# PRELIMINARY DESIGN OF A PUBLIC TRANSPORTATION SYSTEM TO SUPPORT A THEME PARK


**By**

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## ABSTRACT

The purpose of this project was to develop the preliminary design of a public transportation system (PTS) that would support a theme park. Disney's America, a theme park originally planned for Northern Virginia, was used as the basis for this project. The problem was that the primary interstate that serves the park site was already over-crowded; this project was intended to expand the realm of possible transportation solutions to include public-transit solutions.

The following report identifies five feasible transit mode alternatives for the PTS. It shows calculations that were performed to determine various aspects of each transit system design, including headway, operating time, cycle time, number of vehicles, total number of vehicles required, and frequency of service.

This report also describes evaluation criteria that were used in the decision-making process. It presents the results of a life-cycle cost analysis that was performed as part of the evaluation of alternatives. From the alternative systems that were considered, the bus transit system was selected for the PTS.

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# SECTION 1

# INTRODUCTION

## 1.1 PROJECT OBJECTIVE

The objective of this systems engineering project is to perform the preliminary design of a public transportation system (PTS) that would support a theme park. Disney's America, a theme park planned for Northern Virginia, is used as the basis for this project. The project identifies feasible transit mode alternatives, evaluates those alternatives, and identifies a preferred system configuration.

## 1.2 BACKGROUND

The Walt Disney Company planned to build Disney's America, a history theme park, in Prince William County, Virginia. The park would have been located 35 miles west of Washington, D.C., near the town of Haymarket [17]. The site is bounded by Interstate 66 (I-66) on the south and Route 15 on the east. In addition to the theme park attractions, Disney planned hotels, a golf course, a campground, 1.9 million square feet of commercial development, and 2,281 homes for the park site [14]. Development was scheduled to begin in 1995 and end in 2010; the park was expected to open in 1998 [17].

This project is selected because of an interest in the traffic issues that relate to the projected high volume of park visitors and the park's proposed location. Six million people were expected to visit Disney's America each year [16] Furthermore, Disney predicted that 86% of the park-related traffic would use I-66 [16]. The question that begs answering is whether already over-crowded I-66 could handle the additional traffic that would be generated by the park.

Disney's solution to a possible traffic problem is that Virginia should widen segments of I-66 near the park. This approach may be a "quick fix" for traffic in the immediate vicinity of the park, but park visitors first have to get that far along the interstate.

This project represents an effort to move beyond mere speculation about a pending traffic nightmare and move beyond single-minded solutions, such as widening a section of the interstate. The project is intended to expand the realm of possible transportation solutions to include public-transit-related solutions.

During the course of this project, Disney dropped its plans to build the theme park at the Haymarket site. Work continued on the project because the approach could have been used in Prince William County and could be used elsewhere as well. As a point of interest, the Washington Post reported that Disney is keeping its land option open on the Haymarket tract [11].

## 1.3 PROJECT METHODOLOGY

Research is conducted in order to gather Disney's America data relevant to this project. Research is also done to determine the current traffic volume on I-66. The need for a PTS to serve the theme park is identified. The need is also described from the user's point of view because user needs lead to the identification of system characteristics.

A feasibility analysis is done to identify various approaches (i.e., modes of public transportation) that could be used in the design of the PTS. This involves researching public transit modes, and a complete list of references is provided in a separate section of this report.

System operational requirements are defined, then a system maintenance concept is developed that describes the anticipated support environment for the system.

A functional analysis is accomplished to identify major functions that the proposed system must perform. The functional analysis is based on the system operational requirements and the system maintenance concept. An allocation of requirements is done to the appropriate level.

Public transit mode alternatives are identified. The Logit Model (see Appendix A) is used to estimate the number of park visitors who would use public transportation if it were available. Using the results of the model, daily passenger volume and peak-hour passenger volume for the system and the stations are estimated.

Calculations related to the design of each transit system alternative are performed. The calculations determined the following aspects of each alternative system:

- *Headway*--the time between two successive departures of vehicles [10]
- *Operating Time*--the time between the departure of a vehicle from one terminal and its arrival at another terminal [10]
- *Cycle Time*--the round-trip time of a vehicle [10]
- *Number of Vehicles* --the number of vehicles needed to serve peak-hour passenger volume [10]
- *Total Number of Vehicles Required*--the number of vehicles needed to serve peak-hour passenger volume plus the number of spare vehicles [10]
- *Frequency of Service*--the number of transit vehicles passing a point on the line [10]

The amount of air pollutants (i.e., non-methane hydrocarbons, carbon monoxide, and oxides of nitrogen) that would be generated by each system alternative is calculated (see Appendix I).

Capital cost and annual operating and maintenance cost are estimated for each system. A life-cycle cost analysis is performed as part of the evaluation of alternatives, and a preferred transit system is selected.

The steps that would typically follow this preliminary system design would include detail design and development, production and/or construction, utilization and support, and phaseout and disposal. These steps in the systems engineering process are not addressed because they are beyond the scope of this project.

## 1.4 DOCUMENT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2 describes the existing highway system that serves the park site.
- Section 3 describes the proposed public transportation system. It also presents general assumptions (i.e., not specific to any particular transit mode) related to the system.
- Section 4 presents the need for a public transportation system to serve the park.
- Section 5 gives an overview of available transit modes.
- Section 6 presents the mission statement for the PTS and identifies system requirements.
- Section 7 describes the maintenance concept for the system.
- Section 8 presents the functional analysis of the system and the allocation of requirements.
- Section 9 identifies and describes alternative transit modes that were considered for use in the PTS. It includes evaluation criteria and results.
- Section 10 describes the preferred transit system for the PTS.

## SECTION 2

## THE EXISTING HIGHWAY SYSTEM

An existing highway system serves the proposed Disney's America site. I-66 is the primary highway that carries east-west travelers in the vicinity of the park. It is the highway likely to be used by Disney's America visitors coming from Washington, D.C., National Airport, Dulles International Airport, and Union Station. Some number of north-south travelers are also likely to use I-66. For example, park visitors coming from Baltimore, Maryland, could use the Capital Beltway, then I-66; visitors coming from Richmond, Virginia, could take I-95 to the Capital Beltway, then I-66 to the park site.

Route 15 is the primary road that will carry north-south travelers in the vicinity of the park. It is the route likely to be used by Disney's America visitors coming from the Frederick, Maryland, area and southern Pennsylvania.

Figure 1 shows the existing highway system that serves the proposed park site [1].

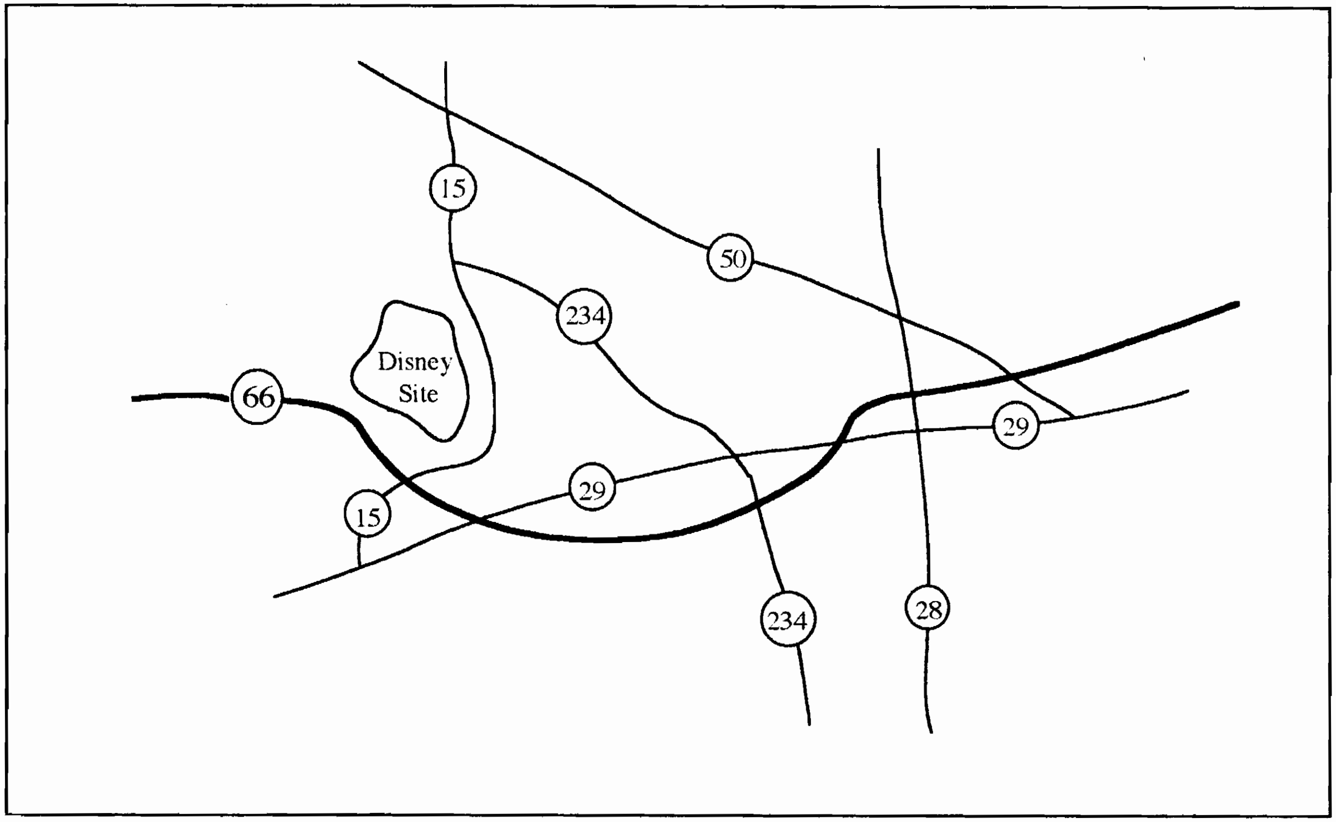



Figure 1. Existing Highway System

# SECTION 3

# THE PROPOSED PUBLIC TRANSPORTATION SYSTEM

This section describes the scope of the proposed PTS. It also presents general assumptions related to the system.

## 3.1 DEFINITIONS

For purposes of this project, a PTS is transportation service that is available, for a fare, for public use. A PTS transports passengers along set routes according to an established schedule [9].

A station is a facility at which passengers are picked up and dropped off by public transit vehicles.

Commuter rail transit is passenger railroad service that usually operates on track that is part of the railroad system [4].

## 3.2 SCOPE OF THE PROPOSED SYSTEM

The PTS is intended to serve park visitors traveling from points east of the park, although visitors coming from the northeast and southeast could use the system as well. This decision is based on Disney's prediction that 76% of the park traffic would come from the east on I-66 and 10% would come from the west on I-66, and the assumption that users of the PTS are likely to be traveling from Washington, D.C., National Airport, Dulles Airport, and Union Station--all sites that are located to the east of Disney's America [16].

Park visitors traveling from west of the Disney site are not served by the system. Public transportation systems should serve densely populated areas. The population density west of the Disney's America site is insufficient to justify the extension of the system to serve that area.

The east-most boarding point for the PTS is a station in the vicinity of the existing Vienna Metrorail station. The selection of the Vienna Metro area as the endpoint of the route is intended to allow park visitors to transfer from the existing Metrorail system to the PTS. The system has two en route stations: one in the Centreville area and one in the Manassas area. The entry point into the system for park visitors traveling from Dulles International Airport is the Centreville station. The entry point for park visitors traveling from National Airport, Union Station, and Washington is the Vienna station.

The west-most point of the system is Disney's America. A station is located at the park site. The east entrance of the park is selected as the visitor drop-off point in order to take advantage of Disney's planned private access road, which brings traffic to the park's east entrance. Since Disney operates other parks, the company has experience managing traffic flow on park grounds; this project defers to that experience.

The length of the route from the Vienna station to the park site is 21 miles, and the length of Disney's private road is assumed to be three miles [1]. Thus, the total one-way length of the transit route is 24 miles. The proposed system is shown in Figure 2.

The PTS may consist of a single transit mode or a combination of modes. If a transit mode alternative consists of vehicles that could use Disney's private access road (i.e., buses), then that system will consist of a single mode. If an alternative consists of vehicles that cannot operate on the access road (i.e., rail vehicles), than that system will consist of a combination of modes--the main-line rail vehicles to transport visitors to the rail station at the Disney site, and shuttle buses to transport them from the rail station to the park entrance via the access road.

