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SUPPLEMENT II

SUMMARY OF CAPITAL AND OPERATIONS & MAINTENANCE COST EXPERIENCE OF AUTOMATED GUIDEWAY TRANSIT SYSTEMS

COSTS AND TRENDS FOR THE PERIOD 1976 - 1979

Prepared by

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A related report is Supplement 1: Summary of Capital and Operations & Maintenance Cost Experience of Automated Guideway Transit Systems Costs and Trends for the Period 1976-1978 (PB 80-146483).

16. Abstract

During 1979, four of the five major Automated Guideway Transit (AGT) systems in the United States carried approximately 35 million passengers at an average operating and maintenance (O&M) of $.14 per passenger. Although cumulative vehicle mileage on AGT systems was slightly lower when compared to 1978 levels, the increased efficiency through more experienced O&M practices as well as maturity of these systems led to an O&M cost of $.99 per vehicle mile for 1979, approximately 10 percent lower than the 1978 figure for AGT and significantly lower than the 1978 figure of $2.48 for conventional transit.

This report summarizes O&M cost experience and trends for the following AGT systems for the period 1976-1979: AIRTRANS, Sea-Tac, Tampa, Disneyworld (WEDway), and Morgantown (O&M data on the Morgantown system is reported through 1978). Capital cost data is reviewed on Morgantown Phase I, AIRTRANS, Tampa, Sea-Tac, Miami, Busch Gardens, Disneyworld, King's Dominion, and Fairlane. New capital cost data has been obtained from the Atlanta and Orlando Airports and the Minnesota Zoological Gardens. In addition to presenting capital and operating and maintenance costs and trends, this report includes analysis of the factors influencing these costs. A section on the differences between urban and non-urban settings of AGT systems has also been included and shows how the costs of existing non-urban systems might relate to a system in an urban deployment in terms of site conditions and site requirements.

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PREFACE

This report summarizes the capital and operations & maintenance cost experience and trends of various Automated Guideway Transit (AGT) systems. Differences in technologies, sites, and operational capabilities of these installations significantly influence the costs reported on them. Initial analysis of these factors is included.

The study was funded by the U.S. Department of Transportation, Urban Mass Transportation Administration (UMTA) through its Office of Technology Development and Deployment. The project was managed by the Office of Socio-Economic and Special Projects. The report was prepared by the Urban Systems Organization at the Transportation Systems Center (TSC).

Mr. Frederick Cooke and Mr. Danadus Muotoh of N.D. Lea and Associates are especially acknowledged for their valuable assistance in collecting data on the various AGT systems.

Special recognition is given to Mr. Thomas Dooley and Mr. Michael Wiklund of TSC for their contributions and support in preparing this report on time. Also Mr. Howard D. Evoy, Program Manager in the Office of Socio-Economic and Special Projects, provided valuable guidance and support.

Transportation Systems Center

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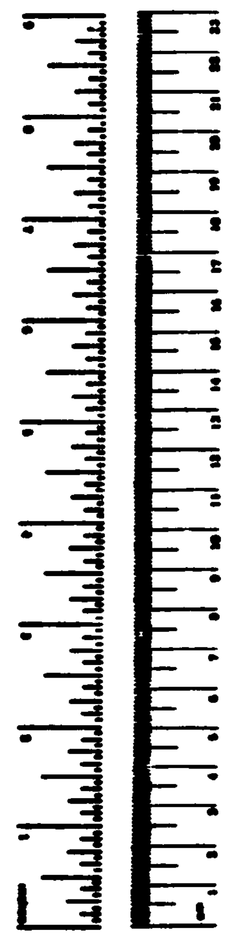
Mary Ellen von Rosenvinge

METRIC CONVERSION FACTORS

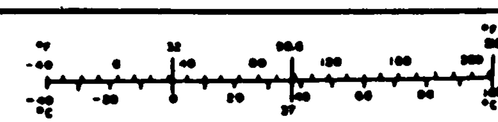
Approximate Conversions to Metric Measures

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



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1. SUMMARY

Existing Automated Guideway Transit (AGT) systems in this country are located primarily in non-urban areas and serve a variety of transportation needs at airports, universities, and recreation centers. The operating and maintenance (O&M) and capital costs of these systems and how they change from year to year is of significant interest in the evaluation of the services that AGT systems provide.

During 1979, four of the five major AGT systems in the United States (Morgantown system shut down for expansion) carried approximately 35 million passengers at an average O&M cost of $.14 per passenger. This figure is considerably lower than that experienced on conventional transit.

Although cumulative vehicle mileage on AGT systems was slightly lower when compared to 1978 levels, the increased efficiency through more experienced operations and maintenance practices as well as maturity of these systems led to an O&M cost of $.99 per vehicle mile for 1979, approximately 10 percent lower than the 1978 figure for AGT and significantly lower than the 1978 figure of $2.48 for conventional transit.

Added to the report this year were capital costs of the newly constructed systems of Atlanta, Orlando and Minnesota. The capital costs of these systems fall within the cost per lane mile envelope of existing AGT systems constructed in previous years. Capital costs of AGT guideways are driven by technology choice, particularly with respect to beam design, and by site-specific factors. Vehicle capital costs are driven by size, particularly as related to the empty weight of the vehicle.

2. INTRODUCTION

Automated Guideway Transit (AGT) is a relatively new concept in urban public transportation in which unmanned, automatically controlled vehicles are operated on fixed guideways along an exclusive right-of-way. AGT systems have been in operation in this country over the past 10 years, demonstrating an ability to serve a variety of public transportation needs and travel purposes. These types of systems have been installed or are under construction for public use at 25 sites in the United States; those currently in operation are generating more than 40 million passenger trips each year.

As part of the Urban Mass Transportation Administration's AGT Socio-Economic Research Program, the capital and operating costs of these systems are being collected and analyzed to provide a better understanding of the economic feasibility of AGT systems. This effort represents the third in a series of reports, beginning in 1978, which present the capital and operating and maintenance (O&M) costs of existing AGT systems and evaluates them with respect to trends with time and comparison to other transportation modes. These reports provide a useful single-source of cost information to transportation planners and local communities in their individual transit decision-making processes. All data has been derived from actual experience with AGT systems that are in operation or construction. The previous reports are:

- T.F. Comparato, T.M. Dooley, F.A.F. Cooke, et al., "Supplement I: Summary of Capital and Operations & Maintenance Cost Experience of Automated Guideway Transit Systems Cost and Trends for the Period 1976-1978," Report No. UMTA-IT-06-0188-79-1, Washington DC, Oct. 1979

- F.A.F. Cooke, C.P. Elms, T.J. McGean, H.W. Merrit, "Summary of Capital and Operations and Maintenance Cost Experience of Automated Guideway Transit Systems," Report No. UMTA-IT-06-0157-78-2, Washington DC, June 1978.

This report supplements and builds upon the data presented in the above two reports wherein capital cost information has been obtained and analyzed c o additional systems at the Orlando Airport in Florida, and the Minnesota Zoological Garden in Apple Valley, Minnesota. In addition, construction costs of the facilities for the system at the Atlanta Airport which were not available in last year's report are presented. Operations and maintenance cost information is provided for calendar year 1979 on four of the five major AGT systems used in last year's report - Airtrans, Sea-Tac, Tampa and Disneyworld. The capital and operating costs for the Morgantown Phase II system are not included in this report since the system was under construction and checkout for most of 1979.

The format and content of this report is different from last year's supplement in that additional narration and illustrations have been added to provide the reader with more information on the reasons for the major cost differences between the various AGT systems. In addition, a qualitative discussion on the important differences (from a cost view point) between the existing activity-center type systems and an urban AGT system is provided to indicate both the applicability and the limitations of using the data presented in this report. The variety of technologies and sites along with supplier/market factors that have been involved with existing AGT systems, coupled with the lack of detailed cost information, makes the process of correlating costs and reasons for costs a very difficult one. Hopefully, this report is another step forward in providing an understanding of the factors which affect the cost of building and operating an AGT system.

Prime responsibility for preparation of the report has been through the Department of Transportation's Transportation Systems Center (TSC). N.D. Lea & Associates provided valuable assistance

in collecting and compiling the latest AGT information from the various AGT suppliers and properties.

3. OVERVIEW OF AGT SYSTEMS STUDIED

3.1 EXISTING SYSTEMS

This report addresses the capital and operations & maintenance costs of selected existing AGT systems in this country that are currently in operation or near completion. (Though a number of AGT systems exist in foreign countries, primarily in test configurations, the availability and applicability of cost information is limited.) These existing systems currently satisfy a variety of transportation needs, i.e., by providing service to captive riders at airports, as a competitive service with respect to other modes at universities and shopping centers and by providing attractive and enjoyable rides at recreation centers. Though utilized extensively to date as the primary source of public transportation in activity center-type applications, the existing systems represent a significant range of technology options, site conditions and performance characteristics. This range of applications results in a diversity of sites and system sizes and configurations varying from the lengthy, multi-loop Airtrans system at the Dallas-Ft. Worth Airport to the short, shuttle-type system at the Fairlane Shopping Center in Dearborn, Michigan. Table 3-1 illustrates the variability in system size, configuration and vehicle capacity between the various systems by presenting the more salient characteristics of each system.

The systems employ proven technology which varies from site-to-site depending on the mobility requirements of the application area and the design approach of the manufacturer. The operational and performance characteristics of these systems also vary greatly from site-to-site and reflect the adaptability of AGT systems to meet the service needs of the respective sites. Therefore, it is these service needs and the physical and environmental characteristics of a given site, that have the largest impact on the specific configuration of technology deployed and

TABLE 3-1. SYSTEM CHARACTERISTICS

SYSTEM	LOCATION	SUPPLIER	SITE DESCRIPTION	GUIDEWAY CONFIGURATION	GUIDEWAY LENGTH LANE MILES/ EQUIVALENT ELEVATED LANE MILES	NUMBER OF STATIONS	NUMBER OF VEHICLES	VEHICLE CAPACITY ACTUAL/ EQUIVALENT PASSENGER PLACES	PERIOD OF OPERATIONS	INITIAL SERVICE DATE
MORGANTOWN PHASE I	MORGANTOWN, W. VA	BOEING	COLLEGE CAMPUS	DOUBLE LANE LINEAR PATTERN	5.26/4.52	3	45	21/23	13 HRS DAILY (M-F) 5.5 WEEKENDS	9/75
AIRTRANS	DALLAS, TX	VOUGHT	AIRPORT	SINGLE LANE MULTI LOOPS	12.8/6.66	28	51	40/42	24 HRS DAY	1/74
TAMPA	TAMPA, FL	WESTINGHOUSE	AIRPORT	DOUBLE LANE SHUTTLES	1.35/1.35	8	8	100/81	18-24 HRS DAY	4/71
SEA-TAC	SEATTLE, WA	WESTINGHOUSE	AIRPORT	2 SINGLE LANE LOOPS, SHUTTLE CONNECTION	1.71/5.13	6	12	102/81	20-24 HRS DAY	2/73
MIAMI	MIAMI, FL	WESTINGHOUSE	AIRPORT	DOUBLE LANE SHUTTLE	0.51/0.51	2	4	99/81	24 HRS DAY	UNDER CONSTRUCTION
ATLANTA	ATLANTA, GA	WESTINGHOUSE	AIRPORT	DOUBLE LANE LOOP	2.29/6.87	6	17	80/84	24 HRS DAY	UNDER CONSTRUCTION
ORLANDO	ORLANDO, FL	WESTINGHOUSE	AIRPORT	DOUBLE LANE SHUTTLES	1.48/1.48	3	8	100/84	24 HRS DAY	UNDER CONSTRUCTION
BUSCH GARDENS	WILLIAMSBURG, VA	WESTINGHOUSE	RECREATION CENTER	SINGLE LANE LOOP	1.33/0.84	1	2	90/81	APR. TO OCT. 8 HRS DAY	5/75
DISNEYWORLD (WEDway)	ORLANDO, FL	WALT DISNEY ENTERPRISES	RECREATION CENTER	SINGLE LANE LOOP	0.87/0.87	1	30,5 CAR TRAINS	20 TRAIN/ 29 TRAIN	10-17 HRS DAY*	7/75
KING'S DOMINION	RICHMOND, VA	UNIVERSAL MOBILITY	RECREATION CENTER	SINGLE LANE LOOP	2.06/0.88	1	6,8 CAR TRAINS	96 TRAIN/ 109 TRAIN	10-12 HRS DAY*	4/75
MINNESOTA ZOO	APPLE VALLEY, MN	UNIVERSAL MOBILITY	RECREATION CENTER	SINGLE LANE LOOP	1.36/1.36	1	3,6 CAR TRAINS	94 TRAIN/ 160 TRAIN	8 HRS DAY*	8/79
FAIRLANE	FAIRLANE, MI	FORD	SHOPPING CENTER	SINGLE LANE SHUTTLE WITH DOUBLE LANE BYPASS	0.61/0.61	2	2	24/27	12.5 HRS DAY	3/76

*ANNUAL AVERAGE

TABLE 3-1 NOTES:

- o Actual lengths of at-grade, elevated and underground guideways have been converted to Equivalent Elevated Lane Miles by use of the following factors: 0.4 - at-grade, 1.0 - elevated, and 3.0 - underground.
- o Equivalent Passenger Places have been calculated based on interior dimensions of the vehicle in order to supply conformity to vehicle capacity. Passenger places are allocated on the basis of a uniform distribution of 33 percent seated and 67 percent standing.
- o For those systems where cars are always entrained, the train is considered as a single vehicle unit.
- o Systems are grouped according to site location and supplier.
- o Atlanta and Sea-Tac are completely tunneled systems; Tampa, Miami, Orlando, Disneyworld and Minnesota Zoo are elevated systems, and the systems which are a combination of elevated and at-grade are Morgantown, Airtrans, Busch, King's Dominion and Fairlane.

its associated capital costs. Because of this relationship to site conditions and the fact the AGT deployments to date have been primarily in activity centers, some limitation does exist with respect to transferring the cost information and experience included in this report to other application types and sites. These limitations are discussed in the following section.

3.2 DIFFERENCES BETWEEN URBAN AND NON-URBAN SETTING

Domestic AGT systems are currently serving airports, recreational and shopping centers, and institutions (See Table 3-1). Only the Morgantown system, connecting the Morgantown downtown area with the West Virginia University campus, provides service in a setting approximately that of an urban public transportation system. The other systems operate within an area owned by the corporation or authority managing the activity center. These are very different environments than an urban area; consequently, the capital costs associated with these systems do not include a number of major components of the cost of an urban deployment. For this reason, it would be useful to briefly discuss some of the differences between current AGT systems and an AGT deployment in an urban area before examining the capital cost data in the next chapter.

AGT systems are appropriate in urban areas primarily on the basis of the mobility requirements of the area in conjunction with land use patterns and population densities. These areas are usually characterized by high population density, a mix of commercial and esidential land use, and high levels of vehicle and pedestrian traffic. Congestion is likely to exist, at least in some sectors, during the peak period. Travel demand varies widely during the day, with peak levels often more than twice the off-peak demand.

These conditions have major implications for the design of the AGT system. Vehicle size, and system throughput capacity must be sized to accommodate passenger loads during the peak periods. Station size and spacing are also influenced by the need for intermodal transfer points connecting AGT with other public transportation services. Park and ride lots must be constructed to permit transfers at AGT intercept points. The likelihood of vandalism and crime is higher in dense urban neighborhoods, which require a more extensive security system for surveillance and enforcement.

Another set of costs not identified with current AGT systems include right-of-way (ROW) acquisition, site modifications, and other costs associated with construction in a busy urban area. ROW acquisition costs depend on property values, local easements and the extent that existing rights-of-way can be utilized for portions of the network. Site modification costs are affected by site-specific variables such as soil conditions and topography, utility relocation and street modifications, traffic control and site accessibility, labor rates and local codes and many other factors. Integrating AGT stations with existing commercial structures and minimizing the disruptive impact on business in the downtown area also contribute to site-specific costs.

In addition to service requirements and site modifications, there are procedural requirements addressed in the deployment of any form of urban public transportation that were not encountered by the existing activity center AGT systems. In order to use public funds to construct a new transportation system, an institutional/political process is involved, including local, regional, and the Federal government. Some of the steps required before final engineering and construction can begin are as follows:

- o Concurrence among local/regional governments
- o Conduct of public hearings
- o Bond issues and public approval
- o An acceptable environmental impact statement
- o Compliances with state and federal regulations
- o UMTA approval of proposals and specifications
- o Concurrence of labor unions
- o Capital grant commitment.

This process is a lengthy one, and the timetable and resultant costs are difficult to estimate. Substantial engineering costs are incurred during this phase, especially if major revisions must be made to the system design. The time-table for this phase (design/public acceptance/funding committment) is usually in the order of 2 to 5 years, hence cost increases due to inflation will occur before construction begins.

