1.59		
		t	2.4	1.8	-1.26		
		p	.025	.084	.220		
	PRT	T_{ijk} =	$S_1^{.899}$	$CL_2^{.659}$	$PC^{-1.799}$		.789
		F	6.90	7.43	8.28		
		t	2.03	2.73	-2.88		
		p	.015	.012	.008		
Campus to Home	Auto	T_{ijk} =	$E_1^{.313}$	$S_2^{.668}$	$AC^{-.503}$		.961
		F	4.10	8.57	1.72		
		t	2.03	2.93	-1.31		
		p	.056	.008	.203		
	PRT	T_{ijk} =	$CL_1^{1.104}$	$P_2^{2.002}$	$PC^{-4.484}$	$RPC^{-1.004}$	.863
		F	29.16	16.22	21.87	2.31	
		t	5.4	4.03	-4.68	-1.52	
		p	.000	.001	.000	.144	

TABLE B-2 (Continued)

Trip Purpose	Mode(k)	Model Description					R^2
Interzonal	Auto	T_{ijk} =	$P_1^{.913}$	$P_2^{.842}$	$AC^{-2.138}$	$RAC^{2.734}$	.647
		F	20.0	19.5	20.4	10.9	
		t	4.47	4.42	-4.51	3.3	
		p	.000	.000	.000	.002	
	PRT	T_{ijk} =	$P_1^{.559}$	$P_2^{.522}$	$PC^{-1.317}$	$RPC^{-1.449}$	.428
		F	10.6	10.5	10.9	7.6	
		t	3.25	3.24	-3.30	-2.76	
		p	.002	.002	.002	.008	

110 Copies

).S. DEPARTMENT OF TRANSPORTATION
;EARCH AND SPECIAL PROGRAMS ADMINISTRATION
TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE, CAMBRIDGE, MA. 02142

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF TRANSPORTATION
613

U.S. MAIL