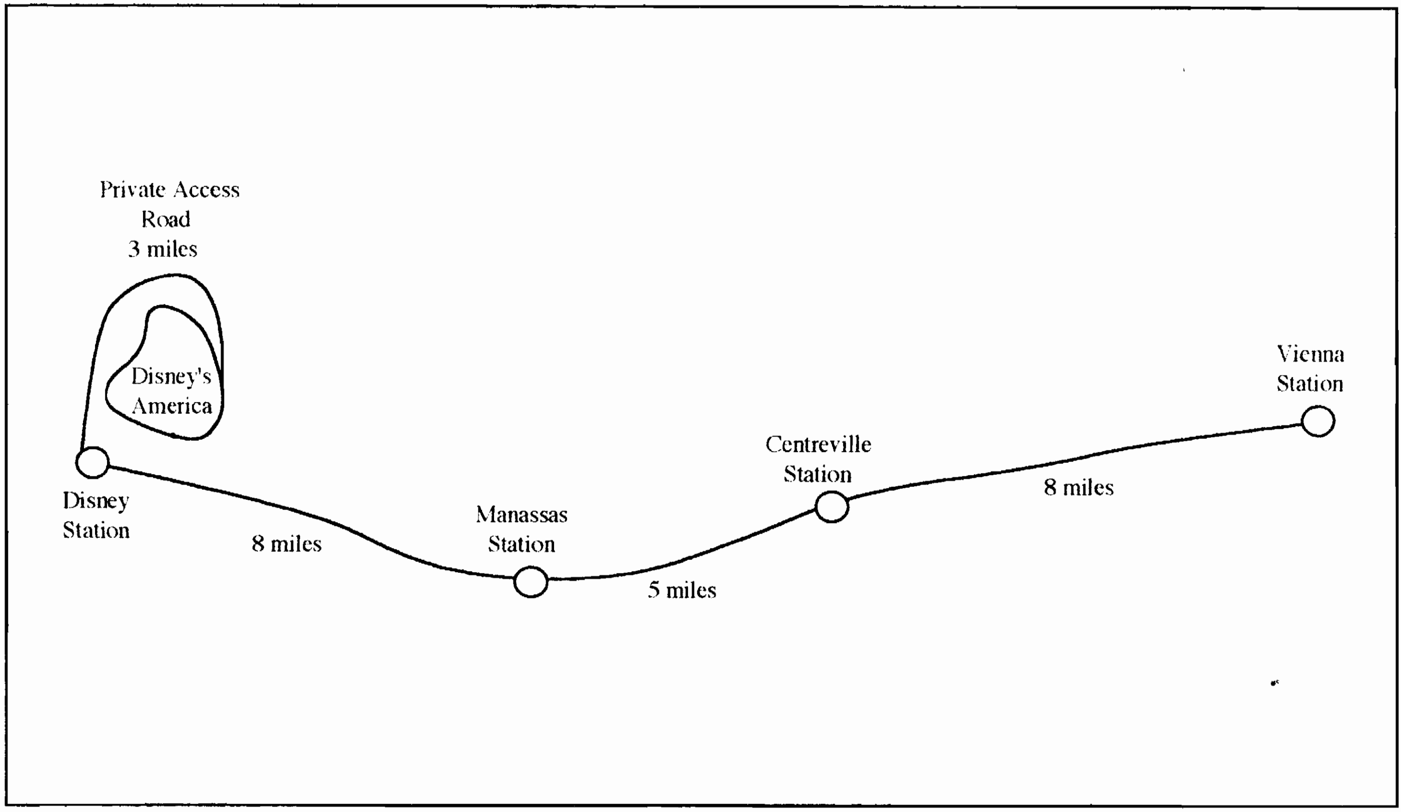



Figure 2. Scope of Proposed Public Transportation System

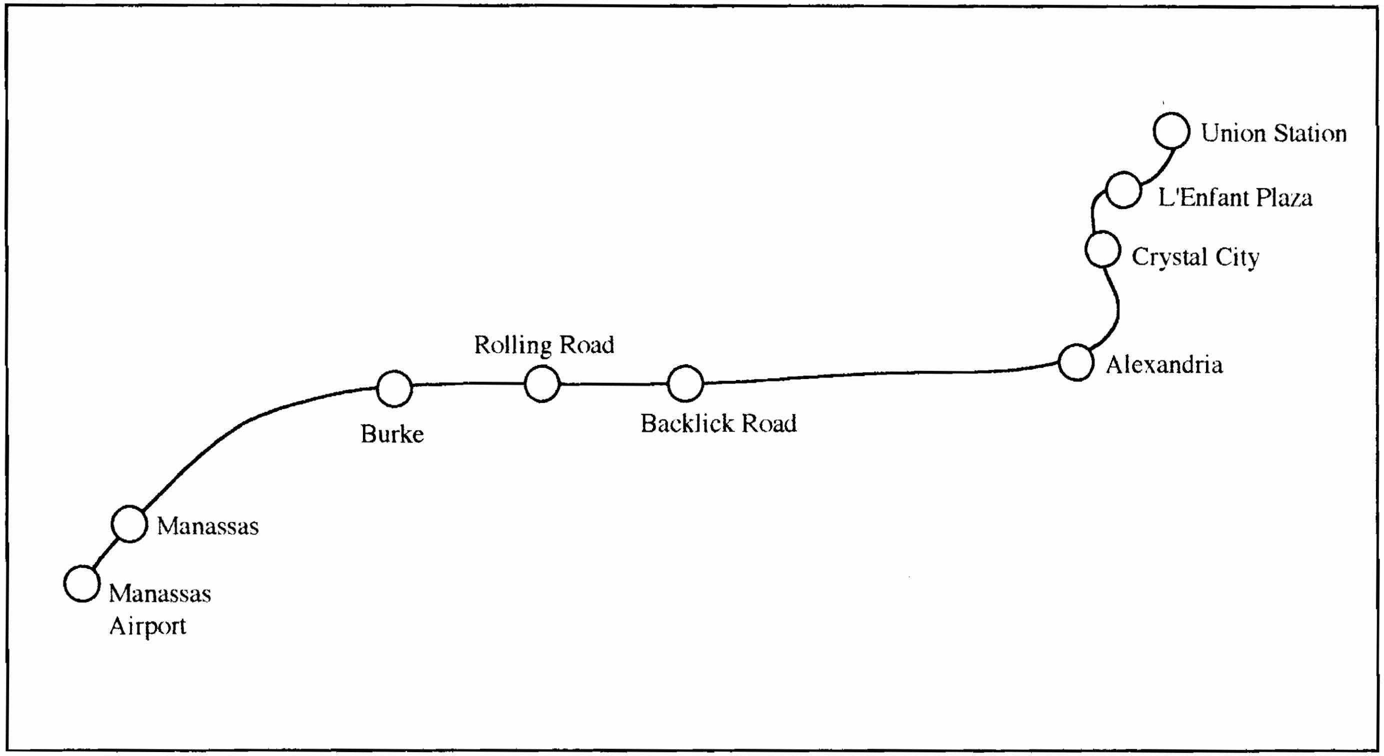
Vehicles are commercial-off-the-shelf (COTS), not custom-designed for this project. The PTS has a rail yard or bus garage for vehicle storage. The yard/garage includes a shop for vehicle maintenance and repair [9].

It would be remiss to consider the construction of a new PTS to serve the park without considering the possibility of extending an existing rail service as an alternative, even though the existing system does not include the above-proposed Vienna endpoint and Centreville station. Virginia Railway Express (VRE) operates commuter rail service from Union Station in Washington, D.C., to Manassas, Virginia. The service operates on Norfolk Southern Railroad track [4]. Although the Manassas line neither originates from nor contains the system endpoint at the Vienna station, extension of the existing commuter rail service is included as an alternative in this project for the following reasons: (1) VRE's Manassas line runs in the desired east-west direction--Union Station is farther east, in fact, than the Vienna Metrorail station; (2) the line is already operating, so the necessary infrastructure is in place; and (3) stations and park and ride facilities already exist between the line's origin at Union Station and Manassas. The west-most point of the PTS is Disney's America, and a station is located at the park site. Figure 3 shows a map of VRE's Manassas line [4].

## 3.3 GENERAL ASSUMPTIONS

The following assumptions apply to the theme park and the proposed PTS, regardless of the transit mode ultimately selected for the system. Assumptions that are specific to each particular transit mode are stated in the appendix for that mode.

1. Disney's America is open from 9:00 am until 11:00 pm. This represents peak-season hours and is based on the hours of Disney World in Orlando, Florida [19].
2. The park is open 365 days a year.




SOURCE: Commuter Rail
State-of-the-Art

Figure 3. Manassas Line of the Virginia Railway Express

3. The PTS operates from 8:00 am until 12:00 midnight; i.e., 16 hours a day.
4. The PTS operates 365 days a year.
5. Peak-hour passenger demand is used for the design of the transportation system [9].
6. The assumed peak hours of each day and anticipated ridership during each peak hour are shown below:

| | Morning | Evening |
|---|---|---|
| 8:00-9:00 | 30% | |
| 9:00-10:00 | 30% | |
| 5:00-6:00 | | 20% |
| 6:00-7:00 | | 20% |
| 9:00-10:00 | | 30% |
| 10:00-11:00 | | 30% |

   The remaining percentage of passengers will use the PTS at various other times throughout the day.
7. Except for commuter rail service, which is already operating, the PTS roughly follows the I-66 corridor.
8. Seating capacity is used for system design; i.e., standees generally are not included in design considerations when the distance to be traveled is greater than three miles [10].
9. The number of vehicles required for the system is determined by calculations shown in the appendices of this report. The total number of vehicles that should be purchased is the number of required vehicles plus 10% of that number for spares [9]. The result of calculations for spares is rounded down because scheduled maintenance (and minor corrective maintenance) will be done during the night when the system is inoperative; i.e., if calculations indicate that 34 vehicles are required, 3 spares will be added, making the total number of vehicles to be purchased for the system 37.

10. It is projected that 30,000 people will visit the park on peak days [16]. Based on the results of the Logit Model (see Appendix A), 12,600 park visitors (peak day) would use public transportation if it were available, and 17,400 visitors would use private auto.
11. Disney predicts that 86% of the park traffic will travel east-west on I-66 [16]. It is assumed that the remaining 14% of traffic will be distributed as 7% traveling from the north and 7% traveling from the south.
12. I-66 can accommodate the 10% of traffic predicted to come from west of the park site.
13. The PTS serves visitors coming from the north, south, and east; i.e., 90% of the visitors. Since 12,600 visitors per peak day would use public transit if it were available, 11,340 people will use the system. The PTS does not serve visitors traveling from west of the park site.
14. Stations are needed at various points along the route. Four stations are included in the design: one in the Vienna Metrorail area; one in the Centreville area, near the intersection of I-66 and Route 29; one in the Manassas area, near Route 234; and one at the Disney's America site.
15. Stations provide restrooms and parking facilities.
16. It is assumed that 70% of the people traveling to the park via the PTS will board at the Vienna station, 15% will board at the Centreville station, and 15% will board at the Manassas station.
17. The distance from the Vienna Metro to Disney's America is 21 miles [1].
18. The interest rate used to determine present value is 10%.
19. According to the Walt Disney Company, Disney will provide a private access road to take visitors to the park [14]. It is assumed that the length of that road is 3 miles.

20. The final destination is the east entrance of the park, to be reached via Disney's private access road.
21. The load factor ($\alpha$) used in design calculations is 0.9. This is the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]. Values for $\alpha$ usually are 0.7 to 0.9 [10]. This value of $\alpha$ (0.9) is selected for the project because fewer vehicles are needed to serve a given number of people if a high value for $\alpha$ is used.

# SECTION 4

# NEED FOR A PUBLIC TRANSPORTATION SYSTEM

## 4.1 OPERATIONAL NEED

Over-crowded I-66 is not able to handle the additional traffic that will be generated by Disney's America. This conclusion is based on the maximum capacity of I-66 and its peak-hour traffic volume.

The capacity of an interstate is discussed in terms of throughput in a one-hour period [20]. The maximum capacity of an interstate is 2,000-2,200 vehicles per lane per hour [20].

I-66 consists of four lanes from Washington to the Capital Beltway, six-lanes from the Beltway to Route 50, and four-lanes from Route 50 to the Fauquier-Prince William County border [16]. During rush hour, the shoulder of I-66 between the Beltway and Route 50 is opened to traffic, and one of the existing lanes is designated a high-occupancy vehicle (HOV) lane, thus converting that section to eight lanes. Figure 4 shows the lane variation of I-66. The figure is not drawn to scale, nor does it show the curvature of the interstate; the figure is intended to show the "bottle neck" points only.

The "rule of thumb" for estimating peak-hour traffic volume is that peak-hour volume is 10% of daily volume [20]. I-66 was designed to carry 47,300 vehicles per day, but it actually carries a daily average of 87,000 vehicles [6]. Using the rule of thumb, the peak-hour traffic volume on I-66 is 8,700 vehicles (i.e., 87,000 * .10).

The Walt Disney Company predicts that its theme park will generate 77,000 vehicle trips per day [14]. This is a conservative estimate insofar as it does not include traffic that will be generated by the inevitable businesses that will be built in the surrounding area; e.g., hotels, shopping malls, restaurants [12, 16]. In fact, a concert

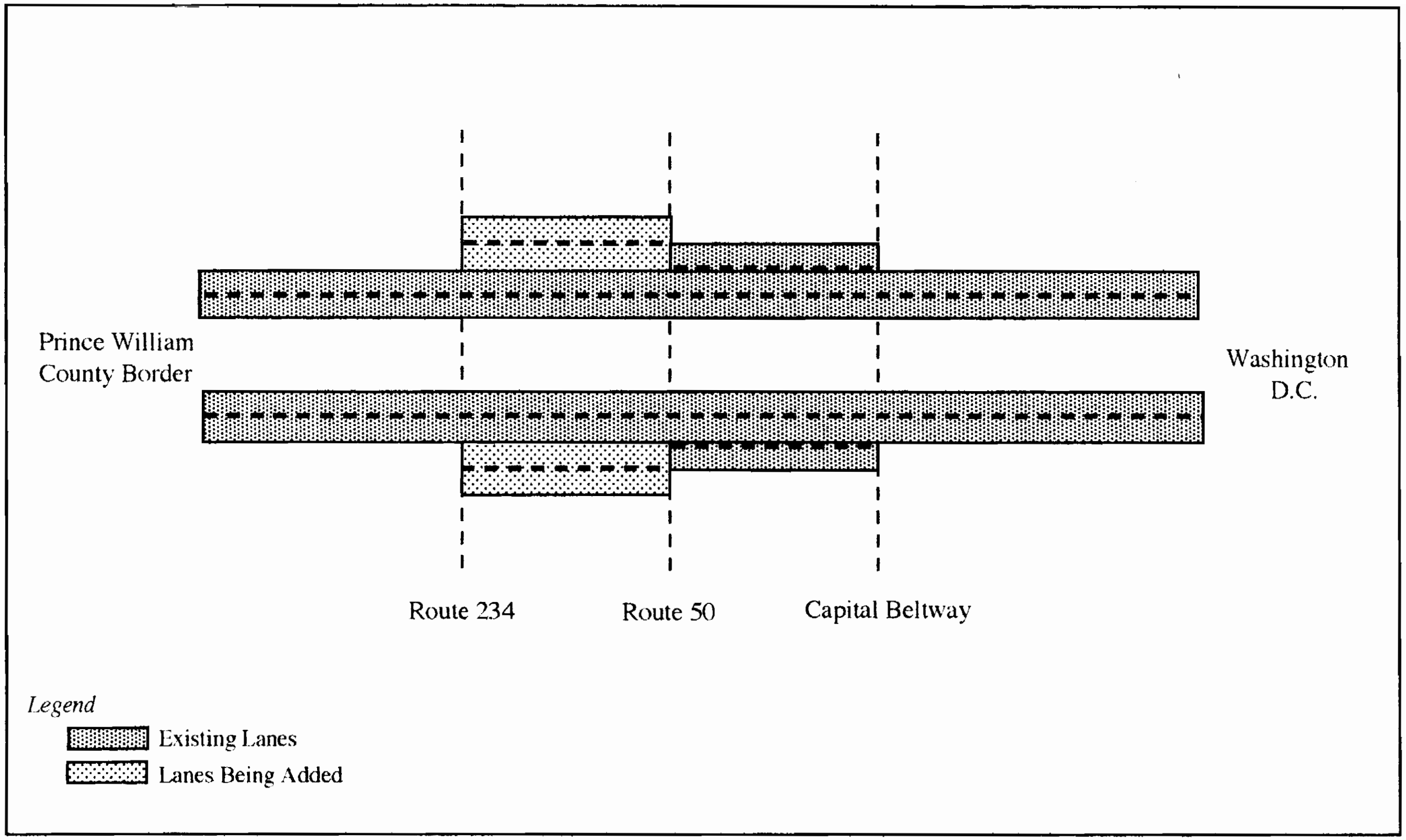



Figure 4. Lanes of I-66

amphitheater with the capacity for 21,000 people and a thoroughbred race track are already planned for the area [7].