While there are constraints and complexities associated with urban AGT deployment that have not been encountered by the AGT systems operating in activity centers, the technology and performance of these systems do meet the requirements of urban AGT. The existing AGT systems encompass a variety of vehicle designs, network configurations, on/off line stations, and communication/control capability, thus exhibiting a range and depth of technology sufficient to comply with urban system requirements. The point to be made here is that the total capital costs reported herein are not directly transferable because of site related factors in urban areas that impact costs and schedules.

For the reasons stated above, the capital costs of the AGT systems currently in operation are not totally representative of an AGT system in an urban setting. Each system is more typical in some respects and less so in others. A comparison has been made among some of the AGT systems included in this report, in terms of the degree to which they represent conditions in a hypothetical urban deployment. This was done in order to assist the reader in understanding how comparable each system is with respect to typical site and station requirements. Those sites which have more in common with urban conditions should be more representative in terms of capital cost components associated with guideway and station construction. This comparison was limited to site conditions and station requirements and does not include the vehicle, guideway, or command/control system technology.

TABLE 3-2. COMPARABILITY OF EXISTING AGT SYSTEMS TO URBAN DEPLOYMENT CONDITIONS AND SERVICE REQUIREMENTS

	MORGANTOWN PHASE I	AIRTRANS	TAMPA	SEA-TAC	ATLANTA AIRPORT	DISNEY-WORLD	MINNESOTA ZOO
TOTAL SYSTEM COST PER LANE MILE*	13,830	5,952	13,277	25,391	24,743	17,559	5,804
SITE CONDITIONS							
ROW Acquisition Required	3.0	1.0	1.0	1.0	2.0	1.0	1.5
Land Use and Population Density	3.0	1.5	1.0	1.5	2.0	1.0	1.5
Extent of Vehicle and Pedestrian Traffic Around Guideway	3.0	1.5	1.5	1.0	2.0	1.5	2.5
Extent of Relocation of Utilities or Existing Structures	3.5	1.0	1.0	1.5	2.0	1.5	2.5
Institutional Issues Encountered (hearings, EIS, displacements, etc.)	3.0	1.5	1.5	1.5	2.0	1.0	2.5
STATION CHARACTERISTICS							
Station Design and Capacity	4.0	3.5	4.0	3.5	3.0	1.5	3.5
Station Spacing, number of stations	4.0	3.5	2.0	3.0	2.5	1.0	1.0
Interfacing of Stations with Other Existing Structures	3.5	2.0	3.0	3.0	2.0	1.5	2.5
Transit Requirements (Fare collection, security passenger information)	3.5	3.5	3.0	2.0	2.0	1.5	2.5
COMPOSITE AVERAGE	3.4	2.1	2.0	2.0	2.2	1.3	2.2

Legend: 1 = Not comparable; 2 = Minimum comparability; 3 = Comparable in some respects; 4 = Nearly equivalent; 5 = Fully equivalent.

*Thousands of 1979 Dollars

In Table 3-2, the ranking of the AGT systems is shown for nine sites and station considerations, together with a composite score for each system, obtained by averaging the scores over all nine categories.

It can be seen from Table 3-2 that Morgantown is most representative of an urban deployment in terms of the site and stations. Airtrans, Tampa, and Sea-Tac are very similar to each other in these respects, and are somewhat less comparable than Morgantown. Disneyworld is the least typical of an urban deployment, implying that its capital costs would probably be less representative, at least with respect to planning and construction of the guideway and stations.

Admittedly, there is no such thing as a "typical" urban site or an AGT technology that is best suited to all urban conditions. Consequently, a set of objective criteria cannot be developed for an assessment of this sort. Nevertheless, the qualitative representations included here, based on subjective judgements as to urban site and station requirements, may still be useful in examining the capital cost data in subsequent chapters of this report.

4. CAPITAL COSTS

4.1 CATEGORY DEFINITION AND OTHER QUALIFYING INFORMATION

For purposes of analysis and a means of providing more useful detail to the reader, the breakdown of the costs is in the form of the "Summary of Capital and Operation Cost Experience of Automated Guideway Transit Systems" report. The seven categories have been identified as follows:

- Guideway - The vehicle roadway including: site preparation, foundations, supporting structures, running and guidance surfaces, wayside switching equipment, and special facilities for melting snow and ice if required.
- Stations - Passenger loading platforms, shelters, access facilities such as ramps, stairways, escalators, elevators, graphics, fare collection equipment, coordinated doors, and other facilities related to the movement of passengers into and out of vehicles.
- Maintenance and Support Facilities - Maintenance and repair shops including such equipment as engineering vehicles.
- Power and Utilities - Electric power transformers, feeders, switchgear, wayside power rails and normal housekeeping power equipment.
- Vehicles - The rolling stock.
- Command and Control - Wayside and central control and communications equipment including operational software and voice and video communication systems.
- Engineering and Project Management - Architectural and engineering services, system design and integration, acceptance testing and overall project management.

ESCALATION

The AGT systems reviewed in this report were not all constructed at the same time. For the purpose of comparative analysis, the capital costs have been adjusted to a uniform 1979 price level. In order to remain consistent with past reports the same indices for escalation have been used and are explained below:

- CPI: The consumers price index for urban wage earners and clerical workers (U.S. cities average) is used to adjust all costs for engineering and project management.
- PPI: The producer price index for machinery and motive products (previously called the wholesale price index) is used to adjust all hardware costs.
- ENR: The engineering news record 20-city construction cost index is used to adjust the cost of all fixed facility construction.

All three indices have a base of 100 for 1967. Listed below are the indices used and their yearly averages.

YEARS	CPI	PPI	ENR
1975	161.2	156.2	206.0
1976	170.3	165.8	223.0
1977	181.5	176.6	240.0
1978	195.4	190.4	258.0
1979	217.7	206.9	279.5

Yearly averages have been used to escalate the costs of the systems included in the 1978 Summary Report. In the other cases, the appropriate starting point for escalation has been either the midpoint of construction or date of procurement.

Analysis of available data shows that the various AGT systems examined maintained their cost records in different formats. Also in many cases the AGT system is an integral part of larger facilities, such as airports, and the costs have not always been separated. Due to these facts, it was necessary to estimate the cost to duplicate the essential transit features.

Research and development costs and right-of-way aquisition costs have been removed from the data to the extent possible.

4.2 CAPITAL COST EXHIBITS

Capital cost data for twelve AGT systems, ten included in previous reports and two new systems, Minnesota Zoological Gardens and Orlando Airport, are presented in Table 4-1. Figure 4-1 is the representation of these costs in a bar chart format. A distribution of these capital costs for the twelve systems is presented in the form of a pie chart in Figure 4-2.

Figures 4-3 and 4-4 indicate how total system costs can be related to system mileage, expressed in equivalent elevated lane miles, and to passenger capacity provided by the vehicle fleet in passenger place miles per hour. Average costs have been supplied on both graphs indicating the extent to which actual values vary from the average.

Plots of two major subsystem costs, guideway and vehicles, are found in Figures 4-5 and 4-6. The purpose for examination of data at a finer level is to better show a correlation between systems and what drives their wide range of costs. Again a linear average is supplied for analysis.

Explanatory notes are provided with each figure.

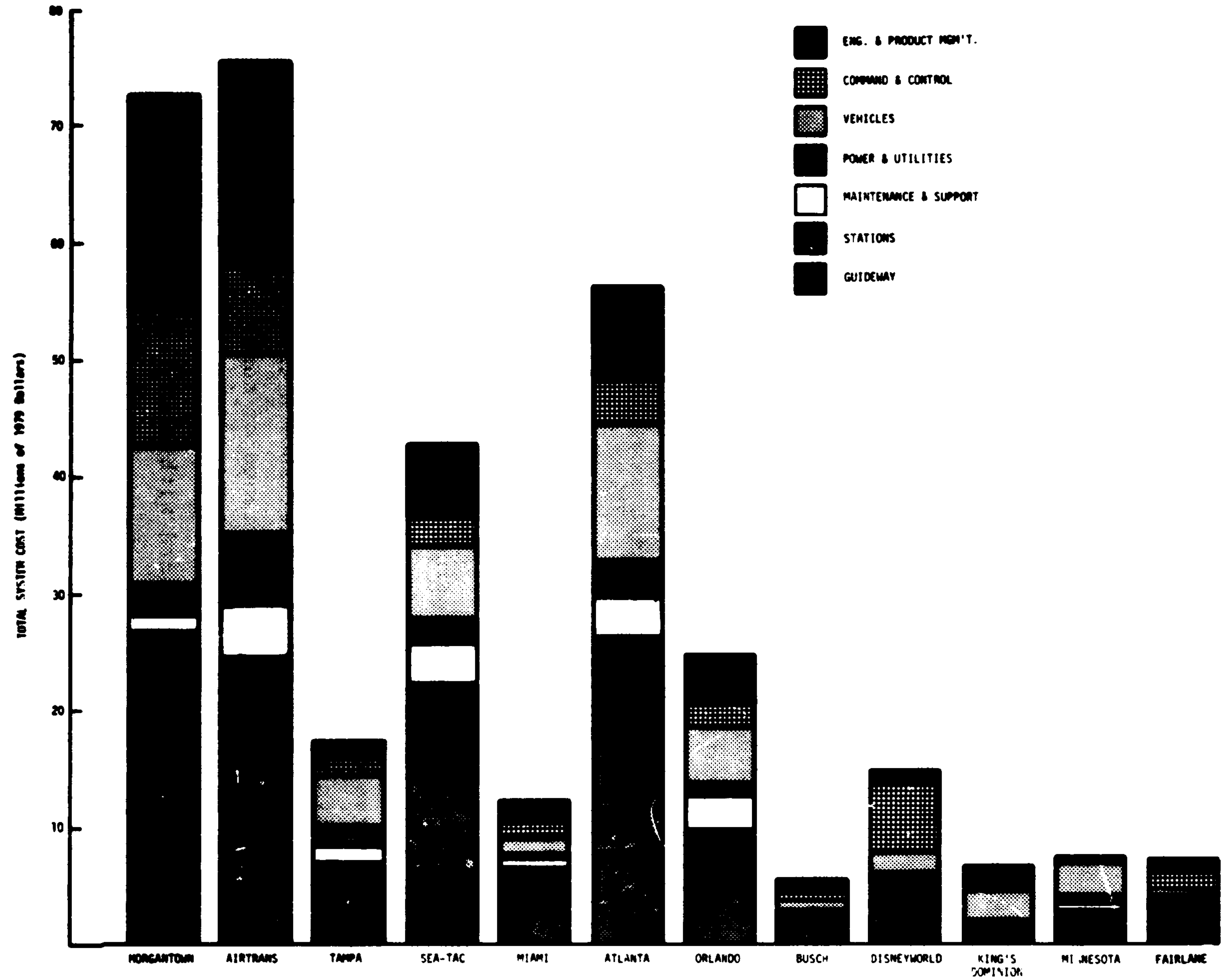


FIGURE 4-1. AGT CAPITAL COST BREAKDOWN

TABLE 4-1. AGT CAPITAL COST* SUMMARY (Thousands of 1979 Dollars)

	MORGANTOWN PHASE I	AIRTRANS	TAMPA	SEA-TAC	MIAMI	ATLANTA	ORLANDO	BUSCH	DISNEY-WORLD	KING'S DOMINION	MINNESOTA ZOO	FAIRLANE
GUIDEWAY												
TOTAL COST	23,875	16,125	4,313	15,500	3,073	17,510	6,168	2,149	2,463	1,350	2,745	2,600
COST PER LANE MILE	4,539	1,260	3,194	9,064	6,026	7,646	4,168	1,616	2,830	655	2,018	4,262
STATIONS												
TOTAL COST	3,188	8,700	2,813	6,925	3,377	9,204	4,554	163	2,013	225	327	521
COST PER STATION	1,063	311	352	1,154	1,689	1,534	1,518	163	2,013	225	327	261
MAINTENANCE & SUPPORT												
TOTAL COST	1,325	4,775	1,141	3,600	929	3,385	2,307	286	745	259	679	149
COST PER VEHICLE	29	94	143	300	232	199	288	143	25	43	226	74
POWER & UTILITIES												
TOTAL COST	3,388	6,238	2,675	2,035	504	3,169	941	476	994	403	746	1,175
COST PER LANE MILE	644	487	1,981	1,190	989	1,384	636	358	1,142	195	548	1,926
VEHICLES												
TOTAL COST	11,194	15,250	3,375	6,188	1,365	11,193	5,162	1,030	3,988	2,813	2,353	915
COST PER VEHICLE	249	299	422	516	341	658	645	515	133	469	784	458
COMMAND & CONTROL												
TOTAL COST	12,750	8,075	1,725	2,541	989	4,124	1,932	634	4,025	43	349	915
COST PER LANE MILE	2,424	631	1,278	1,486	1,939	1,801	1,305	476	4,626	21	257	1,500
ENGINEERING & PROJECT MGM'T.												
TOTAL COST	17,024	17,024	1,882	6,630	2,040	8,076	3,981	1,080	1,048	1,818	694	1,395
TOTAL SYSTEM COST	72,744	76,187	17,924	43,418	12,277	56,661	25,045	5,818	15,276	6,911	7,893	7,670
TOTAL SYSTEM COST PER LANE MILE	13,830	5,952	13,277	25,391	24,073	24,743	16,922	4,374	17,559	3,355	5,804	12,574

*DUPLICATION COST OR ACQUISITION COST

LANE MILES ABOVE ARE SINGLE LANE MILES

TABLE 4-1 NOTES:

- Duplication/acquisition cost is the cost to duplicate the identical system in 1979 dollars.
- Duplication or acquisition costs are rounded to the nearest thousand dollars after escalation. Unit costs, i.e., cost per vehicle are calculated before rounding.
- In instances where there was insufficient information available on the cost of individual or groups of subsystems, engineering estimates have been made.
- For those systems presented in the original Summary Report, capital costs have been adjusted to 1979 price levels. The breakdown of the Miami and Busch data has been revised from the Supplement Report and adjusted to 1979 dollars. New data on Atlanta, Orlando, and Minnesota has been obtained and similarly adjusted to a 1979 price level from either the midpoint of construction or date of procurement using the appropriate indices.
- Tampa - Guideway costs include the cost of a pedestrian walkway.
- Sea-Tac - The figure for Power and Utilities cost from the Summary Report has been disaggregated in order to show separate costs for command and control
- Miami - Guideway costs include the cost of a pedestrian walkway.
- Atlanta - Updated costs have been obtained for the total system excluding the fixed facilities costs which are being reported on for the first time.

  The guideway cost figure includes a back-up pedestrian walkway and has been estimated from the total tunnel costs at the airport, using a square footage allocation for both the AGT system guideway and pedestrain walkway. The walkway amounts to about 30% of the total guideway cost shown.

  Square footage allocations of floor area have been used to determine the following costs: pedestrian mall, stations, control rooms, switchgear locations, and maintenance shops.
- Orlando - The contracted cost for the expansion of the Orlando Airport system was obtained in 1980 dollars. Consequently, an inflation rate of 12 percent has been assumed in order to de-escalate to the 1979 price level.

  The guideway cost includes the cost of a pedestrian walkway.
- Minnesota Zoo - The single station at the Minnesota Zoo is an integral part of the visitor's center; thus, the station cost is an estimate based on that portion of the total structure that is used for the AGT system.

  Cost of Command & Control System includes allocation made for a portion of on-board vehicle control system.

  Power and utilities cost does not include the primary source of electric power which was supplied by the zoo, such as transformers, etc.

COMMENTS

- The data presented for Atlanta, Orlando and Minnesota indicate a range of costs similar to the variation between other systems.
- An unweighted average of guideway costs figured by guideway type shows the following variation. The totally elevated guideways have an average cost of $3,64? per lane mile while the tunneled systems have an average cost per lane mile of $8,35?, more than double the elevated cost. The average cost per lane mile for the combination of elevated and at-grade systems is $2,655, more than three times less than the tunnel cost.