I-66 will carry the bulk of the 77,000 park-related vehicles--Disney expects that 86% of the vehicles (66,220 vehicles) will use I-66 [16]. Using the rule of thumb, the estimated peak-hour traffic volume generated by the theme park is 6,622. Adding the park's peak-hour traffic to the interstate's existing peak-hour traffic (8,700) results in a total peak-hour volume of 15,322 vehicles. It should be noted, however, that there will be some amount of normal traffic increase on I-66 aside from park traffic; this analysis is conservative and does not include the expected normal increased traffic.

The maximum capacity of the four-lane segments of I-66 is 8,000-8,800 vehicles per hour, and the maximum capacity of the six-lane segment is 12,000-13,200 vehicles. The peak-hour volume of 15,332 vehicles exceeds the maximum capacity for those segments of interstate.

If the HOV lane from the Beltway to Route 50 is included in the analysis and is assumed to carry the same volume as the regular lanes, the maximum capacity for the eight-lane segment of I-66 is 16,000-17,600. However, traffic is exceptionally heavy from the Beltway to Route 243; the actual counted average daily traffic volume for that segment is 172,000 vehicles, so the peak-hour volume is 17,200 [16]. Overlaying the park's peak-hour volume of 6,622 vehicles on 17,200 results in a total peak-hour volume of 23,822 vehicles--well beyond the interstate's maximum capacity.

The section of I-66 between Route 50 and Route 234 is being widened from four lanes to eight lanes [6]. The capacity of the widened section (16,000-17,600 vehicles) will exceed the expected peak-hour volume of 15,322 vehicles. However, there will be a bottleneck where the lanes narrow from eight to four, and getting as far as Route 50 will be a challenge for travelers coming from points farther east.

The need for a public transportation system is indirectly supported by the Federal Clean Air Act Amendments of 1990. According to the amendments, the Washington area must achieve a 15% reduction of emissions by the year 1996 [7]. Building new highways to serve the park will allow even more vehicles to pollute the air. Disney's America is located to the west of Washington, and west-to-east blowing winds could create an undesirable increase in air pollution at a time when a decrease is mandated [7]. A public transportation system should reduce the number of vehicles on the highways and thus assist in the mandated reduction of emissions.

## 4.2 USERS' NEED

It is assumed that visitors will want to be able to travel to and from Disney's America without lengthy traffic delays. Many of the visitors will be families with young children. They will want to spend their time enjoying the park's exhibits, not trapped in a traffic jam.

A PTS that serves Disney's America would give park visitors the option of avoiding traffic gridlock. Approximately 12,600 people each day would use public transportation if it were available (see Appendix A for supporting calculations). It is assumed that park visitors would want a transportation system that meets the following needs:

- **Comfortable.** The vehicles should be air conditioned and heated, according to season. The ride should be smooth, with minimum noise [9].
- **Clean.** Floors should be washed or swept. The inside of the vehicle should be free of trash. Seats and windows should be clean. The exterior of the vehicles should be well maintained; e.g., painted.
- **Reliable.** Vehicle arrival should adhere to schedule; no lengthy waits.

- **Simple to use.** The method of fare payment should be easy. Directions to boarding areas and route information should be clear.
- **Good service frequency.** The number of vehicles serving the station should be adequate to handle the passenger volume.
- **Convenient.** Waiting areas should be protected from weather [9]. Transfers should be kept to a minimum. The walking distance from the parking area to the station should be reasonable.
- **Reasonable fare.** The amount of money required to use the system should be fair and attractive to passengers.
- **Seating.** Seats should be comfortable and of adequate size.
- **Safe.** The accident rate of the transit mode should be low. Waiting areas, walkways, and parking lots should be well lit.
- **Fast.** Travel time from boarding point to destination should be reasonable.
- **Parking facilities.** Parking should be available at the stations.
- **Restroom facilities.** Restrooms should be provided in the stations.
- **Wheelchair accessible.** The Americans with Disabilities Act (ADA) of 1990 requires that providers of public transportation equip vehicles with wheelchair lifts [9].

## SECTION 5

## OVERVIEW OF TRANSIT MODES

The application of existing technology is the chosen approach to the design of the PTS. The technology is mature; internal-combustion engines and electric motors are well established, and rail guideways have been used successfully for rail systems for more than 150 years [9].

The Metropolitan Atlanta Rapid Transit Authority (MARTA) advises agencies considering heavy rail (i.e., rail rapid transit) to purchase "state-of-the-art vehicles and tried and proven equipment" [10]. Proven equipment eliminates the possibility of overruns in development time and budget. In addition, histories, such as the maintenance history, are available for review before equipment is purchased. Review of service histories aids in understanding the risks involved with using a particular transit mode.

### 5.1 CHARACTERISTICS OF TRANSIT MODES

Transit modes are described in terms of right-of-way (ROW), technology, and type of service [9]:

- **Right-of-Way.** ROW is the land on which transit vehicles operate. There are three ROW categories [9]:
  - *Category C:* surface streets, mixed with other traffic.
  - *Category B:* physically separated, perhaps by curbs or barriers, but with grade crossings for other vehicles and pedestrians.
  - *Category A:* fully controlled, no grade crossings for other vehicles and pedestrians.

- **Technology.** This characteristic of transit modes relates to the mechanical aspect of the modes--their support, guidance, propulsion, and control [9].
- **Type of Service.** Type of service refers to the type of route served (e.g., city transit), the stopping schedule, and the time of operation [9].

## 5.2 AVAILABLE TRANSIT MODES

Several existing transit modes are appropriate for consideration in the preliminary design of the PTS: bus, light rail transit (LRT), rail rapid transit (RRT), commuter rail transit, and automated guideway transit (AGT). Following is a brief description of each mode.

- **Bus Transit**. Most buses are powered by diesel internal-combustion engines and generally operate on ROW category C [9]. Bus transit is the most common mode of public transportation in the United States [9].
- **Light Rail Transit**. LRT features electrically powered vehicles that can operate on ROW category A, B, and C [9]. LRT service may operate single vehicles or combine several vehicles into a train. Listed below are several existing LRT systems and the area that is served by each system [10]:
    - Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia
    - Sacramento Light Rail, Sacramento
    - San Diego Trolley Inc., San Diego
    - Massachusetts Bay Transportation Authority (MBTA) Green Line, Boston
- **Rail Rapid Transit**. RRT vehicles are electrically powered and operate in trains on fully controlled ROW category A [9]. Listed below are several existing RRT systems and the area that is served by each system [10]:

- Metrorail, Washington, D.C.
- Bay Area Rapid Transit District (BART), San Francisco
- Metropolitan Atlanta Rapid Transit Authority (MARTA), Atlanta
- Chicago Transit Authority (CTA), Chicago

• **Commuter Rail Transit.** Commuter rail transit is passenger railroad service that usually uses existing railroad ROW. Vehicles are powered by electricity or diesel engines [4]. Listed below are several existing commuter rail transit systems and the largest city that is served by each system [4]:
    - Long Island Rail Road (LIRR), New York
    - Metropolitan Rail (Metra), Chicago
    - Maryland Rail Commuter (MARC), Washington, D.C.
    - New Jersey Transit (NJT), New York

• **Automated Guideway Transit**. AGT vehicles operate as a single unit or in trains on exclusive guideways, which are usually elevated [9]. AGT systems use electric propulsion [9] and are fully automated; i.e., they are driverless. Listed below are several existing AGT systems [3]:
    - Dallas-Ft. Worth Airport Airtrans
    - Disney World
    - University of West Virginia
    - Miami Metromover

# SECTION 6

# SYSTEM REQUIREMENTS

## 6.1 MISSION STATEMENT

The prime operating mission of the PTS is to support Disney's America by transporting visitors to and from the park. The PTS primarily focuses on park visitors traveling from east of the park, although visitors coming from the northeast or southeast may use the system as well.

In addition to serving visitors to Disney's America, the east-west bound PTS would help alleviate traffic congestion on I-66.

## 6.2 PTS REQUIREMENTS

The following qualitative and quantitative system requirements are based on user needs (see section 4.2) and stated assumptions regarding the theme park (see section 3.3):

- The system must be capable of transporting 11,340 passengers per peak day (see Appendix A for calculations).
- The system must be capable of transporting 3,402 passengers per peak hour (see Appendix A for calculations).
- The system must be operational by 1998, the year that the park opens.
- The ride experienced by passengers should be smooth.
- The system must have good service frequency. The number of vehicles serving a station should be adequate the handle the passenger volume.
- The system should operate 16 hours per day.
- The system should operate from 8:00 a.m. until 12:00 midnight.
- The system should operate 365 days per year.

- The system must be simple to use. Fare payment should be easy. Directions to boarding areas and route information should be clear.
- The vehicles must have seats.
- The vehicles must have air conditioning and heating.
- The vehicles and stations must be clean and well maintained.
- The system must be convenient to use. Waiting areas should be protected from weather. Transfers should be kept to a minimum. The walking distance from the parking area to the station should be about 0.25 mile, or approximately a five-minute walk [10].
- The system must be safe for passengers to use. Waiting areas, walkways, and parking lots should be well lit. Care should be taken to prevent accidents.
- The system must be accessible to handicapped persons. Ramps and sloped curbs should be available. Vehicles should have wheelchair lifts.
- Transit stations must provide parking facilities and restrooms.
- Reliability for the PTS is defined as adherence to schedule. It is expressed as the percent of on-time arrivals at a station. Assume that a vehicle is considered to arrive on time if it arrives at the station within four minutes of its scheduled arrival time [10]. Reliability for RRT systems is usually 96-99%; assume that the reliability for this system is the average of the range, 97.5%, regardless of whether the chosen alternative is RRT [10].

The reliability of a system affects maintenance costs over the system's life cycle [2]. A connection exists between a system's reliability, maintenance downtime (MDT), and maintenance costs, where MDT is the total time required to repair a system and restore it to full operating status, or to retain a system at full operating status [2].

Actual data of existing transit systems are used as the basis for the O&M values in this project; these data are the reflection of the actual reliability of the existing transit modes, not the assumed reliability that is presented herein. It is recommended that future research be conducted in the area of transit mode reliability and maintenance costs.

- Availability for this system is defined as the percentage of time that a vehicle is available for service [22]. Availability of rolling stock (i.e., cars) for all rail modes is usually 92-95%; for illustrative purposes, assume that the availability for this system should be the average of the range, 93.5%, regardless of whether the chosen alternative is a rail mode [10].

  Availability is impacted by mean time between maintenance (MTBM) and MDT [2]. In the case of the PTS, availability can be positively influenced by the use of standard equipment [22]. An appropriate preventive maintenance program can also positively influence the vehicles' availability.

- The failure rate ($\lambda$) per hour is the number of failures divided by the total operating hours [2]. The failure rate per hour of vehicles in the San Diego Light Rail System is 0.019076; for illustrative purposes, assume that $\lambda$ for rail vehicles in this system is the same, regardless of whether the chosen rail alternative is light rail [22]. It is assumed that buses will fail more frequently than rail vehicles; buses have a shorter life than rail rolling stock. $\lambda$ for buses in the PTS is 0.027872; this value is based on the low end of the range of mean-time-between-failure data from the San Diego Light Rail System [22].
- Mean time between failure (MTBF) is $1/\lambda$ (assuming an exponential distribution) [2]. The MTBF of vehicles in the San Diego Light Rail System ranges from 35.90 hours to 89.64 hours; the average is 52.42 hours [22]. For illustrative purposes, assume that the MTBF for rail vehicles in this system is

the average value 52.42 hours, regardless of whether the chosen rail alternative is light rail [22]. The MTBF for buses in the PTS is 35.90 hours, which is the low end of the light rail range.

- Mean time to repair (MTTR) is the total repair time divided by the number of repairs. The MTTR for vehicles in the San Diego Light Rail System ranges from 20.4 minutes to 69 minutes; the average is 42.28 minutes [22]. For illustrative purposes, assume that the MTTR for rail vehicles in this system is the average value, 42.28 minutes, regardless of whether the chosen rail alternative is light rail [22]. The MTTR for buses in the PTS is 69 minutes, which is the high end of the light rail range.

# SECTION 7

# SYSTEM MAINTENANCE CONCEPT

The maintenance concept presented in this section includes gross maintenance activities only. The final maintenance concept for the PTS should address both corrective and preventive maintenance (see Glossary for definition of terms). Since the system is not in 24-hour-a-day operation, preventive maintenance is performed during the night. Maintenance histories are available for the PTS vehicles, which are COTS, that will aid in the identification of likely maintenance problems and the scheduling of maintenance activities. The maintenance activity descriptions in this section are "generic" because the PTS may include different types of vehicles; e.g., buses and rail transit vehicles.

Maintenance activities for the PTS take place on three levels: at the organizational level, at the intermediate level, and at the depot/producer level [2]. Examples of the types of maintenance that are performed at each level are shown below:

- **Organizational Maintenance**. Organizational maintenance is performed at the operational site. This work is performed by system operating personnel with low maintenance skill level; i.e., previous work experience is not required. The maintenance activities include, but are not limited to, the following routine servicing [9]:
  - Visual inspection
  - Checking operational performance of equipment
  - Fueling
  - Removal of farebox receipts
  - Interior cleaning of the vehicle
  - Exterior washing of the vehicle

- **Intermediate Maintenance.** Intermediate maintenance is performed at the shop. This work is performed by personnel with medium maintenance skill level; i.e., specialized training or technical course work and some experience are required [2]. These more technical maintenance activities include, but are not limited to, the following servicing:
    - Painting of vehicle body
    - Repair of vehicle body
    - Repair of malfunctioning equipment
    - Repair of damaged seats and other interior furnishings
    - Complicated equipment adjustments [2]
- **Depot/Producer Maintenance.** Depot/producer maintenance are performed by the depot/producer's personnel at their facility. The workers should have high maintenance skill level; i.e., specialized training or technical course work and a significant amount of relevant work experience are required. These activities include, but are not limited to, the following servicing [2]:
    - Engine overhauls
    - Major vehicle repairs
    - Equipment (e.g., engine, transmission) rebuilds
    - Intricate factory adjustments

## SECTION 8

## SYSTEM ANALYSIS

### 8.1 FUNCTIONAL ANALYSIS

A functional analysis is accomplished to identify the major functions that the PTS must perform. An operational functional flow diagram is used to show functional interfaces. Figure 5 shows three levels of the operational functional flow diagram for the system. Typically, a complete functional flow diagram would be prepared. For purposes of this project, three levels should suffice.