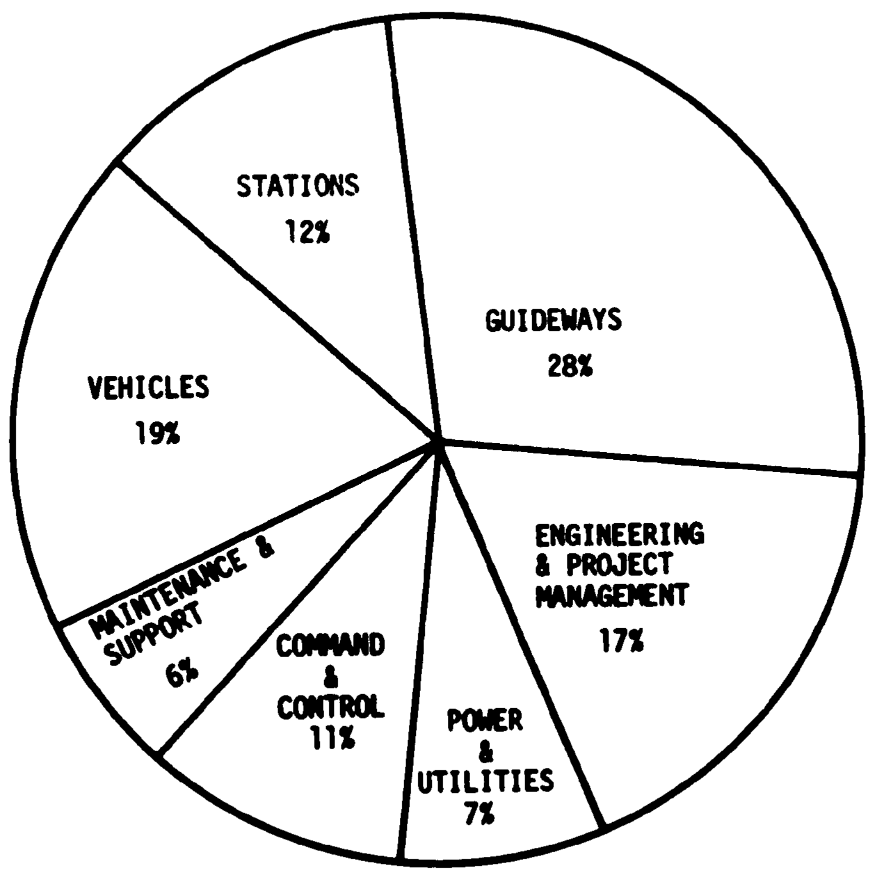


FIGURE 4-2. DISTRIBUTION OF CAPITAL COST FOR TWELVE AGT SYSTEMS

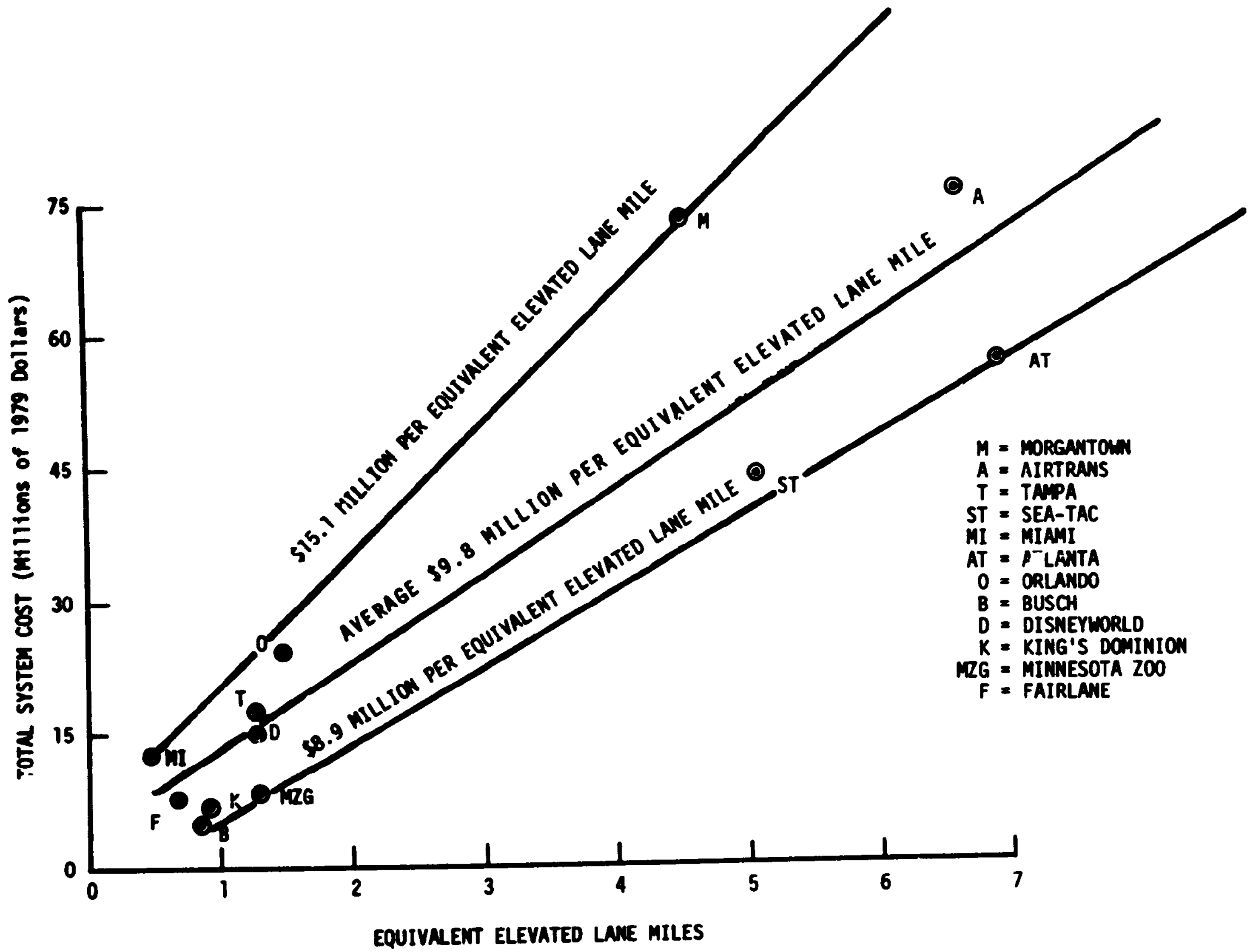


FIGURE 4-3. TOTAL SYSTEM COST VS. EQUIVALENT ELEVATED LANE MILES

FIGURE 4-3 NOTES:

- Equivalent elevated lane miles have been calculated using the following factors:

  0.4 x at-grade length = equivalent elevated length

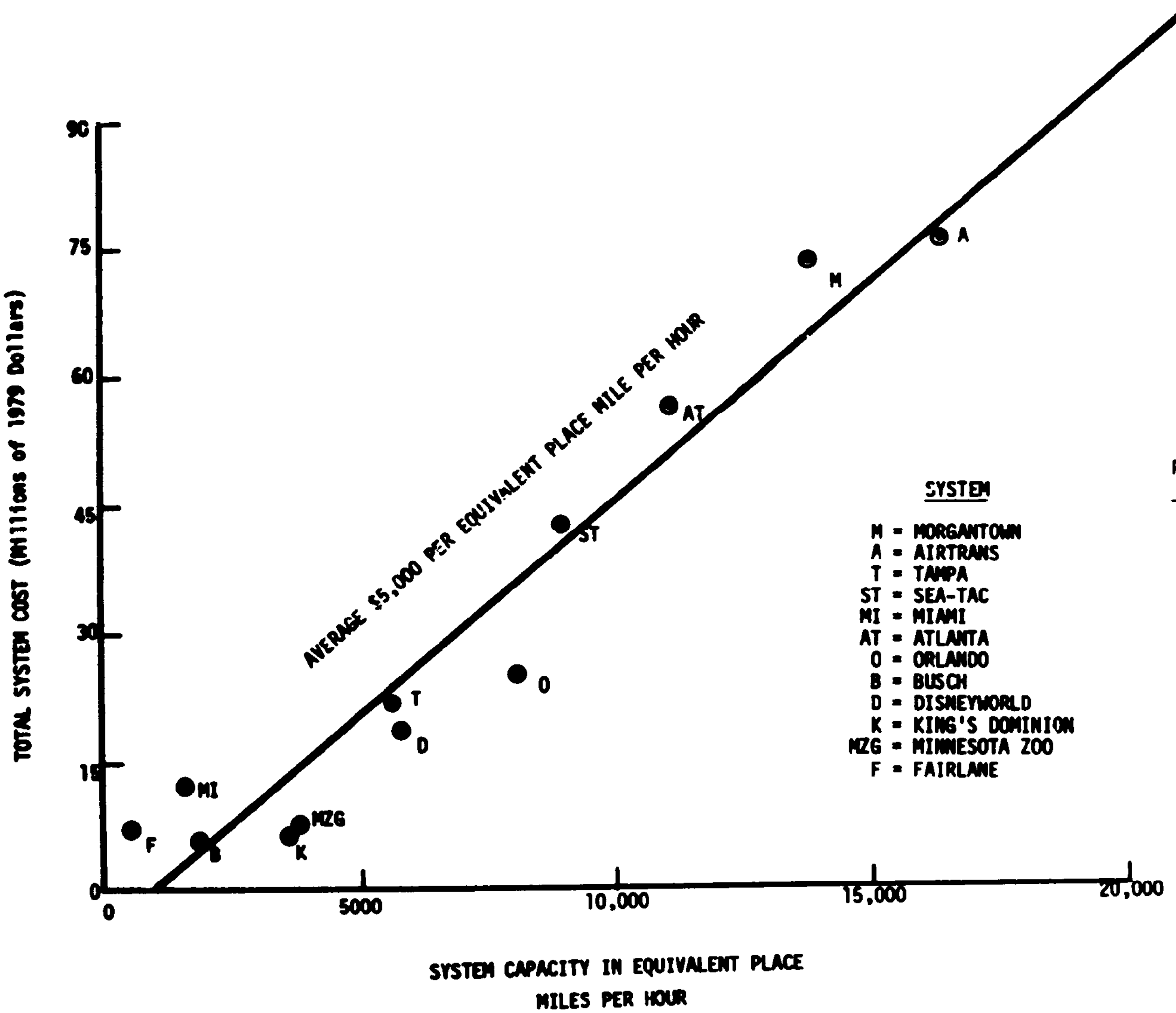
  3.0 x tunneled length = equivalent elevated length

  1.0 x elevated length = equivalent elevated length

  These normalizing factors have been developed by the DOT Transportation Systems Center, based upon analysis of actual cost data as well as estimates for proposed projects.

- The curves plotted on this graph represent the extremes shown by the data points, and the average cost, which is calculated using linear regression, a least squares method for finding a straight line that best fits a set of data points.

- Variations in technologies and site specific factors contribute to the spread of data points



SYSTEM	EQUIVALENT PLACE MILES PER HOUR
M = MORGANTOWN	13869
A = AIRTRANS	16451
T = TAMPA	5702
ST = SEA-TAC	8942
MI = MIAMI	1594
AT = ATLANTA	11053
O = ORLANDO	8064
B = BUSCH	1928
D = DISNEYWORLD	5916
K = KING'S DOMINION	3662
MZG = MINNESOTA ZOO	3840
F = FAIRLANE	529

FIGURE 4-4. TOTAL SYSTEM COST VS. SYSTEM CAPACITY

FIGURE 4-4 NOTES:

- Because of the significant differences in system configuration and for comparison purposes, the capacities of these AGT systems have been expressed in terms of equivalent place miles per hour. This calculation is based on vehicle fleet size, average speed, and passenger capacity.
- Equivalent vehicle capacities have been used in calculating equivalent place miles per hour. Thus, instead of the actual capacity which is determined by the interior arrangement of a vehicle, normalized capacities have been estimated for purposes of comparability on the basis of a uniform distribution of 33 percent seated passengers and 67 percent standing passengers. Floor space of 4.5 sq. ft. is allowed per seated passenger and 2.36 sq. ft. per standee.
- Average speed used in figuring equivalent place miles per hour is based on an estimated value for Orlando, Atlanta and Miami which are not yet operational.
- Using linear regression, a least squares method for finding a straight line that best fits a set of data points, an average system cost of $5,000 per equivalent passenger place per hour is calculated from the system cost/capacity data.

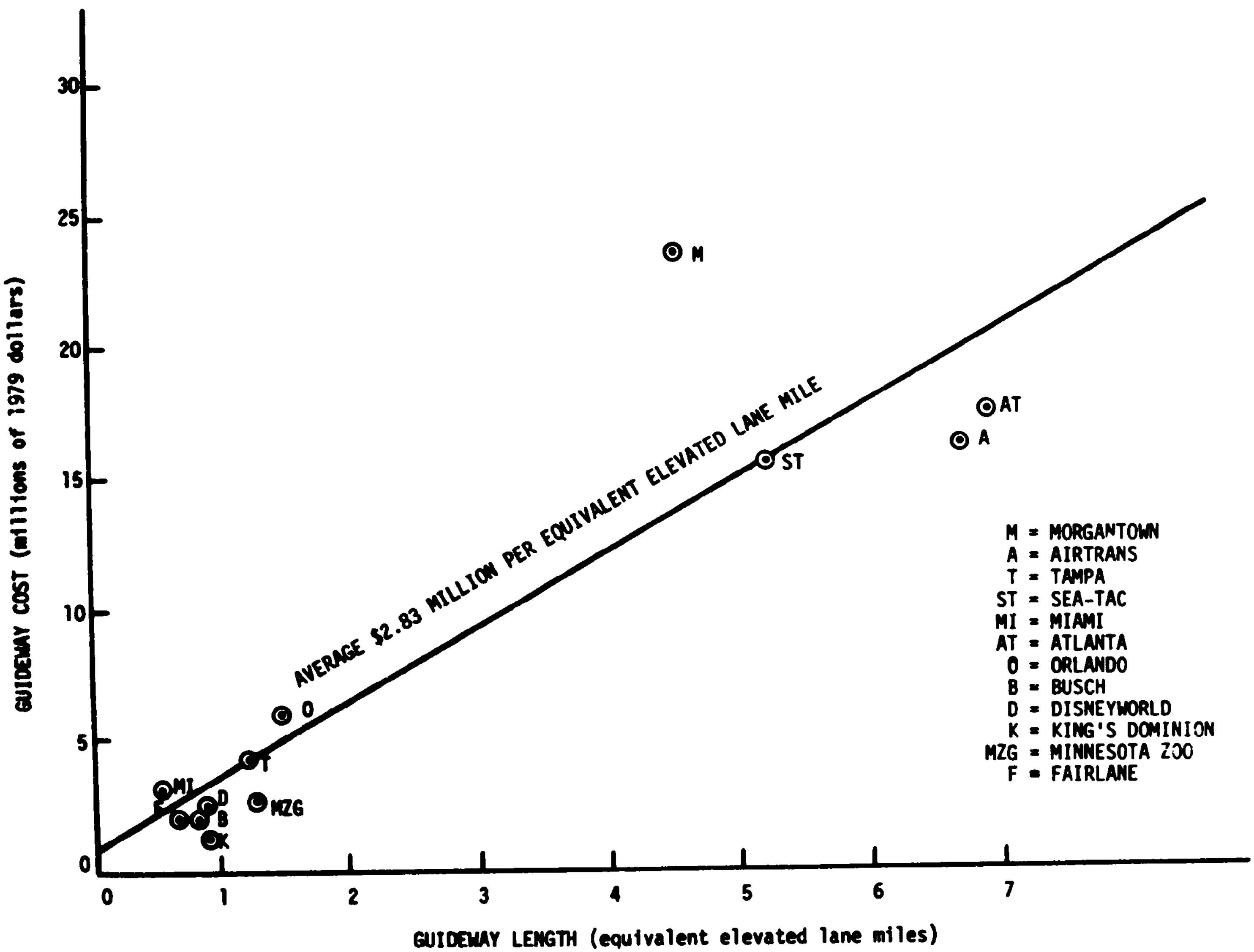


FIGURE 4-5. GUIDEWAY COST VS. EQUIVALENT ELEVATED LANE MILES

FIGURE 4-5 NOTES:

- Equivalent elevated lane miles have been calculated using the following factors: 0.4 for at-grade, 3.0 for tunneled and 1.0 for elevated.
- Replacing system cost with guideway cost when plotting against equivalent elevated lane miles provides a better correlation between systems due to the removal of other factors such as vehicles, command and control, etc.
- Morgantown remains off the curve because of the special circumstances involved in the construction of the system.
- Linear regression, a least squares method for finding a straight line that best fits a set of data points, has been used to compute the average.