A maintenance functional flow diagram is shown in Figure 6. The diagram identifies first-level maintenance functions only. A complete maintenance functional flow diagram would typically be prepared at this step in the systems engineering process for both corrective and preventive maintenance. However, since the components for this system are COTS, maintenance functions are straightforward repair or replacement. For purposes of this project, a gross maintenance functional diagram should suffice.

### 8.2 ALLOCATION OF REQUIREMENTS

The allocation of requirements for the PTS is shown in Figure 7. All vehicles for the PTS will be procured from an outside supplier, so in-depth allocation of requirements is not needed for this project. Values for reliability, availability, MTTR, MTBF, and $\lambda$ are based on the PTS requirements described in section 6.2.

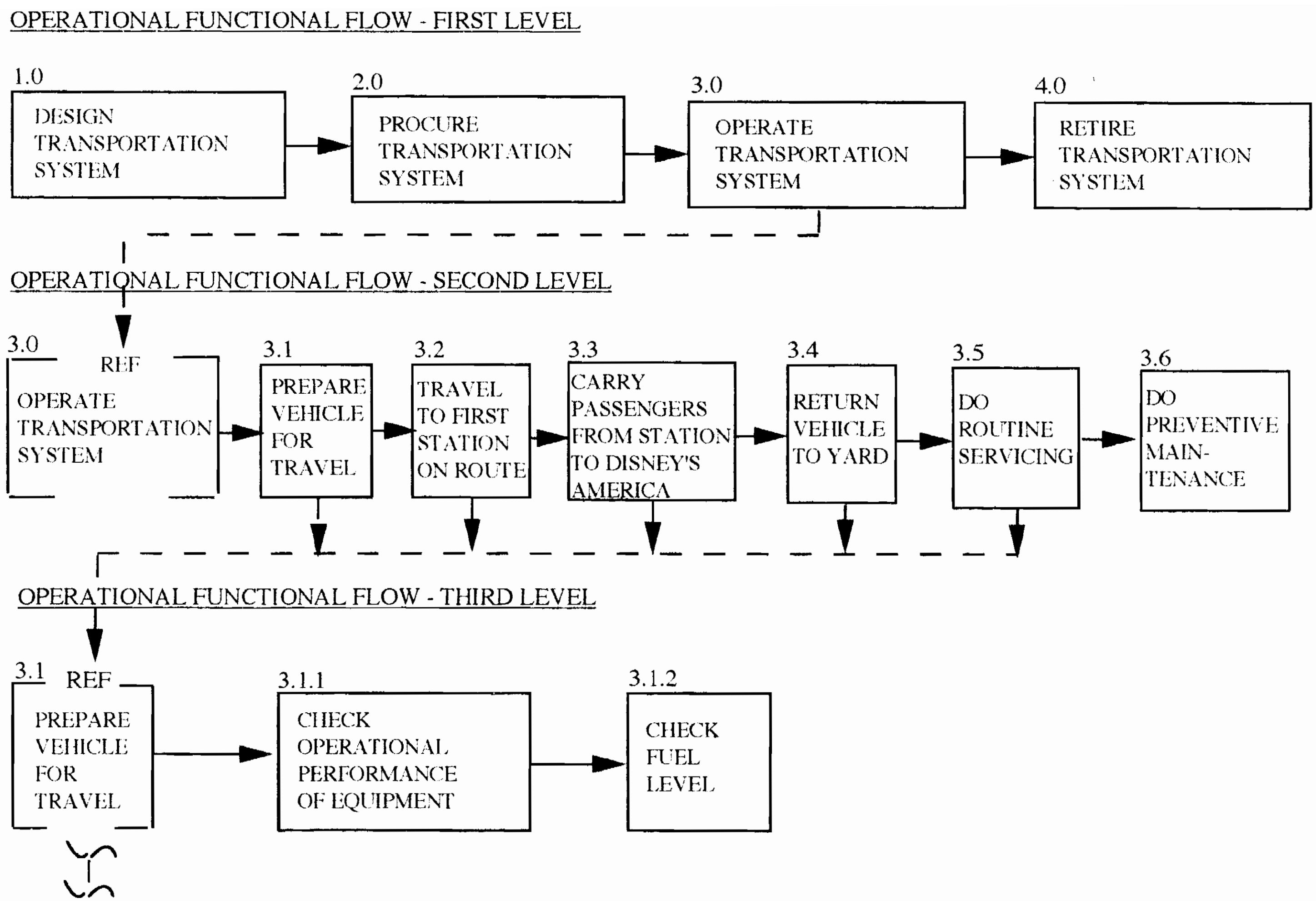



Figure 5. Operational Functional Flow Diagram

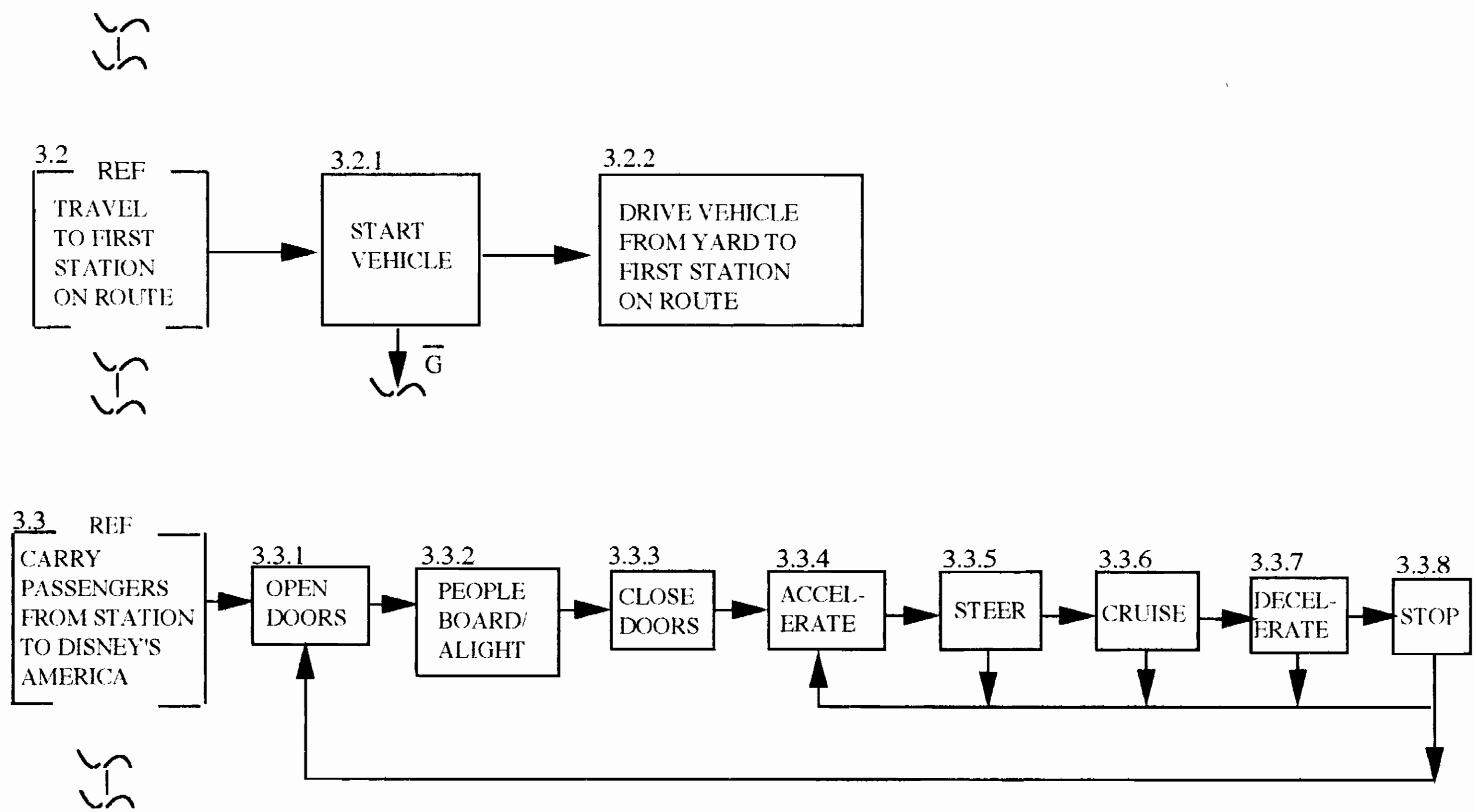



Figure 5. Operational Functional Flow Diagram (Continued)

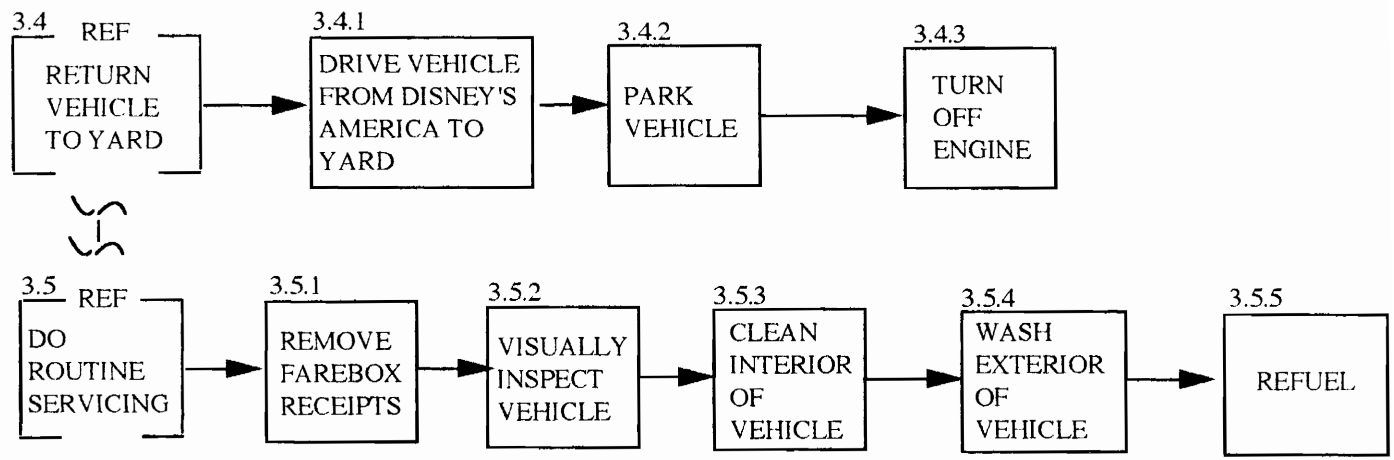



Figure 5. Operational Functional Flow Diagram (Concluded)