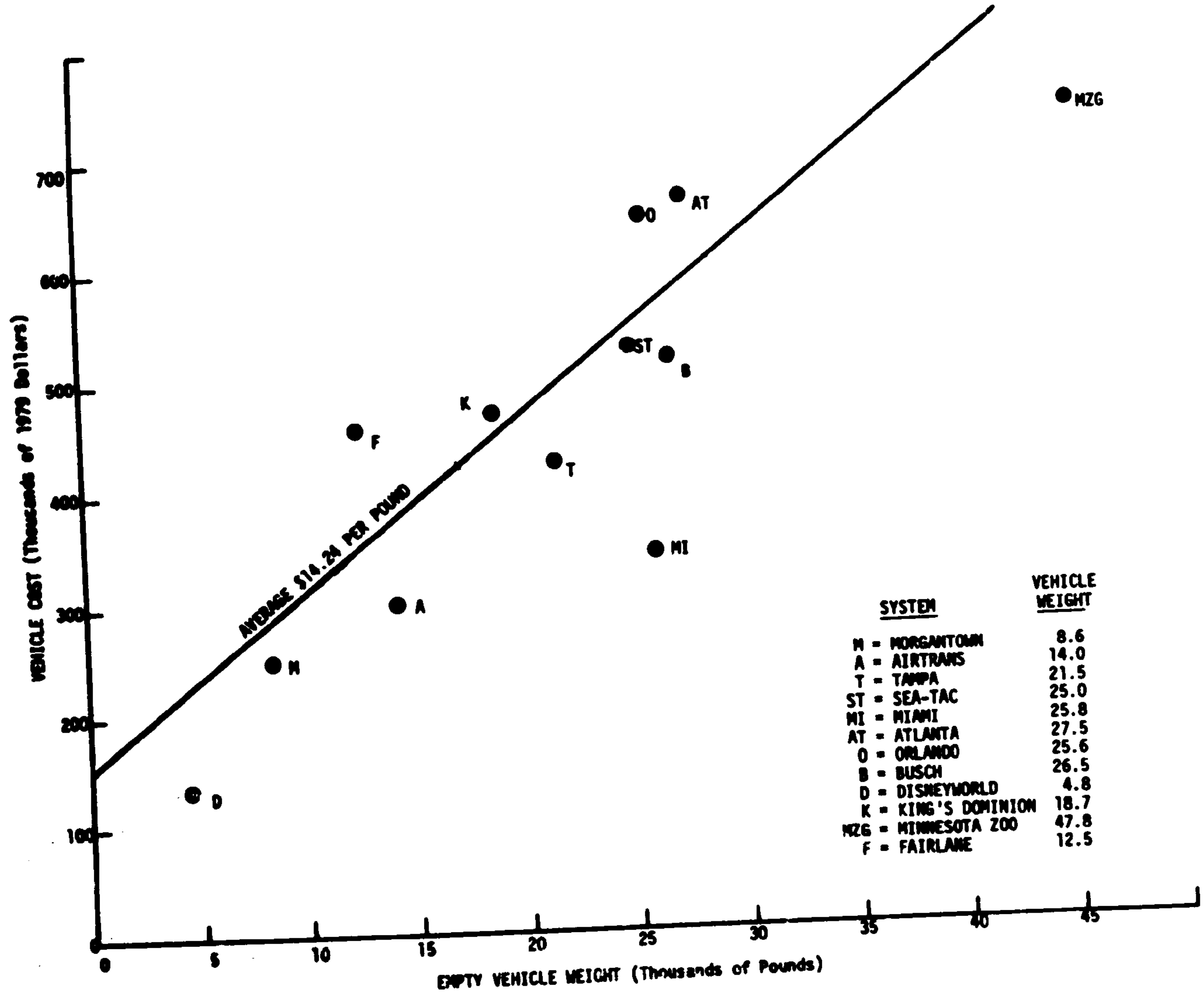


FIGURE 4-6. VEHICLE COST VS. EMPTY VEHICLE WEIGHT

FIGURE 4-6 NOTES:

- o Empty vehicle weights have been obtained from either assessment reports or discussion with suppliers.
- o The graphical representation of vehicle cost vs. empty vehicle weight provides a better correlation of the data than shown on the curve,vehicle cost as related to capacity,in the 1979 Supplement Report.
- o Weights for Disneyworld, King's Dominion and Minnesota Zoo represent the weight of the train.
- o Linear regression, a least squares method for finding a straight line that best fits a set of data points, has been used to compute the average.
- o The spread of Westinghouse system data points may be due to differences in vehicle technologies and site locations.

4.3 DISCUSSION ON CAPITAL COST VARIATIONS

Comparison of the capital costs of the various AGT systems at both a system and subsystem level are shown in tabular form in Table 4-1 and in graphic form in Figure 4-1. Both exhibits indicate significant cost differences among the existing AGT systems. As noted in Section 3.1, one reason for the cost variability is the diversity in system sizes and configurations indicated in Table 3-1. When the effects of size are removed by normalizing the cost data with a size-related parameter (number of lane miles, number of vehicles), major cost variations still remain and are attributable, to a large degree, to differences in both the technology used for each system and the conditions that exist at each site. Since the capital costs for the guideway and vehicle subsystems are the largest contributors to total system cost (See Figure 4-2), these two subsystems are discussed further in the following section in relation to factors and conditions that influence their capital cost. The information included is intended to provide a better understanding of the key variables and parameters that affect the cost of these two major subsystems. In addition, differences between an urban and a non-urban deployment of an AGT system that can have an impact on costs are also discussed.

4.3.1 Guideway

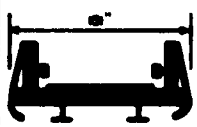
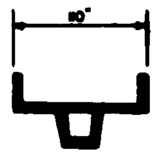
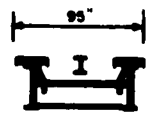
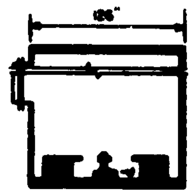
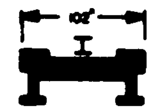
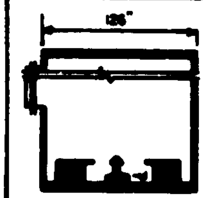
Considering the number of factors that influence the capital cost of an AGT system, it is difficult to correlate the total cost of each system with a single parameter. Figure 4-3 is an attempt to correlate total system cost with a single parameter such as equivalent lane miles, and although system size is accounted for in the plot, technology differences and site variations are not. Although the data points indicate a general range and trend, a considerable spread exists among the various systems. A similar plot (shown in Figure 4-5) using only guideway costs as a function of equivalent lane miles improves the correlation, and indicates a similar pattern of variability.

The capital cost of building and installing a guideway for an AGT system is a function of many factors which depend on both the guideway design (technology) being used and on the site and local conditions that prevail. Numerous designs and construction techniques have been employed in building and installing the guideways of existing AGT systems. Table 4-2 shows the variation in guideway designs among the existing systems along with their actual cost (dollars per lane mile). In addition, some of the key variables associated with the technology that have a significant impact on the cost are presented. Characteristics such as beam shape and material; span length; construction technique; percent elevated, at-grade, and tunneled; materials, etc. are all presented for each of the systems. To what extent, however, each of these characteristics contributed to the guideway cost of the systems in Table 4-2 is not known. Although parametric studies* have developed relationships between some of these characteristics and guideway cost, it is very difficult to develop a good correlation between this information and the cost difference shown in Table 4-2 because of the large number of other variables that exist, primarily the site-specific ones addressed later in this section.

For example, some of the correlations* are as follows:

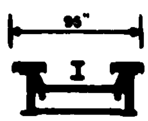
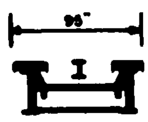
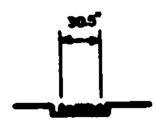
- o Beam shape in terms of complexity of design and width is a very important factor in guideway costs.
- o Longer beam span lengths lead to lower guideway unit costs.
- o Guideway unit costs increase with increasing vehicle load.
- o Guideway costs increase at a rapid rate when the total length of guideway being constructed decreases below 1 to 2 miles.

*"Guideway and Station Concepts," Report No. UMTA-IT-06-0152-79-6, Vol. 7, DeLeuw Cather and Company, July 1979.

GUIDEWAY PARAMETERS \ SYSTEM	MORGANTOWN PHASE I	AIRTRANS	TAMPA	SEA-TAC	MIAMI	ATLANTA
BEAM SHAPE						
ACTUAL LENGTH (MILES) / EQUIV. ELEV. LENGTH	5.26/4.52	12.8/6.66	1.35/1.35	1.71/5.13	0.51/.51	2.29/6.87
PRIMARY MATERIAL(S)	Steel and Concrete	Concrete	Steel and Concrete	Concrete	Steel and Concrete	Concrete
CONSTRUCTION TECHNIQUE	Field Construction, Composite Action	Plant Precast & Prestressed Field Post-Tensioned	Field Construction, Composite Action	Rectangular Cast-In-Place Concrete Running Surfaces	Field Construction Composite Action	Rectangular Cast-In-Place Concrete Running Surfaces
COLUMN TYPE	Wine-Glass Shape, Cast-In-Place Concrete	Tapered, Rectangular Precast Concrete	Tee-Head Cast-In-Place Concrete	Not Applicable (Tunnel)	Tee-Head Cast-In-Place Concrete	Not Applicable (Tunnel)
LOADED* VEHICLE WEIGHT (LBS.)	11,728	20,000	36,500	40,300	26,049	39,400
TYPICAL SPAN LENGTH (FT.)	66	90	58	Not Applicable (Tunnel)	50-110	Not Applicable (Tunnel)
% ELEVATED	68	20	100	——	100	——
% AT GRADE	32	80	——	——	——	——
% UNDERGROUND	——	——	——	100	——	100
GUIDEWAY COST PER LANE MILE ('79 DOLLARS)	4,539	1,260	3,194	9,064	6,026	7,646
GUIDEWAY COST PER EQUIVALENT LANE MILE ('79 DOLLARS)	5,282	2,421	3,195	3,021	6,026	2,548

*Loaded Vehicle = Empty Vehicle Weight + 150 pounds x (actual vehicle capacity). ** Train Weight

TABLE 4-2. GUIDEWAY SYSTEM CHARACTERISTICS

ORLANDO	BUSCH GARDENS	DISNEYWORLD	KING'S DOMINION	MINNESOTA ZOOLOGICAL GARDENS	FAIRLANE TOWN CENTER
					
1.48/1.48	1.33/.84	0.87/.87	2.06/.88	1.36/1.36	0.61/.61
Steel and Concrete	Steel and Concrete	Steel and Concrete	Steel	Steel	Concrete
Field Construction Composite Action	Field Construction Composite Action	Continuous Cast-In-Place Concrete	Prefabricated Off-Site, Field Welded	Prefabrication Off-Site, Field Welded	Plant Precast & Prestressed, Field Post-Tensioned
Information Not Available	Rectangular Cast-In-Place Concrete	Structural Steel	Structural Steel	Structural Steel W Shape	Tapered, Rectangular W/ Rounded Corners, Precast Concrete
40,560	40,001	7,770**	33,100**	61,880**	16,100
Information Not Available	73	50	27-60	73	60
100	40	100	5	90	100
—	60	—	95	10	—
—	—	—	—	—	—
4,168	1,616	2,830	665	2,018	4,262
4,168	2,558	2,830	1,534	2,018	4,262

- A prime variable affecting guideway cost is construction/implementation time.

Using the information above to sort out the cost differences in Table 4-2 is very difficult as previously mentioned. Nevertheless, some general observations can be made relative to Table 4-2 in terms of significant contributing factors to cost. For example, the additional bulk and complexity of the Miami guideway beam plus the fact that the guideway length was under one mile probably had a lot to do with the high cost of that system. In contrast, the simplified box beam configuration of the Minnesota Zoo application was probably a major factor in its low unit cost.

The cast-in-place nature of the Morgantown guideway contributed significantly to the guideway unit cost, whereas the prefabricated type of guideway and also its overall length helped keep the unit guideway cost of the Airtrans system on the low side. Of course, the 100 percent tunneled nature of the Atlanta and Sea-Tac system is a strong reason for their high unit costs.

As stated previously, those variables associated specifically with the site are not included in Table 4-2 and prevent good correlation between the various guideway technologies and their unit cost. Some of the more important site-specific variables that contribute to the difference in guideway costs in Figure 4-2 are as follows:

- Labor Rates and Union Requirements
- Utility Relocation and Street Modification
- Traffic Control and Site Accessibility
- Climate and Construction Season
- Soil Conditions and Topography
- Material Availability and Cost
- Local Building Codes and Requirements

o Environmental Constraints (noise, vibration, etc.).

As one example of variability introduced by site specifics, just the difference in construction cost indices between Atlanta and Minneapolis can introduce, as indicated by Table 4-3, a difference of 33 percent in construction costs between the two sites, assuming everything else was constant.

4.3.2 Vehicles

Another factor which substantially influences the total system cost is the rolling stock or vehicle. The costs of this particular subsystem vary as much as the guideway costs. There are a variety of reasons for this spread and below are some suggestions that will provide insight to what is driving the vehicle cost.

As shown in Table 4-1, there are various system suppliers associated with AGT which initially cause cost discrepancies. Even within the same supplier there is diversity in technology and vehicle characteristics. The majority are bottom supported vehicles on wheels propelled by electric motors with the exception of Disneyworld which is a passive vehicle with a linear induction motor mounted on the guideway. The vehicle system, comprised of either of a single vehicle or a train of vehicles, has a wide spread of weights (which range from 4,770 to 47,780 pounds) and sizes. Most are enclosed vehicles protecting the passengers from the elements, while Disneyworld which is found in a milder climate is open. Many of the vehicles are independent units, but in the cases of Disneyworld, King's Dominion, and Minnesota Zoo, the fleets run in the form of trains. In the case of the Minnesota Zoo train, some variations occur between the cars comprising the train. The lead car is the heaviest because it contains the propulsion and steering mechanisms for the entire train while the rear car is the lightest because of the removal of some seats to provide space for the elderly and handicapped. Some systems include on-board vehicle control while others remain passive.

TABLE 4-3. ENR COST INDICES IN 22 CITIES BASED ON 1913 U.S. AVERAGE - 100

CITY	CONSTRUCTION COST JAN. 80 $INDEX	CONSTRUCTION COST PERCENT CHANGE FROM LAST MONTH	CONSTRUCTION COST PERCENT CHANGE FROM LAST YEAR	BUILDING COST JAN. 80 $INDEX	BUILDING COST PERCENT CHANGE FROM LAST MONTH	BUILDING COST PERCENT CHANGE FROM LAST YEAR
Atlanta....................	2,364.56	-0.8	+10.7	1,616.13	-1.2	+10.1
Baltimore..................	2,719.35	0	+13.5	1,821.34	0	+11.2
Birmingham.................	2,386.12	-1.9	+5.4	1,656.13	-2.7	+8.4
Boston.....................	3,071.68	-0.8	+10.8	1,881.54	-1.1	+8.2
Chicago....................	3,255.91	-0.3	+8.0	1,942.99	-0.6	+7.2
Cincinnati.................	3,349.06	0	+8.0	1,967.81	+0.4	+8.7
Cleveland..................	3,548.99	-0.5	+8.6	1,946.21	-0.8	+7.6
Dallas.....................	2,404.39	-0.9	+15.4	1,719.71	-1.3	+10.5
Denver.....................	2,771.23	+1.2	+8.0	1,793.92	-2.1	+6.0
Detroit....................	3,492.88	0	+8.4	2,043.37	0	+9.4
Kansas City................	3,219.28	+1.1	+5.9	1,867.88	-2.0	+6.4
Los Angeles................	3,630.12	-0.2	+7.7	2,057.17	-0.4	+7.3
Minneapolis................	3,139.11	-0.5	+7.9	1,877.66	-0.8	+8.5
New Orleans................	2,671.05	-0.8	+13.8	1,716.59	-1.3	+9.6
New York...................	3,596.82	+0.5	+8.1	2,113.61	+1.0	+11.9
Philadelphia...............	3,183.94	0	+12.1	1,974.89	0	+16.4
Pittsburgh.................	3,180.58	0	+8.4	1,975.64	0	+10.0
St. Louis..................	3,344.21	0	+7.5	1,845.81	0	+11.1
San Francisco..............	3,806.14	0	+8.4	2,228.05	0	+9.3
Seattle....................	3,495.81	-0.1	+9.3	1,893.61	-0.1	+7.3
U.S.-20 Cities' avg.....	3,131.58	-0.3	+9.1	1,897.49	+0.6	+9.2
Montreal...................	3,055.37	+0.6	+11.8	1,888.18	+1.0	+13.4
Toronto....................	3,331,71	-0.1	+7.1	1,850.11	-0.2	+7.8

The vehicle technology varies from site to site depending upon the requirement of the particular location. Westinghouse vehicles deployed at six sites included in this report are similar in size, type of propulsion, and steering mechanisms, but interior design (presence of seats etc.), switching capabilities, and number of motors per vehicle may vary, depending upon site requirements.

Although some manufacturers remain reluctant to disclose cost information on their hardware, sufficient data are available to perform some analysis. As shown in the Supplement I report, a correlation between vehicle cost and equivalent passenger places produced data points too scattered to establish a definitive trend. In Figure 4-6, a correlation is made between vehicle cost and empty vehicle weight from which a trend has been established. This representation proves to be good since the empty vehicle weight represents the materials purchased.

4.4 COMPARISON WITH OTHER MODES

A major difficulty in comparing the capital cost of AGT systems to conventional transit is dealing with the issue of what type and amount of service is provided for the money involved. Many measures are available to compare service levels. One such measure, which was used in last year's report, is traffic density which represents the number of place miles (vehicle miles x places per vehicle) distributed over the length of the system on an annual basis. Figure 4-7 presents travel densities for the various systems and modes plotted versus a total system cost per equivalent elevated route mile. A bar for each mode is shown which indicates an unweighted average of the systems involved in a given mode. Also presented on the plot are the points representing each of the systems for each mode. In the case of the busway systems, only the Shirley Highway busway system in Washington, DC was used.