MAINTENANCE FUNCTIONAL FLOW - FIRST LEVEL

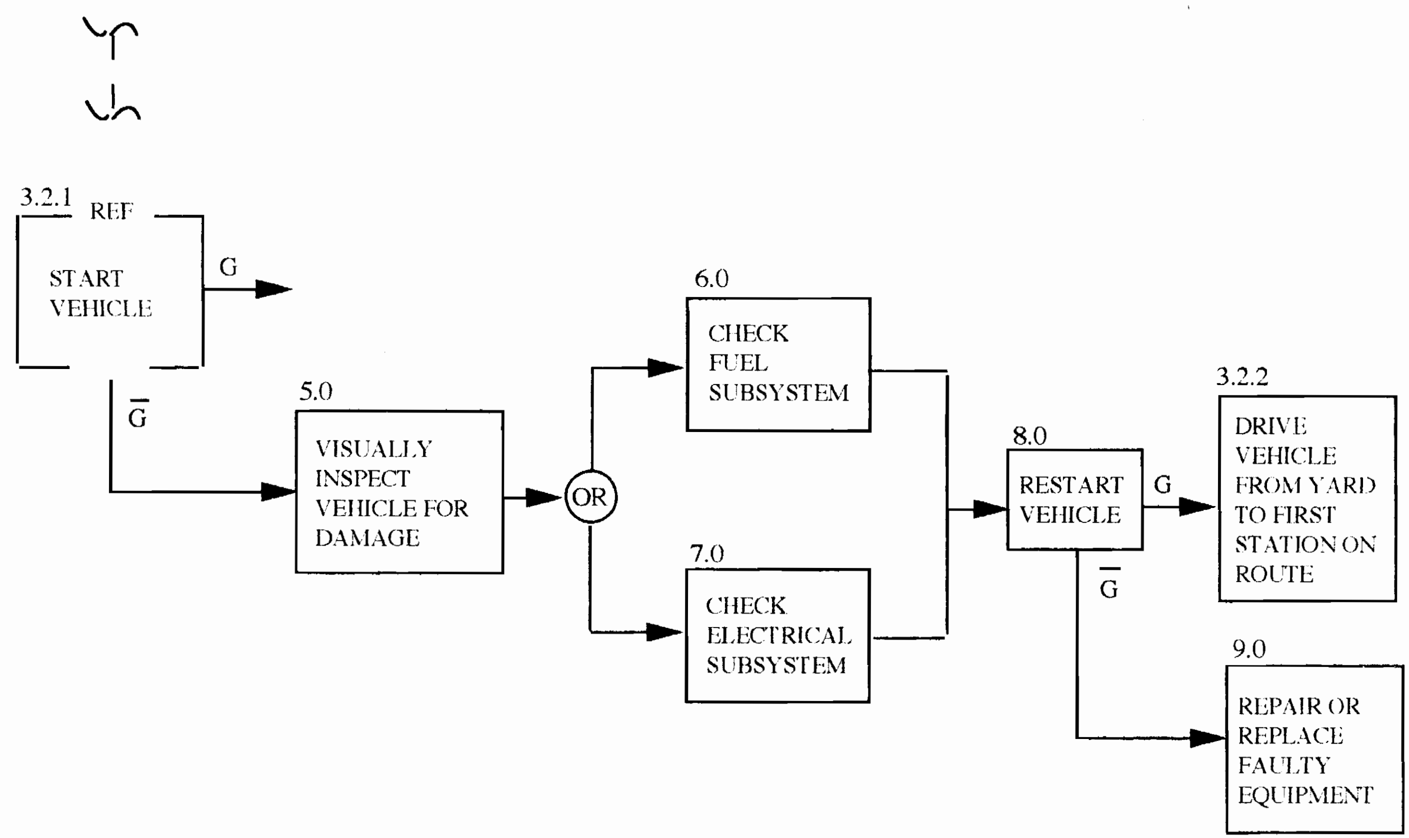



Figure 6. Maintenance Functional Flow Diagram

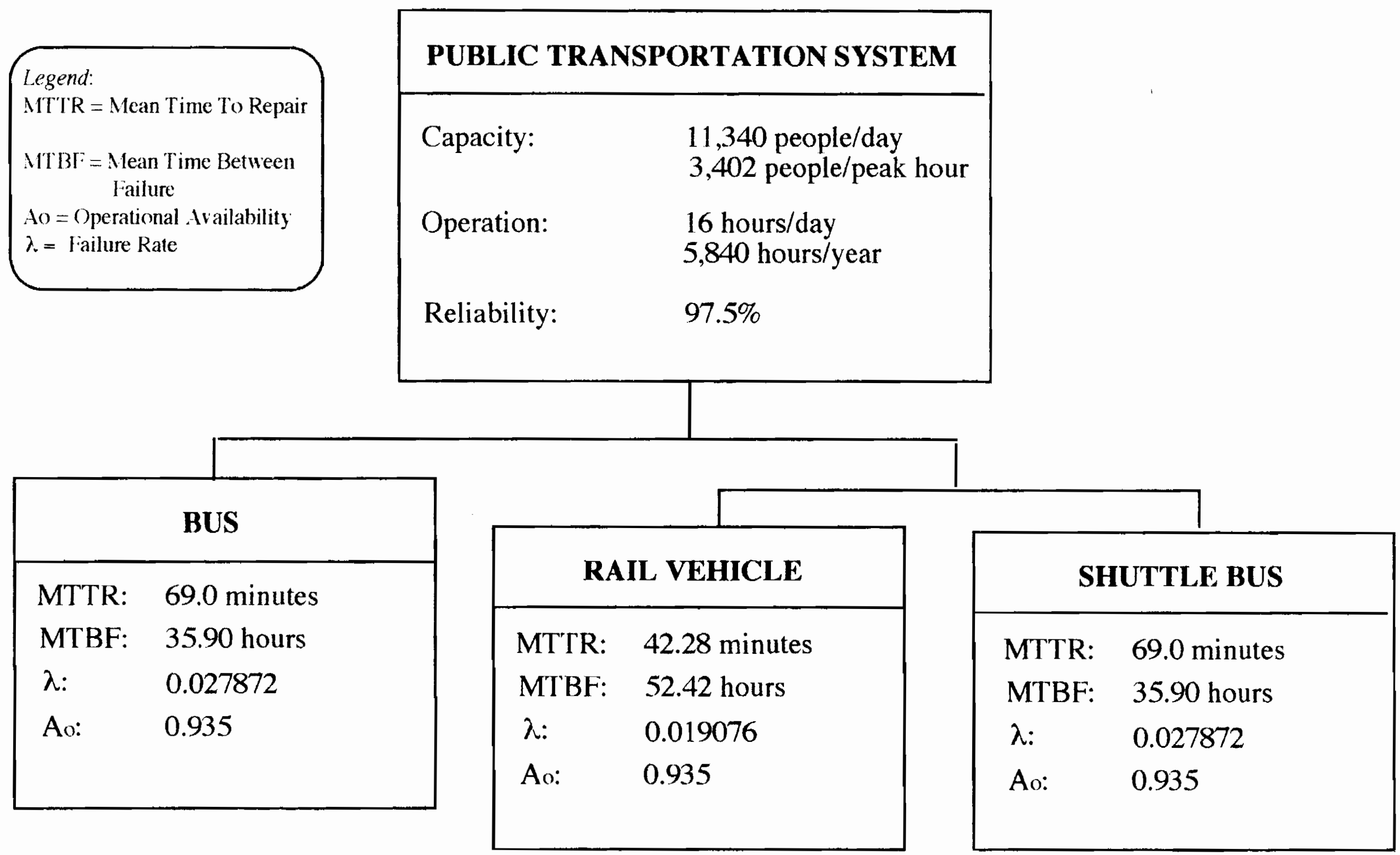



Figure 7. Allocation of Requirements

# SECTION 9

# ALTERNATIVE TRANSIT MODES

The following transit modes are considered for use in the PTS:

- Bus
- Rail Rapid Transit
- Light Rail Transit
- Commuter Rail Transit
- Automated Guideway Transit
- Personal Rapid Transit (PRT)
- Helicopter

However, PRT and helicopters are infeasible for use in this system and are not explored as alternatives because they have very low passenger capacity. PRT systems are a type of AGT; they use automated vehicles and exclusive guideways [9]. PRT vehicles carry individuals or groups of 3-6 people, and the system requires a high investment [9].

## 9.1 DESCRIPTION OF ALTERNATIVES

The following design approaches are evaluated as part of this project:

- **Bus Transit.** Construct an exclusive busway from the Vienna Metrorail station to Disney's America. The system is composed of express buses (i.e., non-stop) and regular buses (i.e., with stops) that transport visitors directly to the east entrance of the park. The design of the bus transit system is presented in Appendix C.
- **Rail Rapid Transit.** Extend the Washington Metropolitan Area Transit Authority (WMATA) Metrorail, an RRT system, from the Vienna Metro

station to Disney's America. This system includes shuttle buses to transport visitors from the rail station at the Disney site to the east entrance of the park. The design of the RRT system is presented in Appendix D.

- **Light Rail Transit.** Construct an LRT system from the Vienna Metrorail station to Disney's America. This system includes shuttle buses to transport visitors from the rail station at the Disney site to the east entrance of the park. The design of the LRT system is presented in Appendix E.
- **Commuter Rail Transit.** Two options are available for taking advantage of the existing Virginia Railway Express (VRE) commuter rail service, which runs on Norfolk Southern Railroad track: (1) extend the existing commuter rail service from Manassas to Disney's America [15], or (2) construct an exclusive busway from VRE's existing Manassas rail station to Disney's America. The design of both commuter rail transit system options is presented in Appendix F.
- **Automated Guideway Transit.** Construct an AGT system from the Vienna Metrorail station to Disney's America. Shuttle buses are used to transport visitors from the AGT station at the Disney site to the east entrance of the park. The design of the AGT system is presented in Appendix G.

Calculations related to the amount of air pollutants generated by each transit design alternative (including the "do nothing" option, discussed in Appendix H), are shown in Appendix I.

## 9.2 EVALUATION CRITERIA

A comprehensive analysis of existing transit modes would typically be performed. Historical data related to various characteristics of each mode, such as the mode's reliability and availability, would be gathered. The following are evaluation criteria for the PTS alternatives:

- **System Capacity.** System capacity is the number of passengers that the system can handle.
- **Reliability.** For the PTS, reliability is expressed as the percent of on-time arrivals at a station.
- **Availability.** For the PTS, availability is expressed as the percentage of time that a vehicle is available for service.
- **Safety.** Safety refers to the number of accidents of the transit mode.
- **Maturity.** The transit mode technology should be mature.
- **Life-Cycle Cost.** Life-cycle cost generally includes research and development cost, production and construction cost, operation and support cost, and retirement and disposal cost. However, the vehicles of the PTS are COTS; thus, life-cycle cost for this system includes capital cost and operating and maintenance cost only.

## 9.3 EVALUATION RESULTS

- **System Capacity.** All transit modes evaluated for use in the PTS have the capacity to handle the expected number of passengers.
- **Reliability.** RRT and commuter rail transit systems have higher reliability than LRT systems, and LRT systems have higher reliability than AGT and bus systems [9, 10]. The assumed reliability of each transit mode, ordered from highest to lowest, is shown below:

| | |
|---|---|
| RRT | 99% |
| Commuter rail | 99% |
| LRT | 98% |

| | |
|---|---|
| AGT | 97% |
| Bus on the busway | 96% |
| Bus on the access road | 93% |

Reliability is lower for buses on the access road because they are not separated from other traffic (e.g., private automobiles and chartered buses) traveling to the park entrance. Adherence to schedule is more difficult in mixed traffic than on an exclusive busway.

The reliability of alternatives that involve shuttle buses includes the reliability of "buses on the access road." Following is the reliability (and ranking) of each PTS alternative:

| | | |
|---|---|---|
| Bus | 89.28% | (4 tied) |
| RRT | 92.07% | (1 tied) |
| LRT | 91.14% | (2) |
| Commuter--Option 1 | 92.07% | (1 tied) |
| Commuter--Option 2 | 89.28% | (4 tied) |
| AGT | 90.21% | (3) |

- **Availability.** Rail vehicles typically have 92% to 95% availability [10]. It is assumed that rail vehicles proposed for the PTS have the average of the two values, i.e., 93.5%.

  Buses have a shorter life than rail cars and therefore could be expected to require maintenance sooner than rail cars. They also have fluid-carrying hoses that could crack and rubber tires that could flatten. Bus engines typically need rebuilt after 225,000 miles, and bus transmissions need rebuilt after 120,000 miles [3]. Shuttle buses operate on the private access road with other traffic and are susceptible to collisions and subsequent body repairs. It is assumed that the availability of buses is 89%.

- **Safety.** The average number of accidents per million miles for each transit mode is shown below [3]:

| | |
|---|---|
| Bus | 46.00 |
| LRT | 6.43 |
| RRT | 0.98 |
| Commuter | 0.59 |
| AGT | 0.98 (assumed same as RRT) |

  The average number of fatalities per million miles for each transit mode is also shown [3]:

| | |
|---|---|
| Bus | 0.220 |
| LRT | 0.020 |
| RRT | 0.003 |
| Commuter | 0.007 |
| AGT | 0.003 (assumed same as RRT) |

- **Maturity.** Bus, rapid rail, light rail, and commuter rail have been used in many transportation systems. AGT systems are somewhat newer; there are 23 AGT systems in the U.S., and the earliest start-up date for such a system is 1971 [3].
- **Life-Cycle Cost.** Figure 8 shows the cost breakdown structure for the PTS, and Table 1 provides a description of the cost categories. A life-cycle cost summary for the transit alternatives is shown in Table 2. The supporting life-cycle cost analysis is presented in Appendix J.

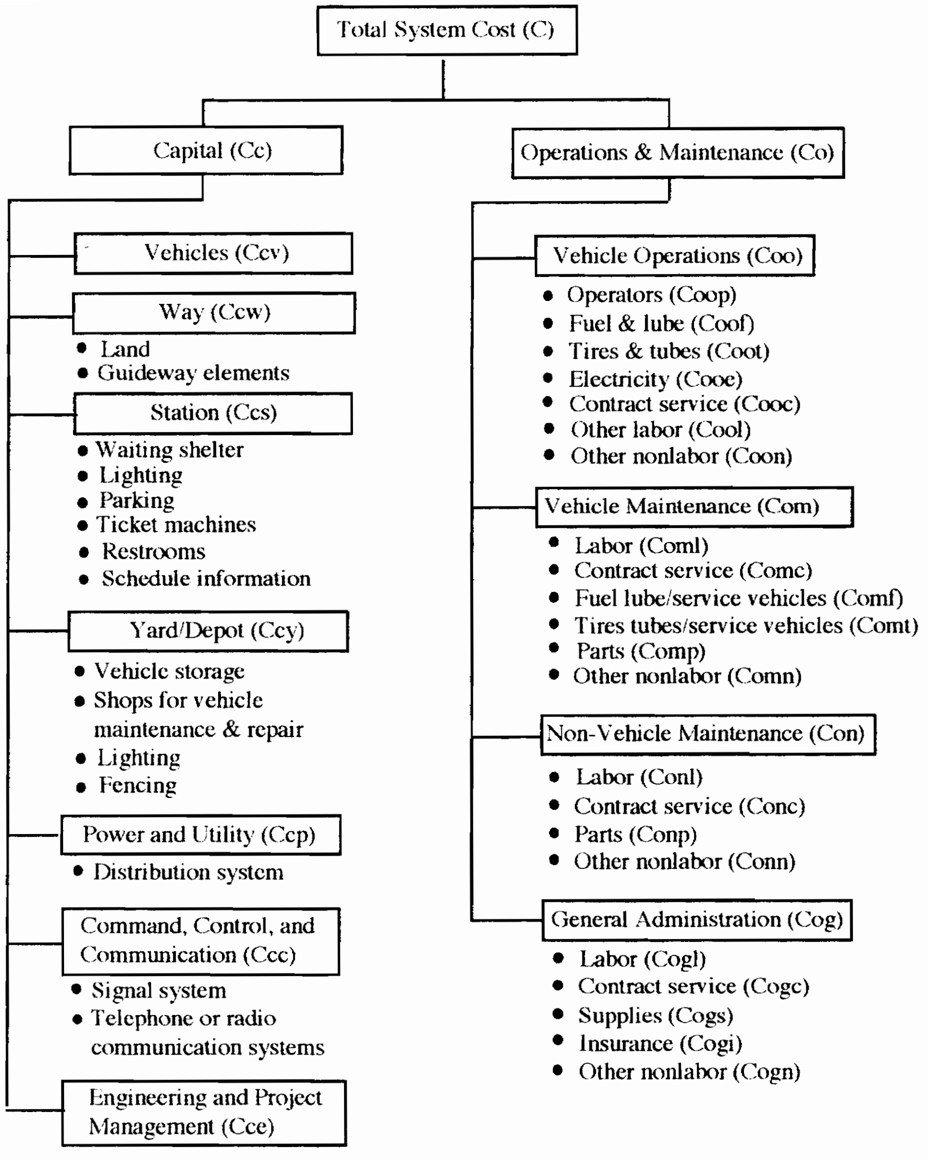



Figure 8. Cost Breakdown Structure

Table 1. Description of Cost Categories

| Cost Category | Description |
| --- | --- |
| **Total System Cost (C)** | For this project, this category includes all future capital cost and operating and maintenance (O&M) cost associated with the proposed public transportation system. |
| **Capital ($C_c$)** | This category includes investment costs for the following items: (1) vehicles, (2) way, (3) rail yard, (4) bus depot, (5) station, (6) power and utility, (7) command, control, and communication, (8) and engineering and project management. |
| **Vehicles ($C_{cv}$)** | This category includes the purchase cost of transportation vehicles, both buses and rail cars. |
| **Way ($C_{cw}$)** | This category includes the cost of land for ROW and stations, as well as way construction [10]. |
| **Yard/Depot ($C_{cy}$)** | This category includes the cost of shops and yards for vehicle maintenance and storage. |
| **Station ($C_{cs}$)** | This category includes the cost of stations, platforms, and parking facilities (park and ride). |
| **Power & Utility ($C_{cp}$)** | This category includes the cost of substations, distribution systems, and catenary or third-rail structures [9]. |
| **Command, Control & Communication ($C_{cc}$)** | This category includes the cost of communication equipment, signal systems, and control facilities [9]. |
| **Engineering & Project Management ($C_{ce}$)** | This category includes the cost of engineering studies and project management [3]. |
| **Operations and Maintenance ($C_o$)** | This category includes costs related to the operations and maintenance of the public transportation system during its life cycle. |