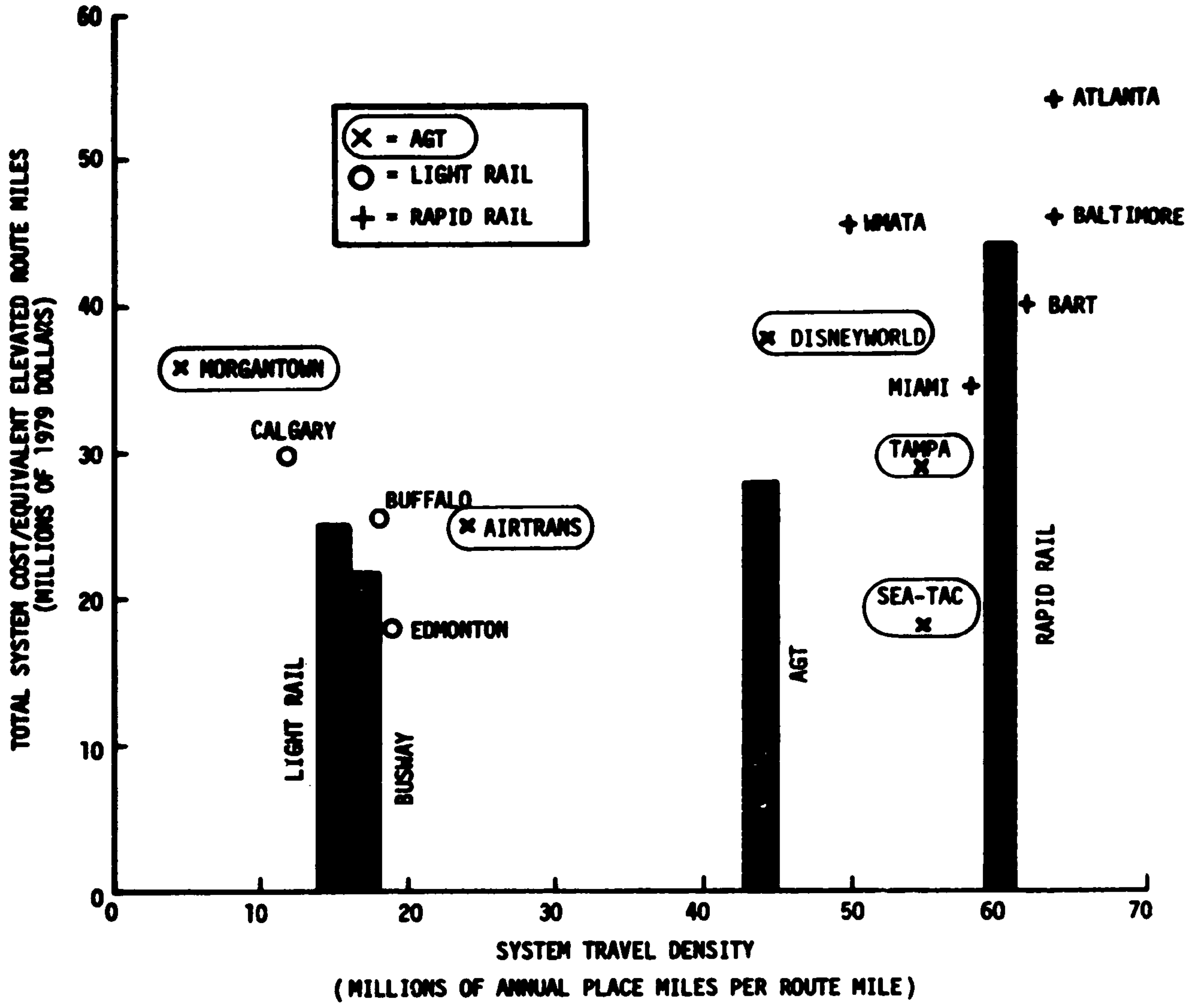


FIGURE 4-7. TOTAL SYSTEM UNIT COST VS. SYSTEM TRAVEL DENSITY

FIGURE 4-7 NOTES:

- Morgantown is shown on the chart, but not included in average since it was not operating last year.
- All averages are unweighted.
- Rapid and light rail data points have been adjusted to reflect most recent estimates.
- The average capital cost of the 4 major AGT systems per equivalent route mile was $27.8 million in 1979 dollars. This is quite comparable to the cost for 3 recent light rail systems for which cost data was available. For the 5 newest rapid rail transit systems WMATA, BART, ATLANTA, BALTIMORE and MIAMI, the average capital cost per equivalent route mile is $44.0 million.
- Lowest in capital cost on a route mile basis was the Shirley Highway exclusive busway serving the Washington, D.C. suburbs, which averaged $22.0 million.
- Actual route miles were adjusted uniformly by applying an 0.4 factor for surface or at-grade mileage and a 3.0 factor for underground distances. For AGT, which involves substantial ramps, test loops, etc., equivalent route miles were estimated by dividing total equivalent elevated lane miles by 2.2.
- The position of each bar on the horizontal scale indicates the systemwide service capacity provided for each of the four modes, expressed in place miles per route mile per year. For comparison purposes, vehicle capacities were calculated on the basis of 4 sq. ft. of gross area per passenger. Annual mileage was either obtained from operating records or estimated on the basis of the size of the proposed vehicle fleet and overall averages for rapid rail (44,753 vehicle miles per vehicle owned per year) and light rail (22,480 vehicle miles per vehicle owned per year) developed from the APTA Transit Operating report.
- Whereas AGT and light rail capital costs were approximately equal, the AGT systems surveyed provided greater service capacity. Thus, for the same average capital cost, the AGT systems operated almost three times more passenger place miles over each mile of route than the light rail systems.
- Note that all rapid rail and light rail systems are clustered near the mean, while AGT systems provide a wider range of service capability.

As expected, rapid rail systems represent the most expensive of the permanent guideway modes, and also provide the highest level of travel density due to long trains moving at fairly high speeds and frequent intervals. Light rail is considerably less capital intensive than rapid rail, but the travel density provided is quite low. The interesting feature of the plot is the spread of the AGT systems data which almost encompass, in terms of travel density, all of the other modes, but at an average cost figure, comparable to light rail and bus, This feature demonstrates the flexibility and adaptability of AGT to the transportation regimes traditionally occupied by conventional transit and at a comparable cost.

Figure 4-8 compares the capital cost distribution of the existing AGT systems to cost distributions from actual construction experience with three rapid rail transit systems. Categories used for breakdown of the rapid rail costs vary somewhat from one system to another and reflect the nature of the project in addition to the difference in cost information detail available from each system. In the case of the MBTA information, for example, the construction is currently in progress, thus the need for a contingency category; also the project is strictly a construction one, thus no vehicle category is shown.

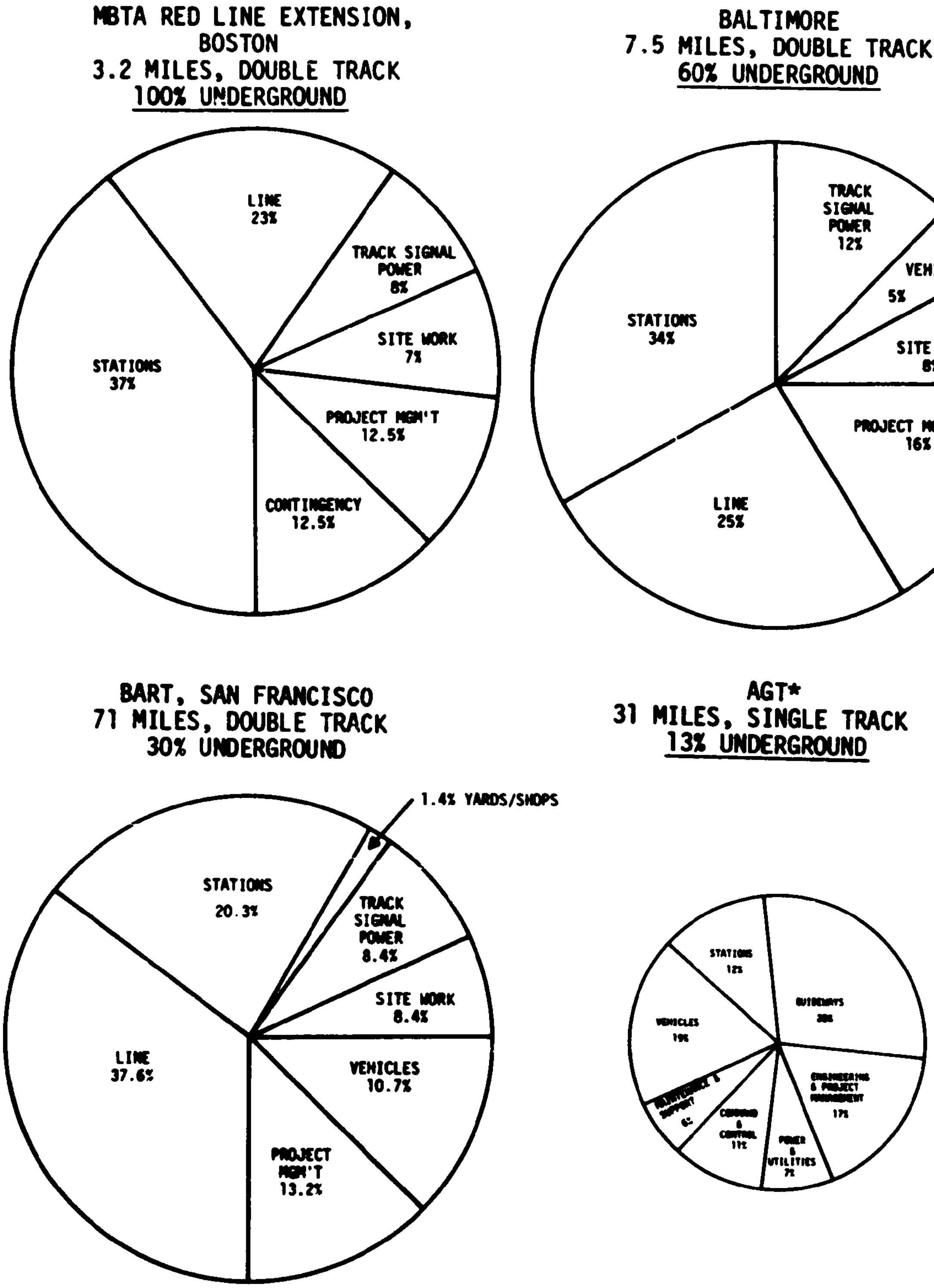
Some pertinent information about each of the three rapid rail projects is shown below:

MBTA-RED LINE EXTENSION

3.2 Miles, double-track, underground

4 Underground stations currently under construction

434 Millions of '79 Dollars



* Radius of pie chart is proportioned to the total system cost per equivalent lane mile.

FIGURE 4-8. COMPARISON OF CAPITAL COST DISTRIBUTION - AGT VS. RAPID RAIL

BALTIMORE

7.5 Miles, double-track, (2.5 elev., 1.0 at-grade 4.0 tunneled)

6 Undergoun⁴ stations

3 Aerial stations

56 Vehicles

714 Millions of '79 Dollars

BART

71 Miles; double-track (24 elev., 27 at-grade, 20 tunneled)

34 Stations

450 Vehicles

3,859 Millions of '79 Dollars

The higher percentage of cost for conventional transit stations is not surprising, considering that many are underground, larger and more elaborate than an AGT type station. Vehicle cost percentage differences reflect the much larger dollar volume being spent on the fixed facilities for conventional transit and, thus, the lower percentage for vehicles.

5. OPERATING AND MAINTENANCE COSTS

5.1 INTRODUCTION

This section presents 1979 cost and performance information on the operation and maintenance of existing AGT systems. Data have been compiled and analyzed for four of the five major operating AGT systems in this country. (No 1979 operating data is presented for the Morgantown System due to the system being shut down during most of 1979 for modification and expansion.) These four systems represent more that 85 percent of the vehicle miles traveled by AGT systems in the United States.

	Active Vehicle Fleet Size	Vehicle Miles Traveled in 1979
Airtrans	51	3,358,000
Sea-Tac	12	528,500
Tampa	8	412,000
Disneyworld	30	621,000
Total	101	4,919,500

These systems have all been operating for over four years, permitting analysis of trends in operating cost over time, as well as breakdowns of operating cost by category, such as labor, materials, utilities, etc. Three of the four systems are located at airports, while the fourth system, is located at Disneyworld in Florida.

When comparing the 1979 O&M costs for AGT systems with the 1978 data for both AGT and conventional transit, the Consumer Price Index (CPI) for urban wage earners and clerical workers in the United States was used to adjust the pre 1979 costs to 1979 dollars. Conventional transit operating cost data for 1979 were not yet available at the time of preparation of this report.

5.2 O&M COST EXHIBITS

A summary of operations and maintenance costs for 1979 is shown in Table 5-1 along with other pertinent operating information. In order to consistently compare place miles provided and unit costs based on vehicle capacity, an equivalent vehicle capacity is used which allocates 33 percent of the available floor space to seated passengers and 67 percent to standing passengers. O&M costs for each system are normalized by several operating parameters.

A breakdown of 1979 O&M costs is shown in Table 5-2 and are separated into the same four major categories as in the previous reports. A further disaggregation within these categories is included when the information was available. Figure 5-1 presents the collective distribution of these data for the four systems for 1979 and indicates a general consistency with previous years.

Figures 5-2 through 5-6 present the O&M cost, the vehicle miles traveled, and O&M cost per mile traveled, per vehicle and per employee in bar-chart form for the year 1979. Fleet size for the four systems remained the same as in 1978. Although total vehicle miles were slightly down from 1978 (≈ 4%) due to Disneyworld and Airtrans, the average cost per mile traveled was also down, which is probably attributable to increasing maturity and experience with the systems.

When analyzing O&M costs per vehicle mile, it should be understood that certain components of the O&M cost vary as a function of the number of miles accumulated on the vehicles while other components represent fixed costs that are independent of vehicle mileage. Cost components (see Figure 5-2) that vary with vehicle mileage are related primarily to maintenance of the system (maintenance labor, spare parts, and materials); in addition, a significant portion of the utility cost is related to power used for vehicle propulsion and is therefore dependent on vehicle miles also. Fixed costs are those components normally associated with operation and administration of the system as well as those utility costs associated with the housekeeping power of the system (lights, communication). For those systems having guideway heating systems such as Morgantown, another variation is introduced into the O&M cost each year, dependent on the severity of the winter environment.

Vehicle mileage and O&M cost trends over the last four years (1976-1979) are depicted in Figures 5-7 through 5-9. All costs are adjusted to 1979 price levels, using the Consumer Price Index, so that trends are distinguishable from inflationary increases over this period. O&M information was available from 1975 to 1978 for the Morgantown system, but not for 1979; thus it has been omitted for consistency reasons from the curve representing the average. The O&M cost trend per vehicle mile, particularly for the Sea-Tac system, continued downward in 1979 as shown in Figure 5-9.

TABLE 5-1. 1979 OPERATIONS AND MAINTENANCE SUMMARY[1]

	AIRTRANS (A)	TAMPA (T)	SEA-TAC (ST)	DISNEYWORLD (D)	4 SYSTEMS (TOTAL)	4 SYSTEMS (AVERAGE)
TOTAL O&M COST ($)	3,297,000	571,500	719,700	303,300	4,891,500	1,222,875
VEHICLE MILES TRAVELED (VMT)[2]	3,358,000[3]	412,000[4]	528,500	621,100	4,919,600	1,229,900
ACTIVE VEHICLE FLEET/EQUIVALENT VEHICLE CAPACITY[5]	51/42[6]	8/81	12/81	30/29	101/233	25/58
ACTIVE FLEET CAPACITY (places)	2142	648	972	870	4632	1158
PLACE MILES TRAVELED	141,900,000	33,400,000	42,800,000	18,000,000	235,200,000	58,800,000
PASSENGERS CARRIED	6,745,300	16,356,000[7]	7,011,830	5,017,203	35,130,333	8,782,583
TOTAL NO. OF EMPLOYEES	107	7	19	12	145	36
O&M COST PER VMT ($)	.98	1.39	1.36	.49	N/A	.99
O&M COST PER VEHICLE OPERATED ($)	64,600	71,400	60,000	10,110	N/A	48,915
O&M COST PER UNIT OF FLEET CAPACITY ($)	1539	882	740	349	N/A	1056
O&M COST PER PLACE MILE ($)	.023	.017	.017	.017	N/A	.021
O&M COST PER PASSENGER ($)	.49	.03	.10	.06	N/A	.14
O&M COST PER EMPLOYEE ($)	30,800	81,600	37,900	25,300	N/A	33,969
EMPLOYEES PER VEHICLE	2.1	.88	1.58	.4	N/A	1.44
PLACE MILES PER EMPLOYEE	1,318,000	4,711,000	2,253,000	1,500,000	N/A	1,633,333

TABLE 5-1 NOTES:

(1) The Morgantown system is not included in this year's O&M cost summary since the system was shut down for Phase II expansion from July 1978 to Sept. 1979.