Table 1. Description of Cost Categories (Continued)

| Cost Category | Description |
|---|---|
| **Vehicle Operations ($C_{oo}$)** | Vehicles operation activities include transportation administration, scheduling, revenue vehicle operations, and vehicle movement control. This category includes costs related to the following items: (1) operators, (2) fuel & lube, (3) tires & tubes, (4) electricity, (5) contract service, (6) other labor, and (7) other nonlabor [5]. |
| **Operators ($C_{oop}$)** | This category includes costs of operators' wages and fringe benefits, such as pension and medical insurance [5]. |
| **Fuel & Lube ($C_{oof}$)** | This category includes costs of fuel and lubricants for the vehicles [5]. |
| **Tires & Tubes ($C_{oot}$)** | This category includes cost of tires and tubes for the vehicles [5]. |
| **Electricity ($C_{ooe}$)** | This category includes the cost of electricity. |
| **Contract Service ($C_{ooc}$)** | This category includes costs of purchasing services provided by the private sector related to vehicle operations [5]. |
| **Other Labor ($C_{ool}$)** | This category includes the cost of other wages and fringe benefits; e.g., supervisors, dispatchers [5]. |
| **Other Nonlabor ($C_{oon}$)** | This category includes the cost of other nonlabor related to vehicle operations; e.g., supplies [5]. |
| **Vehicle Maintenance ($C_{om}$)** | Vehicle maintenance activities include administration, accident and vandalism repairs, inspection, and routine maintenance of revenue vehicles and service vehicles. This category includes the cost of the following items: (1) labor, (2) contract service, (3) fuel lube/service vehicles, (4) tires tubes/service vehicles, (5) parts, and (6) other nonlabor [5]. |
| **Labor ($C_{oml}$)** | This category includes the cost of wages and fringe benefits for workers performing vehicle maintenance [5]. |
| **Contract Service ($C_{omc}$)** | This category includes costs of purchasing services provided by the private sector related to vehicle maintenance; e.g., major vehicle repairs [5]. |

Table 1. Description of Cost Categories (Continued)

| Cost Category | Description |
|---|---|
| **Fuel Lube/Service Vehicles ($C_{omf}$)** | This category includes costs of fuel and lubricants for the vehicles [5]. |
| **Tires Tubes/Service Vehicles ($C_{omt}$)** | This category includes costs of tires and tubes for the vehicles [5]. |
| **Parts ($C_{omp}$)** | This category includes the cost of parts for vehicle maintenance. |
| **Other Nonlabor ($C_{omn}$)** | This category includes the cost of other nonlabor related to vehicle maintenance. |
| **Non-Vehicle Maintenance ($C_{on}$)** | Non-vehicle maintenance activities include maintenance administration unrelated to vehicles, maintenance of the vehicle movement control system, maintenance of track or roadway, maintenance of communication systems, maintenance of fare collection equipment, maintenance of stations, shop, grounds, and equipment, and operation and maintenance of electric power facilities [5]. This category includes the cost of the following items: (1) labor, (2) contract service, (3) parts, and (4) other nonlabor [5]. |
| **Labor ($C_{onl}$)** | This category includes the cost of wages and fringe benefits for workers performing non-vehicle maintenance [5]. |
| **Contract Service ($C_{onc}$)** | This category includes costs of purchasing services provided by the private sector related to non-vehicle maintenance; e.g., maintenance of office equipment [5]. |
| **Parts ($C_{onp}$)** | This category includes the cost of parts for non-vehicle maintenance; e.g., parts for passenger stations [5]. |
| **Other Nonlabor ($C_{onn}$)** | This category includes the cost of other nonlabor related to non-vehicle maintenance. |

Table 1. Description of Cost Categories (Concluded)

| Cost Category | Description |
|---|---|
| **General Administration ($C_{og}$)** | General administration includes preliminary transit system development, ticketing/fare collection, system security, injuries/damages, safety, personnel, legal, insurance, data processing, finance/accounting, purchasing/stores, general engineering, real estate management, office management and services, general management, customer services, promotion, and market research [5]. This category includes the cost of the following items: (1) labor, (2) contract service, (3) supplier, (4) insurance, and (5) other nonlabor [5]. |
| **Labor ($C_{ogl}$)** | This category includes the cost of wages and fringe benefits for workers performing general administration activities [5]. |
| **Contract Service ($C_{ogc}$)** | This category includes the cost of purchasing services provided by the private sector related to general administration; e.g., computer software needs [5]. |
| **Supplies ($C_{ogs}$)** | This category includes the cost of supplies related to general administration. |
| **Insurance ($C_{ogi}$)** | This category includes the cost of insurance for the transportation system; e.g., operating liability [5]. |
| **Other Nonlabor ($C_{ogn}$)** | This category includes the cost of other nonlabor related to general administration. |

Table 2. Life-Cycle Cost Summary

| Alternative | Actual Cost (1000 $) | Present Cost (1000 $) |
|---|---|---|
| Bus Transit System | 983,552 | 369,815 |
| Rail Rapid Transit System | 3,213,821 | 1,333,344 |
| Light Rail Transit System | 1,849,320 | 743,180 |
| Commuter Rail Transit System-Option 1 | 2,232,287 | 901,970 |
| Commuter Rail Transit System-Option 2 | 494,622 | 187,721 |
| Automated Guideway Transit System | 1,997,715 | 819,046 |

## SECTION 10

## PREFERRED TRANSIT SYSTEM

The preferred alternative for the PTS is the bus transit system. The cost of the bus system is $369 million, which is well below the cost of the closest rail alternative (LRT, $743 million). The bus transit system requires the construction of an exclusive busway from the Vienna Metro station to Disney's America. Express buses (i.e., non-stop) and regular buses (i.e., with stops) transport visitors directly to the east entrance of the park. The PTS includes 75 express buses and 30 regular buses.

All of the modes considered for the PTS have adequate system capacity and maturity of technology. The reliability of the bus transit system is 89.28%, and the availability is 89.0%. Neither value meets the requirement for the PTS. However, it must be noted that the reliability and availability attributed to bus transit are assumed in this project. On the other hand, the O&M costs are based on actual data for existing systems and thus are a reflection of the actual reliability and availability of each transit mode. Future research is recommended is refine the reliability and availability aspects of the transit modes.

The alternative with the lowest life-cycle cost is the commuter rail transit system, option 2 (i.e., busway from the existing commuter rail station in Manassas). Commuter rail also had the lowest number of accidents and the second-lowest number of fatalities. However, commuter rail transit is not the preferred alternative because of the limited schedule of the existing rail service; i.e., the hours of operation were not adequate to serve park visitors. VRE only operates four daily round trips on its Manassas line [4]. Commuter rail service between Union Station and Manassas is offered during morning rush hour (four trains depart Manassas between 5:32 am and 7:32 am) and evening rush hour (four trains depart Union Station between 4:25 pm and 6:20 pm) [24]. VRE does not offer service on Saturday or Sunday. In order to serve Disney's America, the existing service would have to be extended to accommodate passengers during the morning, mid-day, late evening, and on weekends. Additional capital and O&M costs would be incurred because extension of the existing operating hours is likely to require more operators, maintenance personnel, and rail cars. If the existing commuter rail service shares the guideway with freight trains, as most commuter rail services do [4], extension of passenger service to adequately support park visitors may be impossible.

Travel time is assumed to be constant across the alternatives. In reality, travel time would vary among the modes. It is recommended that future research address any difference that varying travel times would make in the design process.

It is also recommended that future work take into consideration the seasonal aspect of a theme park. For example, it could be expected that fewer people visit the park (and, therefore, fewer people use a PTS) in the winter than in the summer. Flexibility could be an important issue in the selection of a system.

# APPENDIX A
# THE LOGIT MODEL

Not everyone would use public transportation if it were available; some percentage of people would still prefer to use private automobiles. The number of people who would use public transportation to visit Disney's America must be determined before design work begins. The logit model is the tool that is used estimate ridership for the proposed public transportation system.

This section briefly describes the logit model. It presents the results of running the model as part of this transportation system design project.

## A.1 DESCRIPTION OF THE LOGIT MODEL

The logit model is a mathematical model that is used to make predictions of mode choices [10]. The binomial logit model is used when two choices are available; i.e., alternative 1 and alternative 2. The probability that alternative 1 is chosen is given by the following formula:

$$Pr(1) = \frac{\exp(V_1)}{\exp(V_1) + \exp(V_2)}$$

where:

Pr(1): the probability that a person chooses alternative 1

exp( ): the exponential function

$V_1$: the deterministic component of the utility of alternative 1

$V_2$ : the deterministic component of the utility of alternative 2

The probability that alternative 2 is chosen is one minus the probability that alternative 1 is chosen.

Ordinarily, the deterministic component ($V_i$) of the utility of a particular transportation mode results from surveys or studies that have been conducted. For this project, $V_i$ is assumed to be determined by travel time, cost, and the annual income of the traveler. The deterministic component of the utility of a mode is expressed as follows:

$$V_i = -T_i - 5C_i/Y$$

where:

i: the transportation mode

$V_i$ the deterministic component of the utility of mode i

$T_i$ : travel time (in hours)

$C_i$ : cost (in dollars)

Y: annual income (in thousands of dollars)

For example, suppose that it is necessary to determine the probability of individuals choosing to ride a bus versus choosing to drive their own automobiles. Assume that the annual income of the travelers is $30,000; therefore, Y=30.

Time and cost assumptions:

| Mode | Time | Cost |
|---|---|---|
| Bus | 1.0 | $0.50 |
| Automobile | 0.5 | $2.00 |

Deterministic components of modes' utilities and exponentials:

| | Y=30 | |
|---|---|---|
| Mode | V | exp(V) |
| Bus | -1.08 | 0.34 |
| Automobile | -0.83 | 0.44 |
| Sum | | 0.78 |

Corresponding choice probabilities:

| Mode | Pr(Mode) |
|---|---|
| Bus | 0.44 |
| Automobile | 0.56 |
| | 1.00 |

## A.2 APPLICATION OF THE LOGIT MODEL

Numeric values of the time (T), cost (C), and annual income (Y) attributes were not available directly for this application of the logit model. Values for the attributes were determined through a combination of assumptions and calculations.

### A.2.1 Assumptions

- The average operating speed of public transit vehicles is 49 miles per hour (mph). This is the average speed of bus, RRT, LRT , commuter rail transit, and AGT, as shown in the appendices.
- The average operating speed of automobiles is 50 mph. This is the average of the allowed speed on I-66 (55 mph) and Route 15 (45 mph).
- The cost of using public transportation includes the fare and the value of travel time (in dollars per vehicle hour); parking is free. The fare is $2.00, and the value of travel time is $13.45 per hour [3].
- The cost of using private automobile is the cost of the travel time, $10.34 per hour [3]. Parking at Disney's America is free.
- The average annual income of visitors to the park is $50,000.
- "One-way" direction is used for the run of the logit model.

### A.2.2 Calculation of Time (T)

Travelers using public transportation to the park will board at the Vienna Metrorail station (one-way distance of 21 miles), the Centreville area station (one-way distance of 13 miles), and the Manassas area station (one-way distance of 8 miles). The average of these three values is used to determine T.

| | | | | | | |
|---|---|---|---|---|---|---|
| Distance/rate | = | 21/49 | = | 0.43 hours | Vienna to Disney's America |
| Distance/rate | = | 13/49 | = | 0.27 hours | Centreville to Disney's America |
| Distance/rate | = | 8/49 | = | 0.16 hours | Manassas to Disney's America |
| T = (0.43+0.27+0.16)/3 | | | = | 0.29 hours | Average time - public transportation |

The same method is used to determine T for travelers using private automobiles to the park.

| | | | | | |
|---|---|---|---|---|---|
| Distance/rate | = | 21/50 | = | 0.42 hours | Vienna to Disney's America |
| Distance/rate | = | 13/50 | = | 0.26 hours | Centreville to Disney's America |
| Distance/rate | = | 8/50 | = | 0.16 hours | Manassas to Disney's America |
| T = (0.42+0.26+0.16)/3 | | | = | 0.28 hours | Average time - private automobile |

### A.2.3 Calculation of Cost (C)

The cost of using public transportation to the park is the value of travel time plus the cost of the fare.

$13.45*0.29 = $3.90

C = $3.90+$2.00 = $5.90

The cost of using private automobile to the park is the value of travel time.

$10.34*0.28 = $2.895, rounded to $2.90

C = $2.90

### A.2.4 Logit Model Results

Because the average annual income of visitors to the park is assumed to be $50,000, Y=50 for the following calculations.

Time and cost:

| Mode | Time | Cost |
|---|---|---|
| Public | 0.29 | $5.90 |
| Automobile | 0.28 | $2.90 |

Determine $V_i$ for public transportation:

$$
\begin{aligned}
V_i &= -T_{ij} - 5C_{ij}Y \\
&= -0.29 - 5(5.90)/50 \\
&= -0.88
\end{aligned}
$$

Determine $V_i$ for automobile:

$$
\begin{aligned}
V_i &= -T_i - 5C_{ij}Y \\
&= -0.28 - 5(2.90)/50 \\
&= -0.57
\end{aligned}
$$

Deterministic components of modes' utilities and exponentials:

| | Y=50 | |
|---|---|---|
| Mode | V | exp(V) |
| Public | -0.88 | 0.41 |
| Automobile | -0.57 | 0.57 |
| Sum | | 0.98 |

Corresponding choice probabilities:

| Mode | Pr(Mode) |
|---|---|
| Public | 0.42 |
| Automobile | 0.58 |
| | 1.00 |

Results:

30,000 visitors*0.42 = 12,600 visitors, peak day, would use public transportation

30,000 visitors*0.58 = 17,400 visitors, peak day, would use automobiles

# APPENDIX B

# PASSENGER VOLUME CALCULATIONS

This section shows the daily passenger volume and peak-hour passenger volume for the system and the stations.