(2) Figure for Disneyworld reflects train miles, since the system operates with 5-car trains.

(3) Proportion of total vehicle miles traveled by passenger vehicles.

(4) Total VMT at Tampa was not measured; it was essentially equivalent to the 1978 VMT, according to the airport authority.

(5) Equivalent vehicle capacity has been calculated on the basis of 33 percent of passengers seated and 67 percent standing, with an allowance of 4.5 square feet of floor space per seated passenger and 2.36 square feet per standing passenger. By use of these equivalent vehicle capacities, the passenger carrying capabilities of the four systems can be compared more realistically.

(6) Active fleet of 51 refers to passenger vehicles operated regularly. The two utility vehicles are not included in this number.

(7) Estimate based on total enplaned and deplaned passengers for airport.

COMMENTS

- The average vehicle logged approximately 48,700 miles during 1979, an increase of about 11 percent over 1978.
- The O&M cost per VMT of $0.99 for the four systems is based on a weighted average and is dominated by the Airtrans system with its large costs and accumulated mileage relative to the other systems. On an unweighted basis, the average O&M cost per VMT is $1.06.
- O&M cost per passenger indicates a wider spread among the systems than the O&M cost per VMT and is attributable to the variations in vehicle capacities and passenger load factors experienced by the four systems.
- O&M cost per place mile indicates a rather consistent level among the four systems.

TABLE 5-2. 1979 OPERATIONS AND MAINTENANCE COST BREAKDOWN(1)

	AIRTRANS	SEA-TAC	TAMPA (2)	DISNEYWORLD
LABOR				
Operations	$ 261,510	$ 81,600	$ 4,460	$135,690
Maintenance	1,614,300	410,760	11,140	37,670
UTILITIES				
Electricity	276,300	16,320	76,790	52,660
Other	-	-	-	-
MATERIALS & SERVICES				
Contract Service	-	111,830	466,300(4)	13,330
Spare Parts & Materials	895,665	99,190		46,830
GENERAL & ADMINISTRATIVE	249,225	-(3)	12,770	17,120
TOTAL (1979 Dollars)	$ 3,297,000	$719,700	$571,500	$303,300

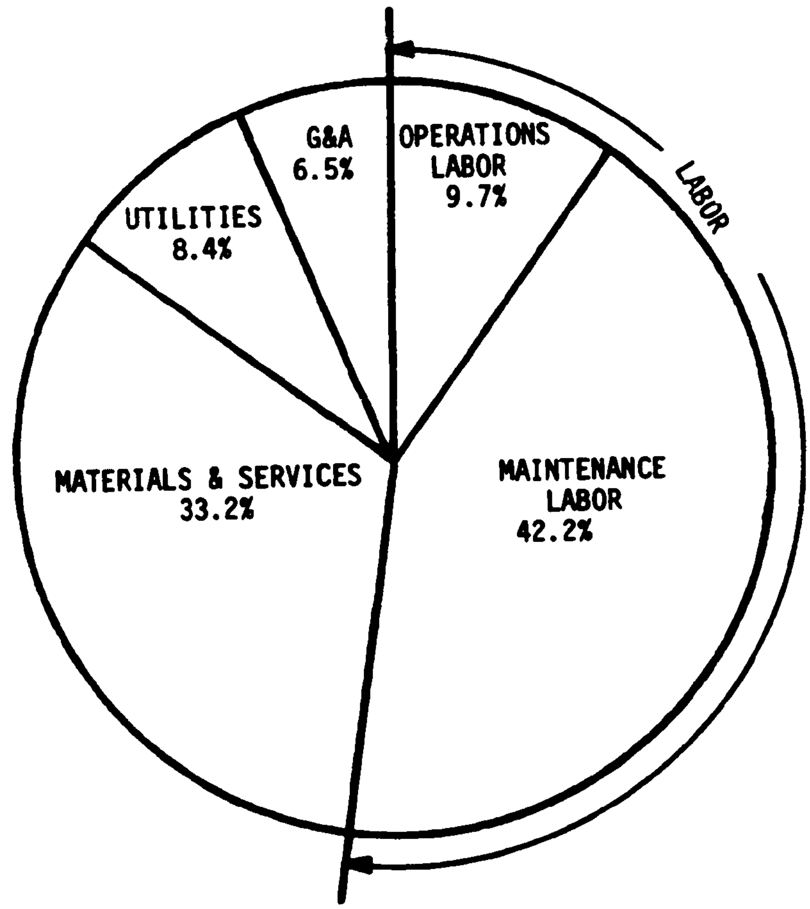
TABLE 5-2 NOTES:

(1) The Morgantown system is not included in this year's O&M cost breakdown since the system was shut down for Phase II expansion from July 1978 to Sept. 1979.

(2) All costs for Tampa were estimated by escalating 1978 values by the Consumer Price Index ratio between 1978 and 1979.

(3) For Sea-Tac G&A costs are included in other cost categories.

(4) Dollar figure shown here for Tampa represents combined costs for Contract Service and Spare Parts and Materials.



NOTES:

- o The 1979 O&M cost distribution did not change radically from the 1978 figure in last year's report. Changes that have taken place are attributable more to the absence of the Morgantown costs in the 1979 data set than to actual changes in the cost distribution of labor/materials/utilities.
- o Materials and services accounted for 33.2 percent of total expenditures. This includes spare parts and consumable supplies as well as contract services for specialty work such as motor rewinding, computer maintenance, outside cleaning services, etc. Obviously a portion of these costs involve labor, but to what extent is not known.
- o Labor comprised 51.9 percent of the total O&M cost for 1979 and is based on a total number of 145 personnel for the four systems. This amounts to about 1.4 employees per active vehicle and about $17,635 per employee per year.

FIGURE 5-1. 1979 O&M COST DISTRIBUTION FOR FOUR MAJOR AGT SYSTEMS

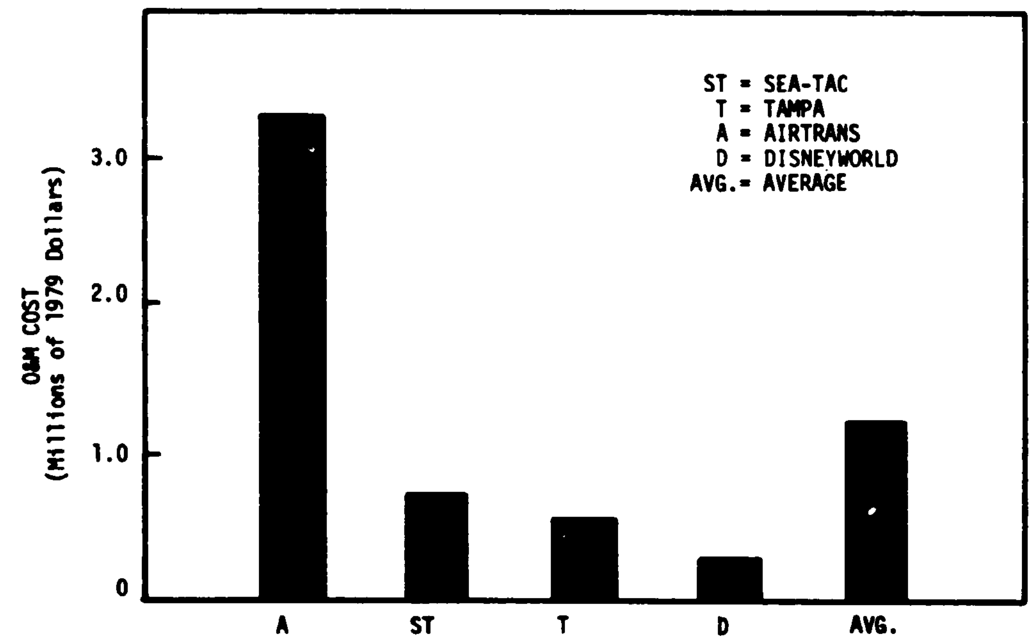


FIGURE 5-2. 1979 O&M COSTS FOR FOUR AGT SYSTEMS

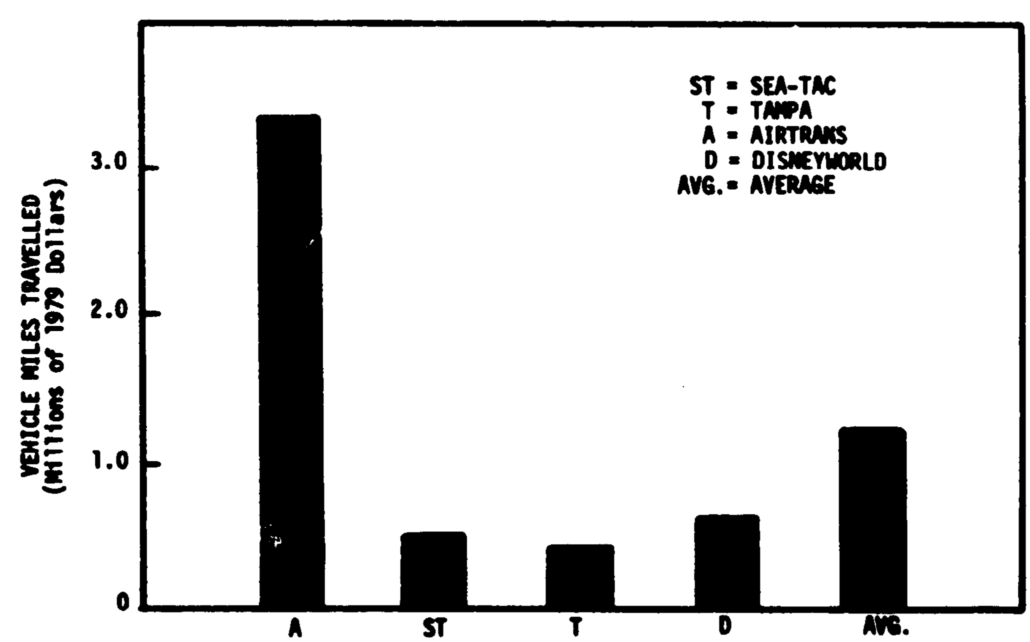
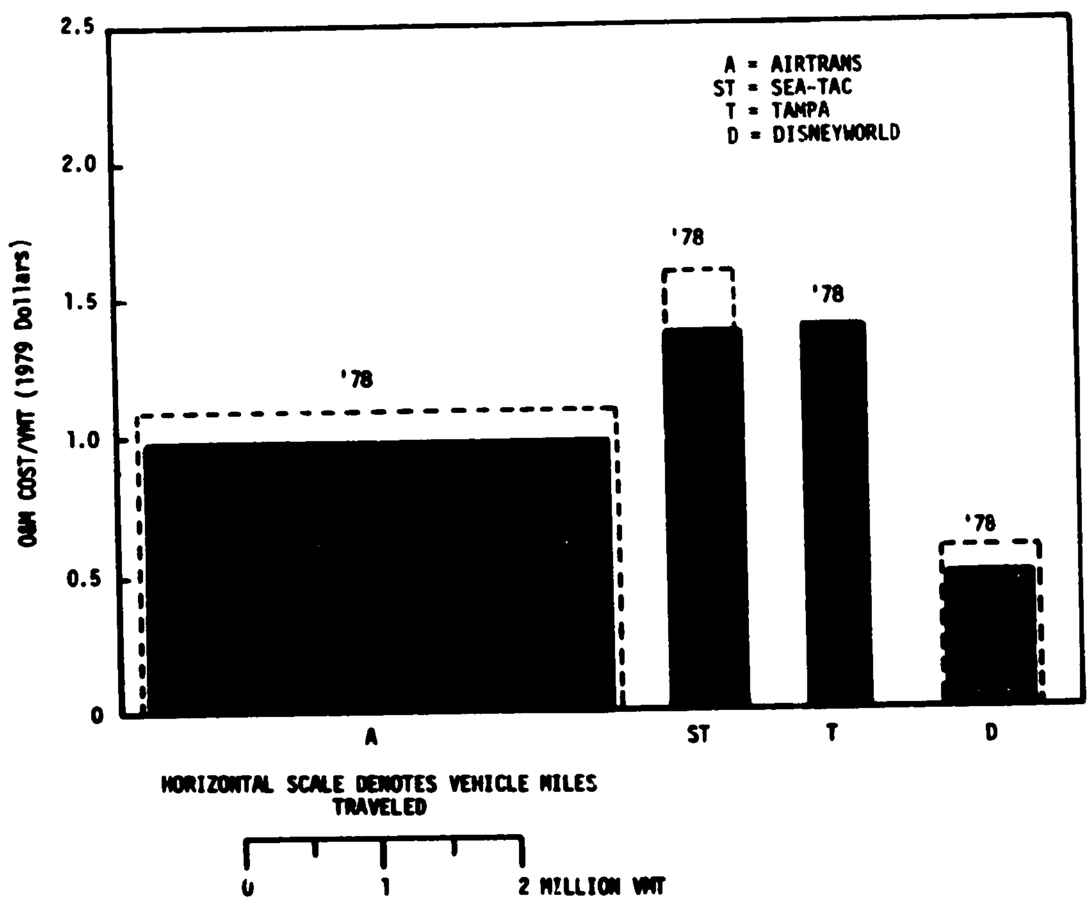


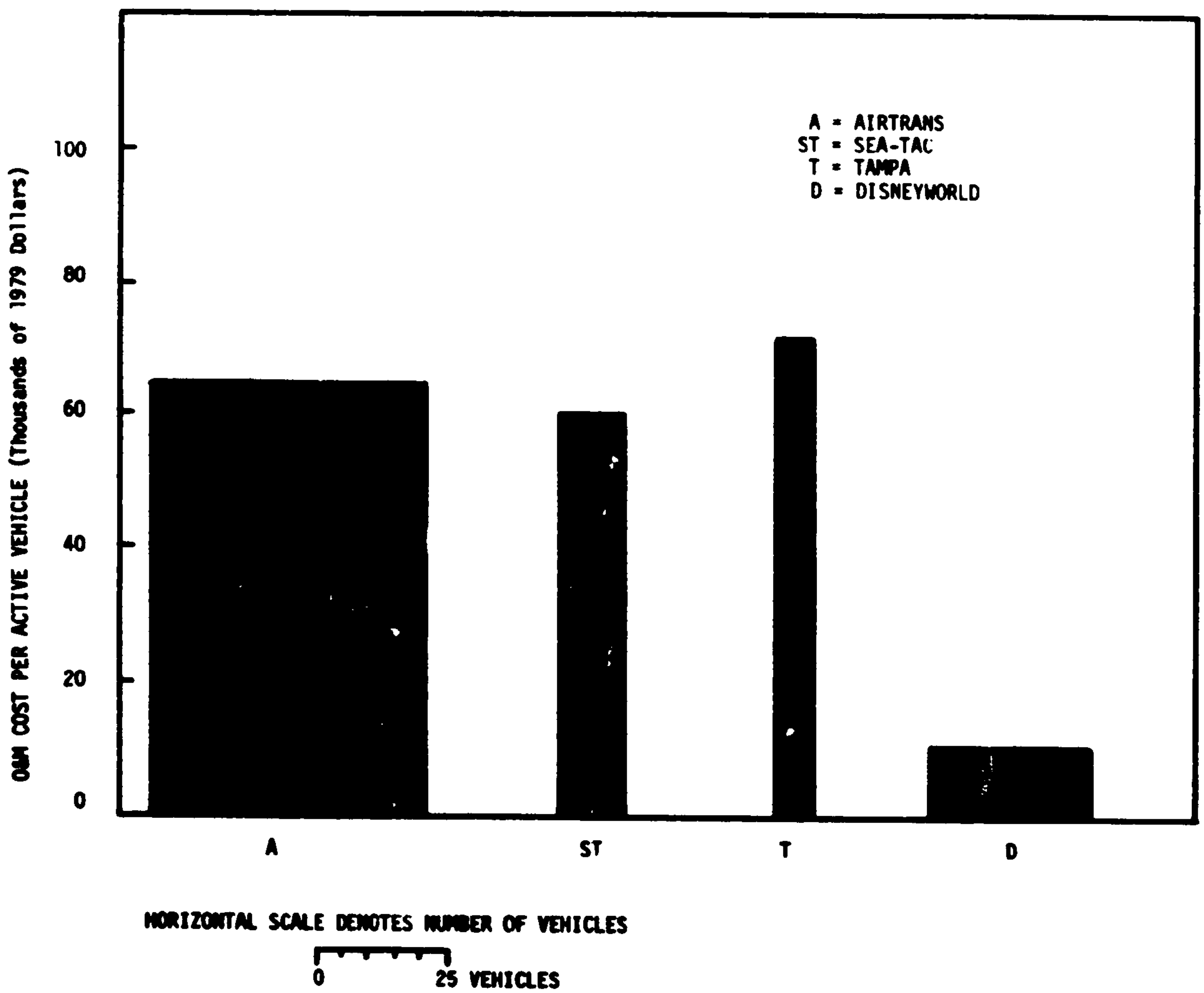
FIGURE 5-3. 1979 VEHICLE MILEAGE TRAVELED BY FOUR AGT SYSTEMS



NOTES:

- Shaded areas reflect 1979 data. Where 1978 data differs, these amounts are indicated by dotted lines.
- The shaded area of each bar is proportional to the total O&M cost for each system

FIGURE 5-4. COMPARISON OF O&M COSTS PER VEHICLE MILE TRAVELED (VMT) FOR 1979



NOTE:

- The average O&M cost per active vehicle for 1979 is $48,915 when considering all four systems. Without the small, passive vehicle systems of Disneyworld, the cost per active vehicle increases to $64,620.

FIGURE 5-5. COMPARISON OF O&M COSTS PER ACTIVE VEHICLE FOR 1979

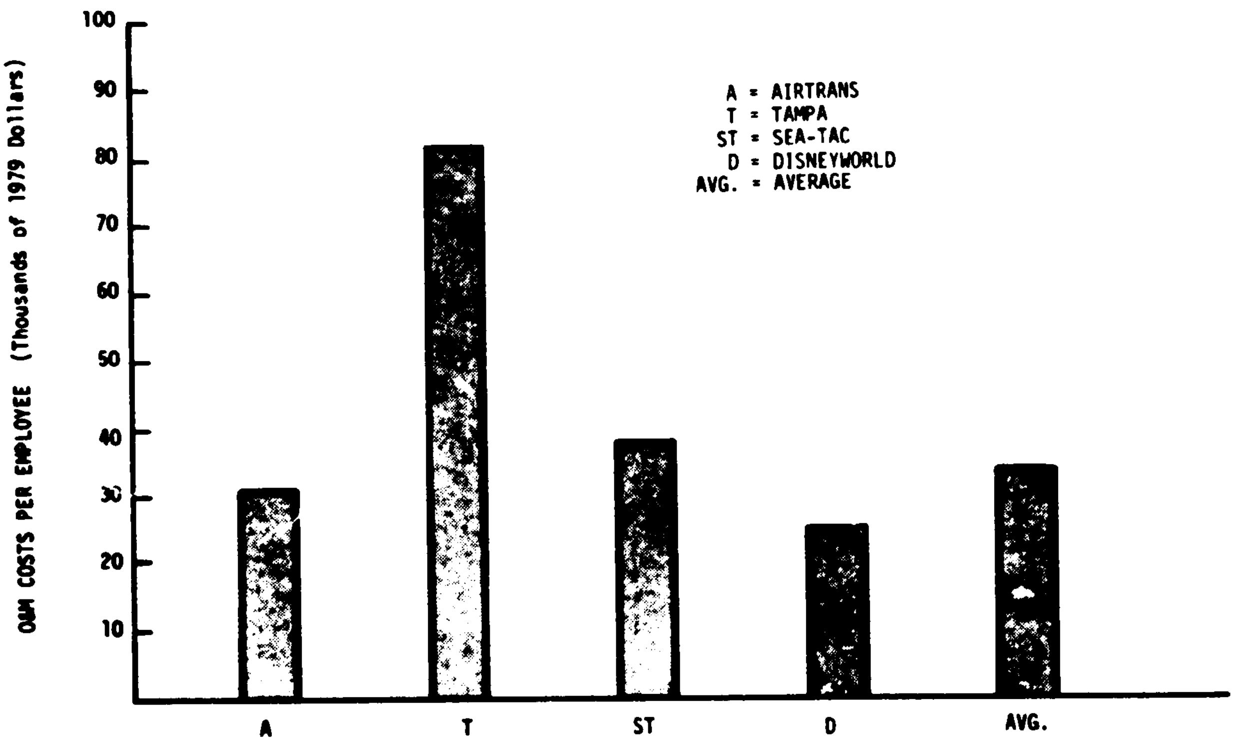


FIGURE 5-6. COMPARISON OF O&M COSTS PER EMPLOYEE FOR 1979

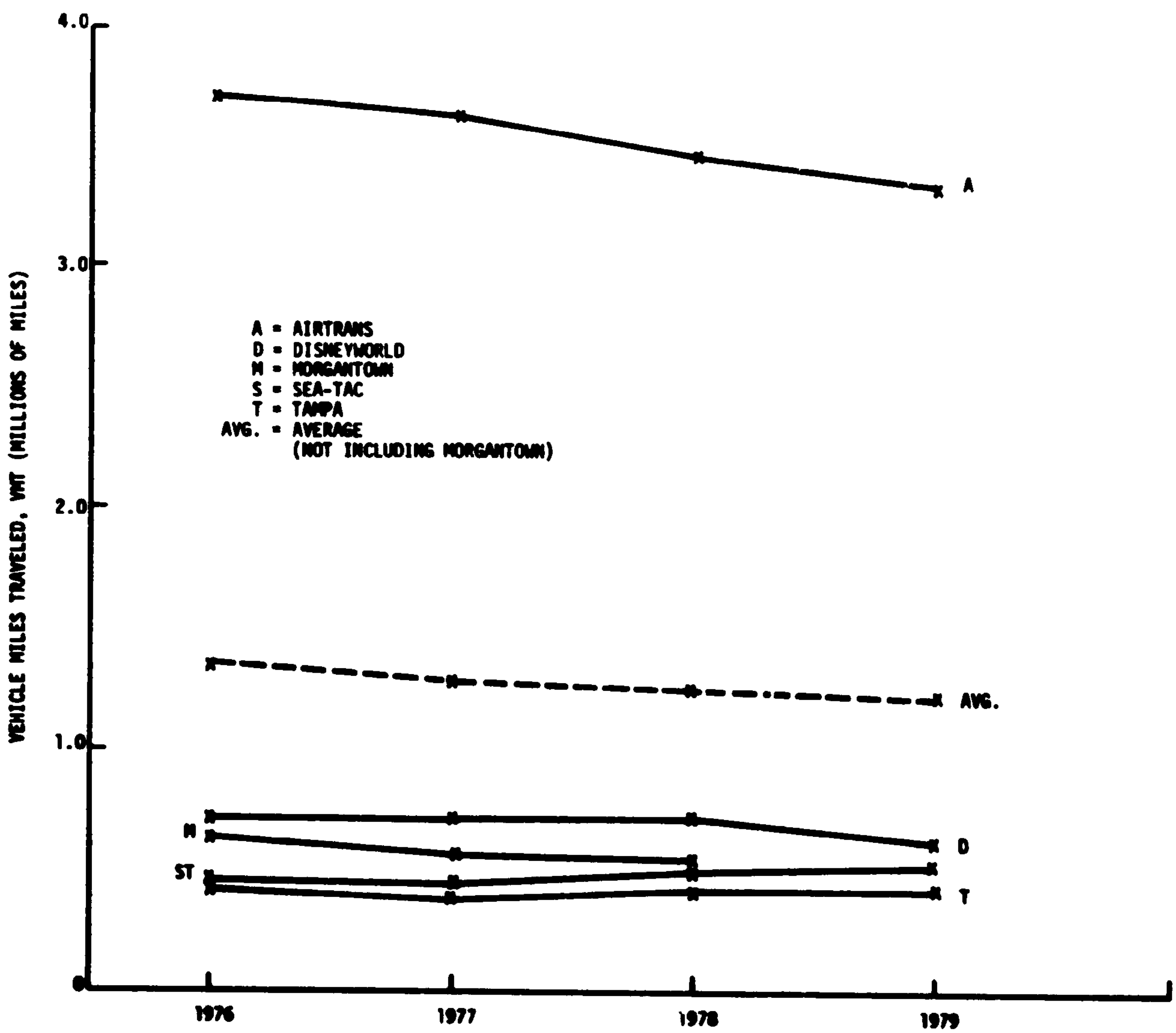
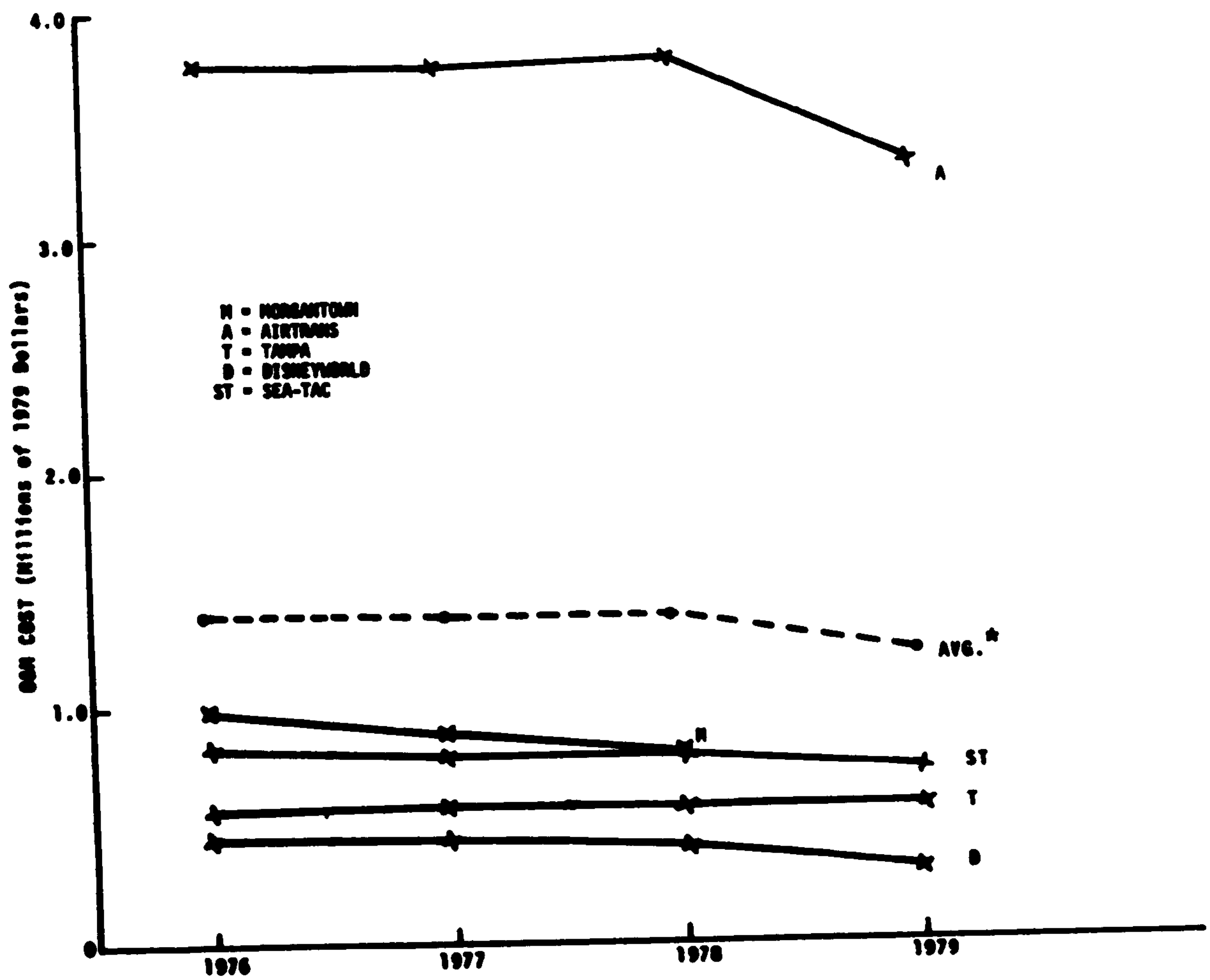
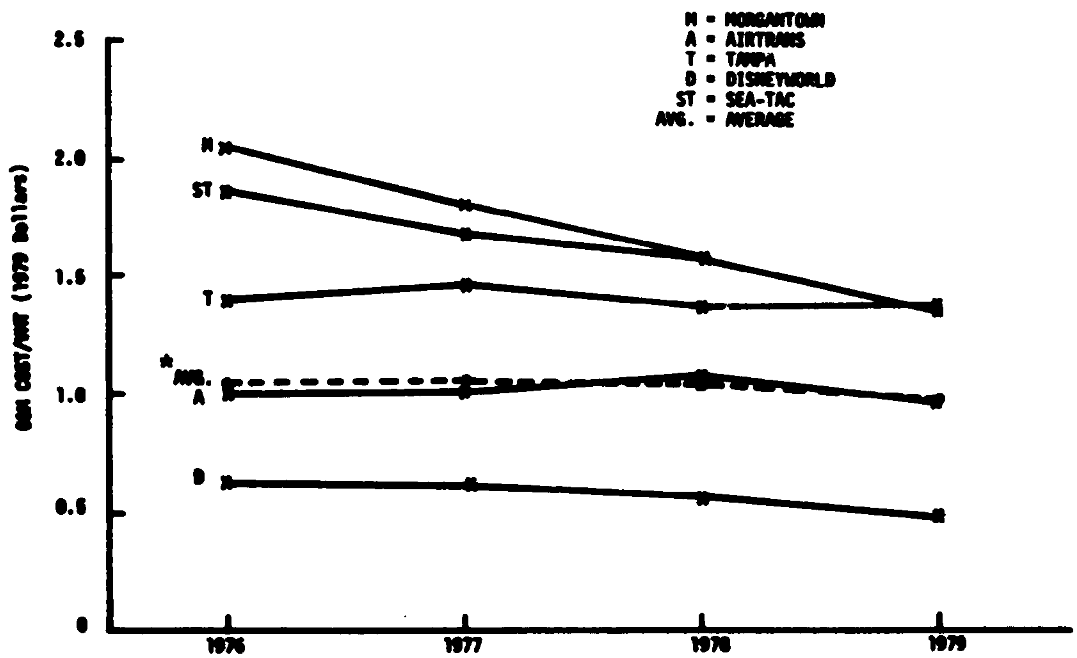


FIGURE 5-7. TREND OF VEHICLE MILES TRAVELED FOR FIVE AGT SYSTEMS



* Average does not include Morgantown.

FIGURE S-8. TREND OF O&M COSTS FOR FOUR AGT SYSTEMS



*Average does not include Morgantown.

FIGURE 5-9. TREND OF O&M COSTS PER VEHICLE MILE FOR FOUR AGT SYSTEMS

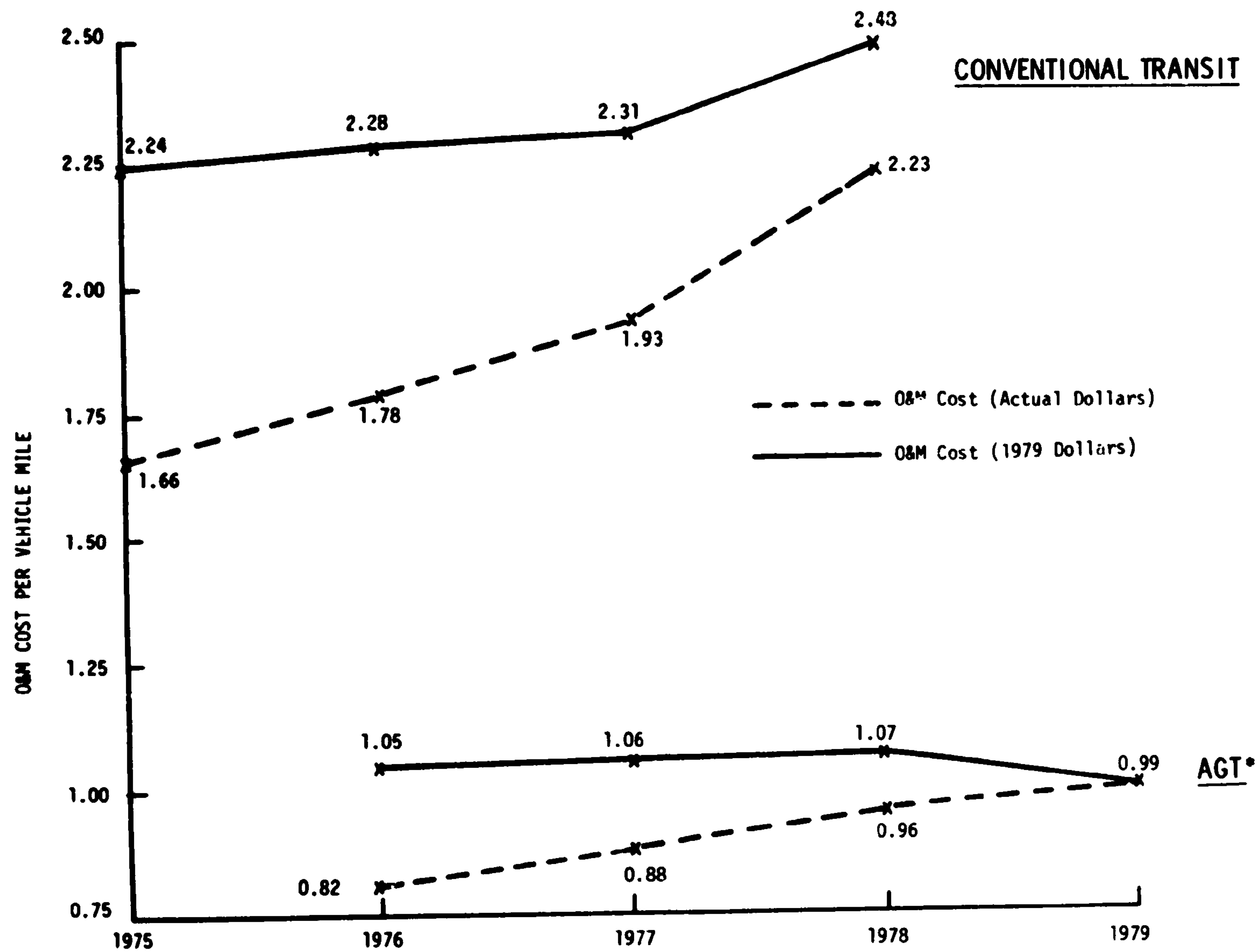
5.3 COMPARISON OF AGT AND CONVENTIONAL TRANSIT COSTS

When comparing AGT systems with conventional transportation modes in relation to operating and maintenance costs, it is important to recognize that such comparisons are relevant only when all modes provide the same type and level of service. Existing AGT systems provide circulation service in relatively small, specialized activity centers in contrast to regional or corridor service provided by existing bus and rail systems. In contrast to conventional transit systems which experience peak service periods twice a day, AGT systems provide a relatively high level of service throughout the day and tend to utilize vehicles more intensively during the day. Thus, unit vehicle operating costs are lowered for AGT due to more vehicle miles and hours being generated for their relatively small size. Therefore, it should be understood that simplified comparisons on a cost per vehicle mile basis are presented to indicate an overall contrast between the various modes.