## B.1 DAILY PASSENGER VOLUME - SYSTEM

30,000 park visitors, peak day

30,000 * 0.42 = 12,600 park visitors would use public transportation (from logit model)

12,600 * 0.90 = 11,340 park visitors will use the transportation system each day

## B.2 DAILY PASSENGER VOLUME - STATIONS

11,340 * 0.70 = 7,938 park visitors board at Vienna station each day

11,340 * 0.30 = 3,402 park visitors board at Centreville and Manassas stations each day; i.e., 1,701 passengers at Centreville and 1,701 passengers at Manassas

## B.3 PEAK-HOUR PASSENGER VOLUME - SYSTEM AND STATIONS

11,340 * 0.30 = 3,402 park visitors, system peak hour load

3,402 * 0.70 = 2,382 park visitors, Vienna peak hour load

3,402 * 0.30 = 1,021 park visitors, Centreville and Manassas peak hour loads; i.e., 511 passengers at Centreville and 511 (rounding) passengers at Manassas

# APPENDIX C

# BUS TRANSIT SYSTEM

This section presents the design of the bus transit system. Bus transit requires the construction of an exclusive busway from the Vienna Metro station to Disney's America. Express buses (i.e., non-stop) and regular buses (i.e., with stops) transport visitors directly to the east entrance of the park. Figure 9 shows the proposed bus transit system.

## C.1 ASSUMPTIONS

In addition to the assumptions presented in section 3.3 regarding the transportation system in general, the following assumptions are relevant to the bus transportation system design:

- The busway is exclusive; buses only.
- The busway is two lanes, one in each direction.
- The cost of constructing the two-lane busway is $10 million per mile [10].
- The busway is 24 miles long.
- Stations are off-line.
- Articulated buses (60') are used.
- Seating capacity of articulated buses is 73 passengers [3].
- Terminal time ($t_t$) is 5 minutes [10].
- Average operating speed is 50 mph on the expressway and 45 mph on the private road.
- Minimum headway is 3 seconds [10].

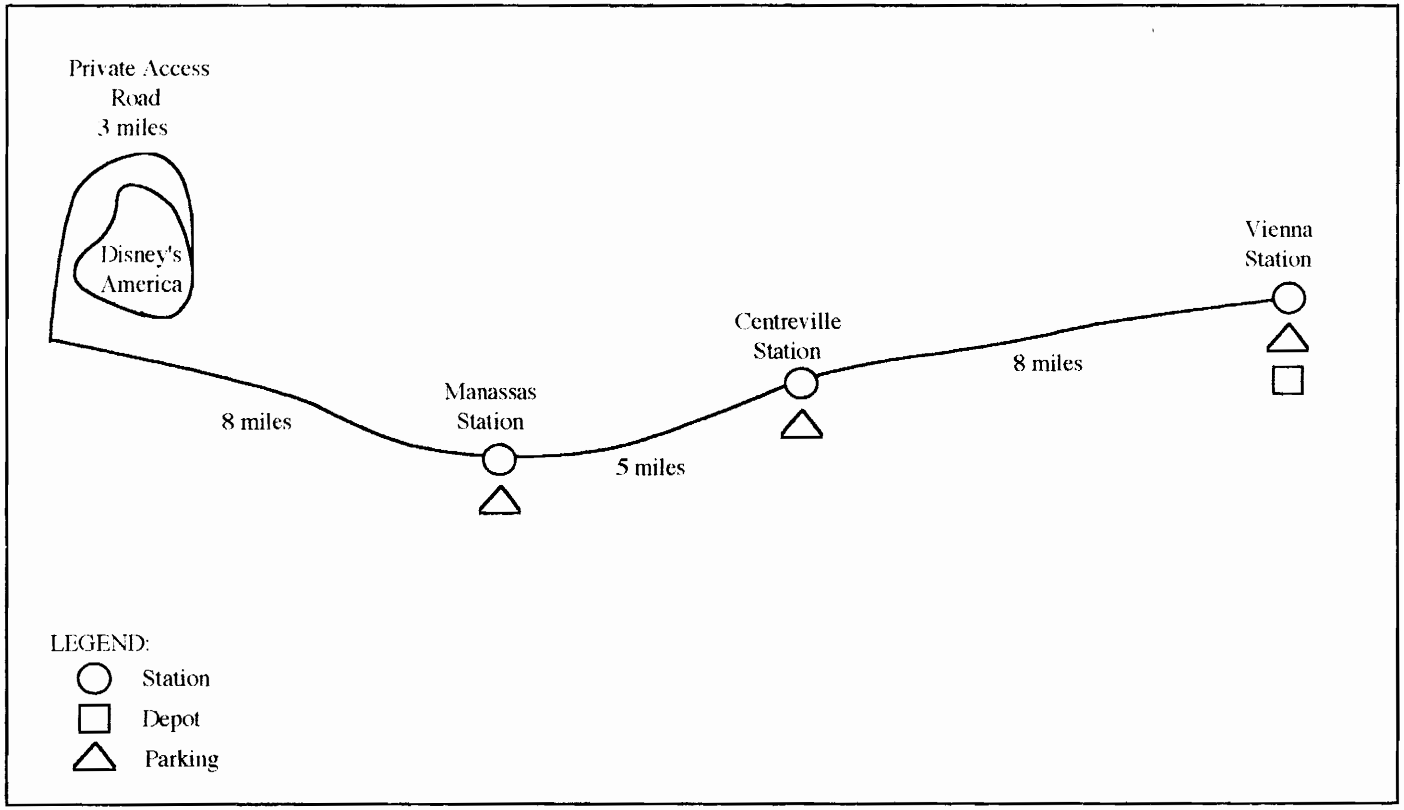



Figure 9. Bus Transit System

- Passengers traveling to Disney's America and boarding at Vienna will ride the express bus; 70% of the passengers will board at Vienna.
- Regular buses will depart from Vienna, but only passengers with Centreville or Manassas destinations will board regular buses there.
- Passengers traveling to Disney's America and boarding at Centreville or Manassas will ride the regular bus; 15% of the passengers will board at Centreville, and 15% of the passengers will board at Manassas.
- Express bus peak-hour load is 2,382 passengers (70% of 3,402).
- Regular bus peak-hour load is 1,021 passengers (30% of 3,402).
- Stations are needed at Vienna, Centreville, and Manassas. An area for boarding and unloading at Disney's America already exists.
- Parking is available at the Vienna, Centreville, and Manassas stations.
- One bus depot is needed, and it is located at Vienna.

## C.2 DESIGN CALCULATIONS

### C.2.1 Express Bus

#### C.2.1.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 73}{2{,}382}$$

$$= \frac{3{,}942}{2{,}382}$$

$$= 1.65$$

$$= \underline{1} \text{ minute}$$

where:

- $h$: headway--the time between two successive departures of vehicles (in minutes) [10]
- $\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]
- $C_v$: vehicle capacity (seating only, no standees) [10]
- $P$: maximum load of passengers per hour [10]

### C.2.1.2 Operating Time

$$
\begin{aligned}
T_o &= (d/r) * 60 \\
&= (21/50) * 60 + (3/45) * 60 \\
&= 25.20 + 4.0 \\
&= \underline{29.2} \text{ minutes}
\end{aligned}
$$

where:

- $T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]
- $d$: distance
- $r$: rate

### C.2.1.3 Cycle Time

$$
\begin{aligned}
T &= 2(T_o + t_t) \\
&= 2(29.2 + 5) \\
&= \underline{68.4} \text{ minutes}
\end{aligned}
$$

where:

$T$: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

$t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

#### C.2.1.4 Number of Vehicles

$$N = T/h$$
$$= 68.4/1$$
$$= 68.4$$
$$= \underline{69} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further in the system design. The bus service will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/68.4) shows that a bus will run 14 cycles each day. Each bus will carry 73 passengers per cycle, or 1,022 passengers per day. The system's 69 express buses can transport 70,518 passengers per day, which exceeds the expected 7,938 daily park visitors.

### C.2.1.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares}$$
$$= 69 + 6$$
$$= \underline{75} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down; i.e., 35 * 0.10 = 3.5 = 3

### C.2.1.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$
$$= \frac{2{,}382}{0.9 * 73}$$
$$= 36.26$$
$$= \underline{37} \text{ vehicles per hour}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the express buses is 37 vehicles per hour. Each bus carries 73 passengers, so the system can transport 2,701 park visitors during peak hour. This number exceeds the expected peak-hour load of 2,382 passengers for the express-bus portion of the bus transit system.

## C.2.2 Regular Bus

### C.2.2.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 73}{1{,}021}$$

$$= 3.86$$

$$= \underline{3} \text{ minutes}$$

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_V$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

### C.2.2.2 Operating Time

$$T_o = (d/r * 60 + 10) + (d/r * 60)$$

$$= ((21/50) * 60 + 10) + ((3/45) * 60)$$

$$= 35.20 + 4.0$$

$$= \underline{39.2} \text{ minutes}$$

where:

$T_O$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

d: distance

r: rate

#### C.2.2.3 Cycle Time

$$T = 2(T_o + t_t)$$
$$= 2(39.2 + 5)$$
$$= \underline{88.4} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

$t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

#### C.2.2.4 Number of Vehicles

$$N = T/h$$
$$= 88.4/3$$
$$= 29.47$$
$$= \underline{30} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further in the system design. The bus service will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/88.4) shows that a bus will run 10 cycles each day. Each bus will carry 73 passengers per cycle, or 730 passengers per day. The system's 30 regular buses can transport 21,900 passengers per day, which exceeds the expected 3,402 daily park visitors.

### C.2.2.5 Total Number of Vehicles Required

$$\begin{aligned}\text{Total} &= N + \text{spares} \\ &= 30 + 3 \\ &= \underline{33} \text{ vehicles}\end{aligned}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

### C.2.2.6 Frequency of Service

$$\begin{aligned}f &= \frac{P}{\alpha * C_v} \\ &= \frac{1{,}021}{0.9 * 73} \\ &= 15.54 \\ &= \underline{16} \text{ vehicles per hour}\end{aligned}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the regular buses is 16 vehicles per hour. Each bus carries 73 passengers, so the system can transport 1,168 park visitors during peak hour. This number exceeds the expected peak-hour load of 1,021 passengers for the regular-bus portion of the bus transit system.

## C.3 CAPITAL COST (Cc)

### C.3.1 Vehicle (Ccv)

The average capital cost of a 60' articulated bus was $279,900 in 1990 dollars [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each articulated bus in 1994 dollars is $409,773 ($279,900 * 1.464).

$409,773 * 108 = $<u>44,255,484</u> capital cost of vehicles

### C.3.2 Way (Ccw)

A 21-miles busway will be built from the Vienna station to the park. The Walt Disney Company is responsible for the cost of the three-mile private access road.

$10,000,000 * 21 = <u>$210,000,000</u> capital cost of way

### C.3.3 Depot (Ccy)

The average cost per vehicle for a bus facility without indoor vehicle storage was $91,700 in 1990 dollars [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost per vehicle for a bus depot in 1994 dollars is $134,248 ($91,700 * 1.464).

$134,248 * 108 buses = <u>$14,498,784</u> capital cost of depot

### C.3.4 Station (Ccs)

The cost of a bus station is assumed to be $200,000 [10]. Parking facilities are provided at each station. These facilities may be high-rise garages or at-grade lots. Calculations to determine the number of parking spaces required, the cost of parking facilities, and the total station cost for the system are shown in the following subsections.

#### C.3.4.1 Vienna Station

There will be 7,938 park visitors boarding at the Vienna station. It is assumed that 75% of the passengers will transfer from the existing Metrorail and thus will not have automobiles to park.

7,938 * 0.75 = 5,954 people do not have an automobile to park

7,938 - 5,954 = 1,984 people have an automobile to park

It is also assumed that there will be two people in each automobile.

1,984/2 = 992 parking spaces are needed at Vienna station

There are 300 parking spaces provided in a high-rise garage and 692 spaces provided in at-grade lots. It is assumed that the cost for each space in the high-rise garage is $10,000, and the cost for each space in the at-grade lots is $5,000 [10].

300 * $10,000 = $3,000,000 high rise
692 * $5,000 = <u>$3,460,000</u> at-grade
$6,460,000 total parking cost at Vienna station

#### C.3.4.2 Centreville Station

There will be 1,701 park visitors boarding at the Centreville station each day. It is assumed that there will be two people in each automobile.

1,701/2 = 851 parking spaces are needed at Centreville station

There are 300 parking spaces provided in a high-rise garage and 551 spaces provided in at-grade lots.

| | | | |
|---|---|---|---|
| 300 * $10,000 | = | $3,000,000 | high rise |
| 551 * $5,000 | = | $2,755,000 | at-grade |
| | | $5,755,000 | total parking cost at Centreville station |

#### C.3.4.3 Manassas Station

Parking costs at the Manassas station are the same as costs at the Centreville station; i.e., $5,755,000.

#### C.3.4.4 Station Total

| | | |
|---|---|---|
| Vienna: | $ 6,460,000 | parking |
| | 200,000 | station |
| Centreville: | 5,755,000 | parking |
| | 200,000 | station |
| Manassas | 5,755,000 | parking |
| | 200,000 | station |
| Total | $18,570,000 | total station cost |

### C.3.4 Power and Utility (Ccp)

This item is not a major cost contributor for buses and is not addressed [9].

### C.3.5 Command, Control, and Communication (Ccc)

Command, control, and communication for a bus system consists of two-way voice radios and silent alarms [9]. This cost item is insignificant for buses and is not addressed.

### C.3.6 Engineering and Project Management (Cce)

This item is not a major cost contributor for buses and is not addressed [9].

Table 3 shows the capital cost for the bus transit system.

## C.4 OPERATING AND MAINTENANCE COST (Co)

Operating and maintenance (O&M) cost items are based on cost per unit of service, where the unit of service may be platform hours, vehicle miles, or route miles. The units of service for the bus transit system must be determined before the O&M costs are estimated.

Platform hours are the hours that the operator is in charge of the vehicle [23]. It is assumed that one operator is needed for each bus. There are 108 buses (75 express buses and 33 regular buses, not counting spares). Assuming that each operator is in charge of a vehicle for seven hours each day, the bus transit system involves 275,940 platform hours each year.