Using available data from the American Public Transit Association for conventional transit as a yardstick, AGT system O&M unit cost data (cost per veh. mile) compares favorably as shown in Figure 5-10. The trend over time indicated by the two basic modes also show AGT with a favorable downward trend while the curve for conventional transit, steadily increases and exceeds the inflation rate (CPI) by a percent or two. When compared on a seat-mile basis in Figure 5-11, conventional transit, with a generally higher per vehicle capacity than AGT, shows a closer correlation in unit cost over time to AGT than shown in Figure 5-10. As expected, the trends over time for both modes is similar to those indicated in Figure 5-10. Figure 5-12 shows a similar comparison in bar-chart form, where conventional transit costs have been diaggregated into the three major modes of bus, light rail and rapid rail and compared to the four AGT systems. Figure 5-13 provides a comparison in O&M cost breakdown between conventional transit and AGT.

Several factors lead to the difference shown in Figure 5-10 in O&M cost per vehicle between AGT and conventional transit. A comparison of wage rates between some of the AGT systems and conventional transit systems in the same geographic area was made and although information was somewhat limited, the comparison showed that AGT system wages could be anywhere from 17 to 24 percent lower than conventional transit wages. With labor costs comprising about 50 percent of the total O&M for AGT, use of conventional transit wage levels for AGT systems would increase the average O&M cost per vehicle mile from $.99 to about $1.08.

Also, due to the limited length of the AGT guideways, lower maintenance cost per vehicle mile traveled would be possible. However, more frequent stops of an AGT system could lead to higher maintenance costs for the vehicle in terms of door, propulsion and brake cycles, and tire wear. In addition, and as a result of the marketing, planning and advertising activity that is an essential part of public transportation systems, a much larger administrative staff is required for conventional transit with an associated increase in G&A expense.



* AGT numbers do not include Morgantown System.

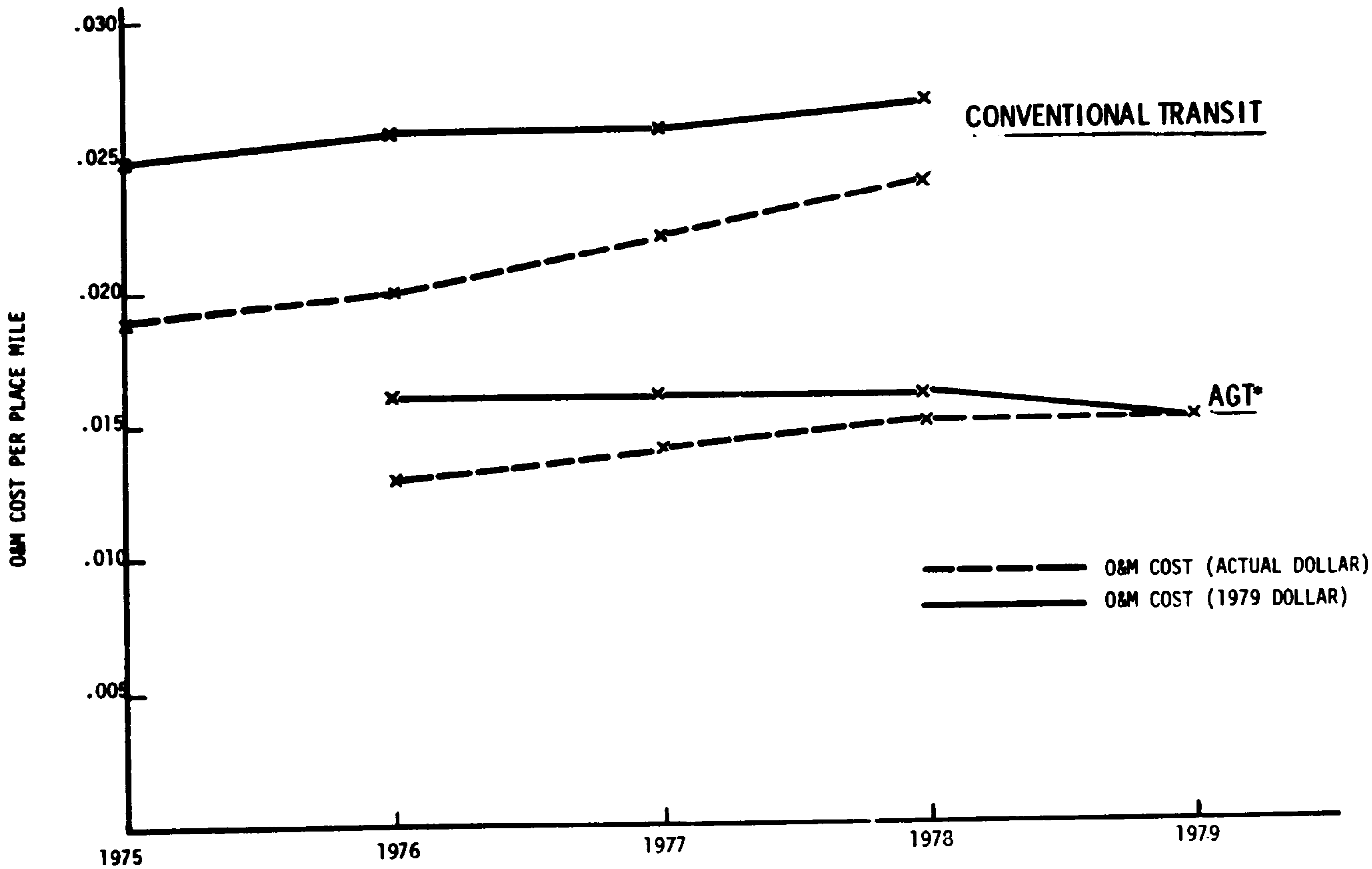
FIGURE 5-10. O&M COST TRENDS PER VEHICLE MILE FOR AGT AND CONVENTIONAL TRANSIT

FIGURE 5-10 NOTES:

- o Costs for conventional transit, i.e., bus and rail, have been adjusted to exclude amounts spent for traffic solicitation, advertising, depreciation, amortization, taxes, licenses, rents, etc., since the AGT O&M costs do not include them. Data on conventional transit cost for 1979 are not yet available.
- o Both AGT and conventional transit costs have been adjusted to 1979 price levels on the basis of CPI index as follows:

	Index	Escalation Factor
1975	161.2	1.35
1976	170.3	1.28
1977	181.5	1.17
1978	195.4	1.11
1979	217.7	

- o Conventional transit figures for 1978 were obtained from the 1978 Annual Fact Book published by the American Public Transit Association.
- o Numbers shown are based on a weighted average of the systems involved.



*AGT Numbers do not include Morgantown System.

FIGURE 5-11. O&M COST TRENDS PER PLACE MILE FOR AGT AND CONVENTIONAL TRANSIT

FIGURE 5-11 NOTES:

- Cost for conventional transit, i.e., bus and rail, have been adjusted to exclude amounts spent for traffic solication, advertising, depreciation, amortization, taxes, licenses, rents, etc., since the AGT O&M costs do not include them. Data on conventional transit cost for 1979 are not yet available.
- Both AGT and conventional transit costs have been adjusted to 1979 price levels by the CPI.
- Conventional transit figures for 1978 were obtained from the 1978 Annual Fact Book published by the American Public Transit Association.
- For purposes of comparing AGT systems to conventional transit, the capacities of vehicles were calculated on a uniform basis as follows:

gross area (length x width) ÷ 4 sq ft/passenger = Places

Information used to obtain places for conventional transit assumed the above value of 4 sq ft per place, thus AGT place values presented previously in Section 4 of this document were adjusted to reflect the 4 sq ft figure.

- Numbers shown are based on a weighted average of the systems involved.

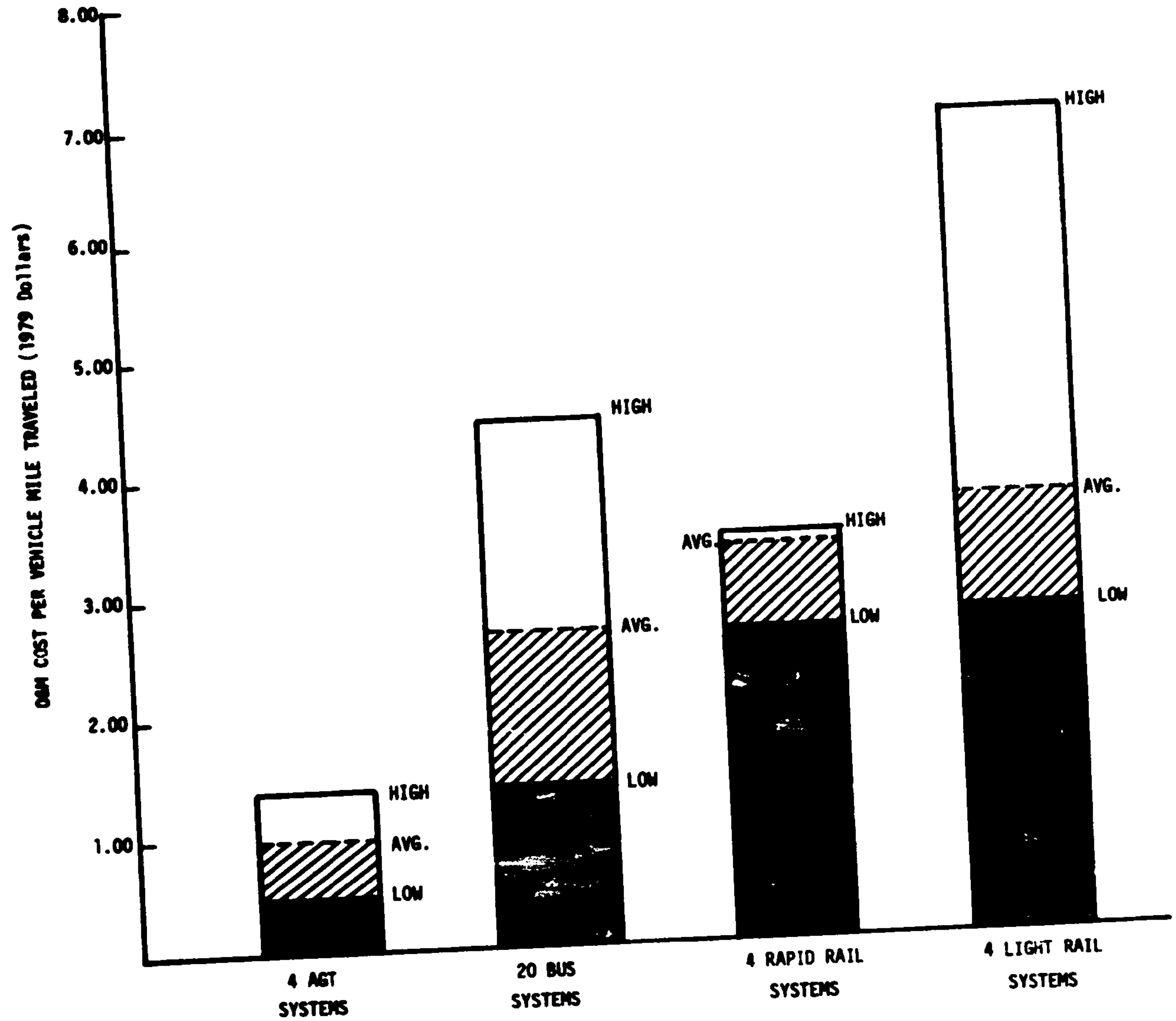


FIGURE 5-12. COMPARISON OF O&M COST PER VEHICLE MILE TRAVELED

FIGURE 5-12 NOTES:

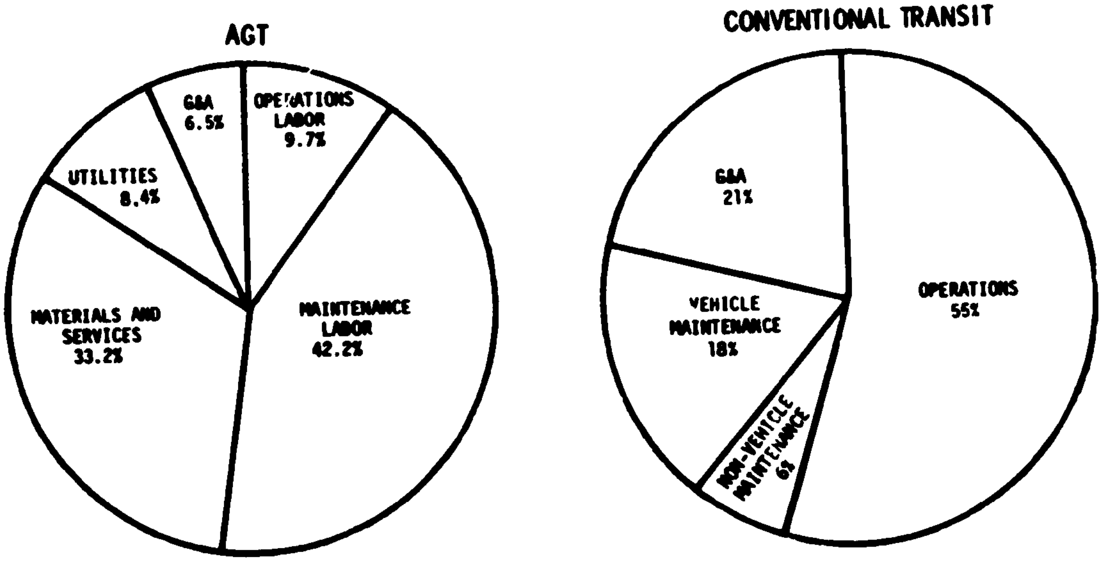
- o The average line indicated on each bar represents a weighted average of the systems included in that particular data set. The proximity of the average line to either the high line in the case of rapid rail or to the low line in the case of light rail is caused by the domination of one system in the small data set as shown below.

- o The ranges for O&M costs are as follows:

	AGT	BUS	LIGHT RAIL	RAPID RAIL
High	1.39	4.42	7.09	3.41
	Tampa	New York City	Philadelphia	New York City
Low	0.49	1.37	2.71	2.62
	Disney-world	Albany	New Orleans	PATCO

- o Conventional transit figures (bus, rapid rail and light rail) are for 1978 operations escalated to 1979 figures while AGT costs represent 1979 experience.

- o Selection of bus systems in the data set covers a range of bus properties in regards to fleet size so that costs are not biased by fleet size factor.



NOTES:

- Pie chart for conventional transit is based on cost figures in the American Public Transportation Association (APTA) Fact Book from 1978. AGT information is based on the four systems reported herein for 1979. Breakdown of costs for conventional transit is limited to the extent shown above.
- The significant contrast between AGT and conventional transit shows up, as expected, in the percentages associated with operation and maintenance. A significant difference also exists between the percentages related to G&A expenses with the difference attributable to the larger administrative staffs of conventional transit.

FIGURE 5-13. INTERMODAL COMPARISON OF O&M COST DISTRIBUTION

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