Vehicle miles are the miles that the vehicle travels. The system operates 16 hours a day, 365 days a year, for a total of 5,840 hours (or 350,400 minutes). The express bus requires 68.4 minutes to complete 48-mile cycle, and the regular bus requires 88.4 minutes. Dividing the total minutes by the cycle time and multiplying the result by 48 results in 436,080 vehicle miles per year for the bus transit system.

Route miles represent the end-to-end mileage of the line [5]. The bus system consists of 24 route miles.

Table 3. Bus Transit System Capital Cost

| Activity | Cost Category | Actual Cost (1000 $) |
|---|---|---|
| Capital Cost | Cc | |
| Vehicles | Ccv | 44,255 |
| Way | Ccw | 210,000 |
| Yard/Depot | Ccy | 14,499 |
| Station | Ccs | 18,570 |
| Power & Utility | Ccp | |
| Command, Control, & Comm. | Ccc | |
| Engineering & Project Mgt. | Cce | |
| **TOTAL CAPITAL COST** | | **287,324** |

Actual O&M cost data of the Chicago Sub Bus Division for the year 1988 is used to estimate the O&M cost of the proposed bus system. The source of the data is the O&M cost data base presented in DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems." The 1988 values have been converted to 1994 dollars. Table 4 shows the actual O&M cost for the bus transit system.

Table 5 shows the bus transit system costs and the percentage of total for each cost.

Table 4. Bus Transit System Annual Operating and Maintenance Costs

| Activity | Cost Category | Actual Cost (1000 $) |
|---|---|---|
| Annual Operating & Maintenance Cost | Co | |
| Vehicle Operations | Coo | |
| Operators | Coop | 10,454 |
| Fuel & Lube | Coof | 93 |
| Tires & Tubes | Coot | 23 |
| Electricity | Cooe | |
| Contract Service | Cooc | 59 |
| Other Labor | Cool | 1,770 |
| Other Nonlabor | Coon | 24 |
| Vehicle Maintenance | Com | |
| Labor | Coml | 371 |
| Contract Service | Comc | 70 |
| Fuel Lube/Service Veh. | Comf | 6 |
| Tires Tubes/Service Veh. | Comt | |
| Parts | Comp | 147 |
| Other Nonlabor | Comn | |
| Non-Vehicle Maintenance | Con | |
| Labor | Conl | 6 |
| Contract Service | Conc | 54 |
| Parts | Conp | 8 |
| Other Nonlabor | Conn | 54 |
| General Administration | Cog | |
| Labor | Cogl | 417 |
| Contract Service | Cogc | 255 |
| Supplier | Cogs | 31 |
| Insurance | Cogi | 178 |
| Other Nonlabor | Cogn | 147 |
| **TOTAL ANNUAL O&M COST** | | **14,166** |

## Table 5. Bus Transit System Costs

| Activity | Cost Category | Actual Cost (1000 $) | % of Total |
|---|---|---|---|
| Capital | Cc | | |
| Vehicles | Ccv | 44,255 | 8.38% |
| Way | Ccw | 210,000 | 39.76% |
| Yard/Depot | Ccy | 14,499 | 2.75% |
| Station | Ccs | 18,570 | 3.52% |
| Power & Utility | Ccp | | |
| Command, Control, & Comm. | Ccc | | |
| Engineering & Project Mgt. | Cce | | |
| **TOTAL CAPITAL** | | **287,324** | 54.40% |
| Operations & Maintenance | Co | | |
| Vehicle Operations | Coo | | |
| Operators | Coop | 177,718 | 33.65% |
| Fuel & Lube | Coof | 1,581 | 0.30% |
| Tires & Tubes | Coot | 391 | 0.07% |
| Electricity | Cooe | | |
| Contract Service | Cooc | 1,003 | 0.19% |
| Other Labor | Cool | 30,090 | 5.70% |
| Other Nonlabor | Coon | 408 | 0.08% |
| Vehicle Maintenance | Com | | |
| Labor | Coml | 6,307 | 1.19% |
| Contract Service | Comc | 1,190 | 0.23% |
| Fuel Lube/Service Veh. | Comf | 102 | 0.02% |
| Tires Tubes/Service Veh. | Comt | | |
| Parts | Comp | 2,499 | 0.47% |
| Other Nonlabor | Comn | | |
| Non-Vehicle Maintenance | Con | | |
| Labor | Conl | 102 | 0.02% |
| Contract Service | Conc | 918 | 0.17% |
| Parts | Conp | 136 | 0.03% |
| Other Nonlabor | Conn | 918 | 0.17% |
| General Administration | Cog | | |
| Labor | Cogl | 7,089 | 1.34% |
| Contract Service | Cogc | 4,335 | 0.82% |
| Supplier | Cogs | 527 | 0.10% |
| Insurance | Cogi | 3,026 | 0.57% |
| Other Nonlabor | Cogn | 2,499 | 0.47% |
| **TOTAL O&M** | | **240,839** | 45.60% |
| **GRAND TOTAL** | | **528,163** | 100.00% |

# APPENDIX D

# RAIL RAPID TRANSIT SYSTEM

This section presents the calculations related to the design of the RRT system. The RRT alternative involves extending the Washington Metropolitan Area Transit Authority (WMATA) Metrorail from the Vienna Metro station to Disney's America. Shuttle buses are used to transport visitors from the rail station to the east entrance of the park. Figure 10 shows the proposed RRT system.

## D.1 ASSUMPTIONS

In addition to the assumptions presented in section 3.3 regarding the transportation system in general, the following assumptions are relevant to the RRT system design.

### D.1.1 Rail

- Peak-hour load is 3,402 passengers.
- $\alpha$ is 0.9.
- Acceleration rate is 3 feet/second/second.
- Deceleration rate is 4 feet/second/second.
- Average duration of standing at stations $t_s$ is 25 seconds.
- The existing Metrorail system cannot handle the volume of Disney visitors without adding rail vehicles.
- A rail yard already exists, but it must be expanded to accommodate the additional vehicles needed to transport Disney visitors. Assume that the yard is at Vienna.

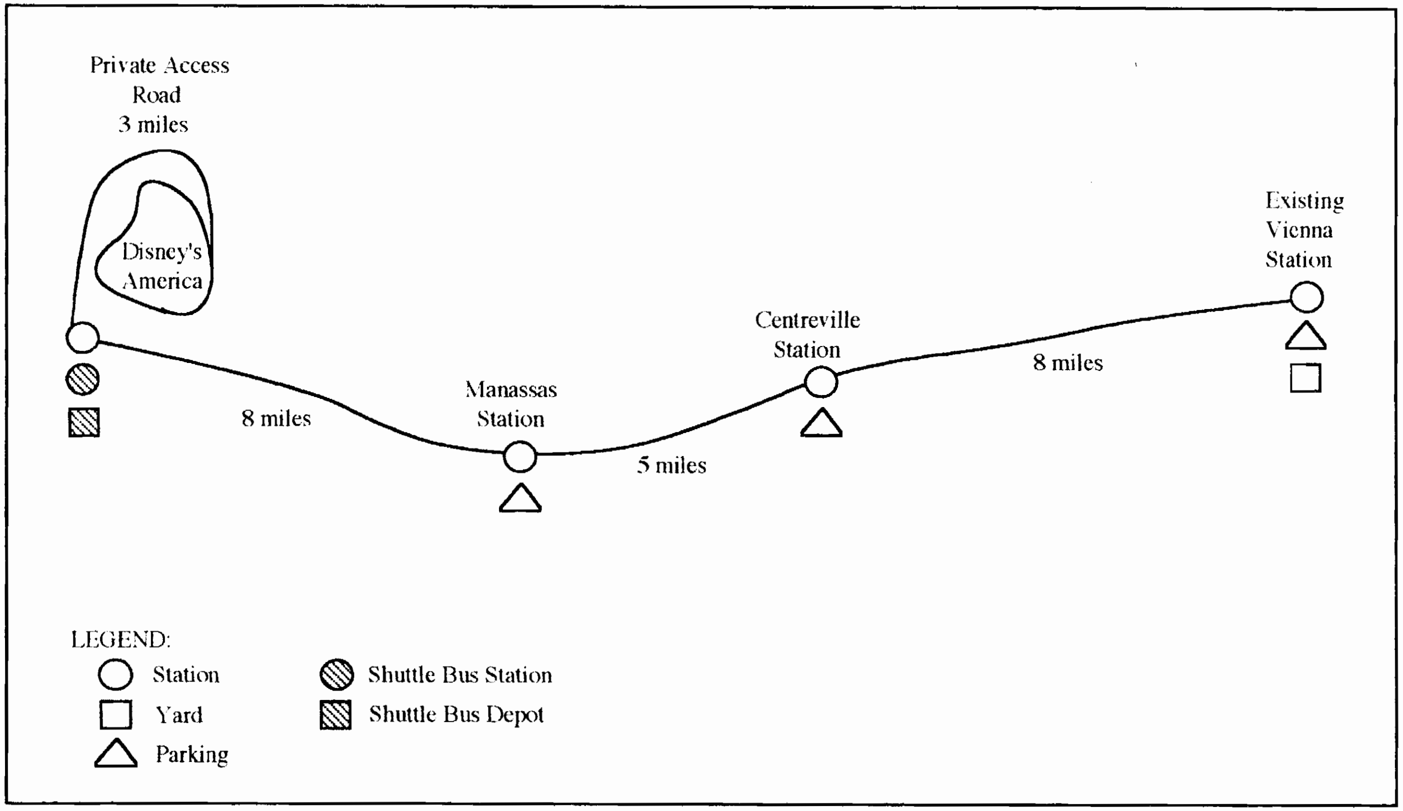



Figure 10. Rail Rapid Transit System

- Parking spaces must be added to the existing parking facilities at Vienna to accommodate Disney visitors who drive to the Metro station.
- Stations are needed at Centreville, Manassas, and the park site.
- Parking is available at the Vienna, Centreville, and Manassas stations.
- The one-way length of the rail segment of the route is 21 miles.
- Seating capacity of the vehicle is 68 people (actual Metrorail vehicle capacity) [10].
- Minimum scheduled headway in peak is 3 minutes (actual Metrorail headway) [10].
- Maximum operating speed is 75 mph (actual Metrorail maximum operating speed) [10].

### D.1.2 Shuttle Bus

- The one-way length of the shuttle bus segment of the route is 3 miles.
- Conventional transit buses (40') are used.
- The seating capacity of a shuttle bus is 53 passengers [3].
- The average operating speed on the private road is 45 mph.
- Peak-hour load is 3,402 passengers.

## D.2 CALCULATION OF AVERAGE OPERATING SPEED--RAIL

### D.2.1 Average Operating Speed--Vienna to Centreville

The maximum speed possible as a function of station spacing is determined by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$

$$= ((2*3*4*42{,}240)/(3 + 4))^{0.5}$$

$$= \underline{380.56} \text{ feet/second}$$

$$380.56 \text{ feet/second} = 259.47 \text{ mph}$$

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 42,240 feet (8 miles)

Travel time from Vienna to Centreville is determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$

$$= 42{,}240/110 + 110/2(1/3 + 1/4) + 25$$

$$= \underline{440.90} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (75 mph or 110 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 42,240 feet (8 miles)

Average speed from Vienna to Centreville is 95.80 feet/second (42,240/440.90) or 65 mph.

### D.2.2 Average Operating Speed--Centreville to Manassas

The maximum speed possible as a function of station spacing is found by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$

$$= ((2*3*4*26{,}400)/(3 + 4))^{0.5}$$

$$= \underline{300.86} \text{ feet/second}$$

$$300.86 \text{ feet/second} = 205.13 \text{ mph}$$

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 26,400 feet (5 miles)

Travel time from Centreville to Manassas is determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$

$$= 26{,}400/110 + 110/2(1/3 + 1/4) + 25$$

$$= \underline{296.90} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (75 mph or 110 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 26,400 feet (5 miles)

Average speed from Centreville to Manassas is 88.92 feet/second (26,400/296.90) or 60 mph.

### D.2.3 Average Operating Speed--Manassas to Disney's America

The average operating speed from Manassas to the Disney site is 65 mph (see above calculations for Vienna to Centreville).

## D.3 DESIGN CALCULATIONS

### D.3.1 Rail

#### D.3.1.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 68}{3{,}402}$$

$$= 1.08$$

= 1 minute, but minimum scheduled headway in peak hour is 3 minutes

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

#### D.3.1.2 Operating Time

From previous calculations, travel time ($T_s$) from Vienna to Centreville is 440.90 seconds or 7.35 minutes, travel time from Centreville to Manassas is 296.90 seconds or 4.95 minutes, and travel time from Manassas to Disney is 440.90 seconds or 7.35 minutes.

$$T_o = T_s = 7.35 + 4.95 + 7.35$$

$$= 19.65 \text{ minutes}$$

where:

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### D.3.1.3 Cycle Time

$$T = 2(T_o)$$
$$= 2(19.65)$$
$$= \underline{39.30} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### D.3.1.4 Number of Vehicles

$$N = T/h$$
$$= 39.30/3$$
$$= 13.10$$
$$= \underline{14} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further in the system design. The RRT system will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/39.30) shows that a rail vehicle will run 24 cycles each day. Each vehicle will carry 68 passengers per cycle, or 1,632 passengers per day. The system can transport 22,848 passengers per day, which exceeds the expected 11,340 daily park visitors.

### D.3.1.5 Total Number of Vehicles Required

$$\begin{aligned} \text{Total} &= N + \text{spares} \\ &= 14 + 1 \\ &= \underline{15} \text{ vehicles} \end{aligned}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

### D.3.1.6 Frequency of Service

$$\begin{aligned} f &= \frac{P}{\alpha * C_v} \\ &= \frac{3{,}402}{0.9 * 68} \\ &= 55.59 \\ &= \underline{56} \text{ vehicles per hour} \end{aligned}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the rail transit system is 56 vehicles per hour. Each vehicle carries 68 passengers, so the system can transport 3,808 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the rail transit system.

### D.3.2 Shuttle Bus

#### D.3.2.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 53}{3{,}402}$$

$$= 1.04$$

$$= \underline{1} \text{ minute}$$

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

### D.3.2.2 Operating Time

$$T_o = d/r * 60$$

$$= 3/45 * 60$$

$$= \underline{4} \text{ minutes}$$

where:

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

d: distance (in miles)

r: rate (in mph)

### D.3.2.3 Cycle Time

$$T = 2(T_o + t_t)$$

$$= 2(4.0 + 5)$$

$$= \underline{18.0} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

$t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

### D.3.2.4 Number of Vehicles

$$N = T/h$$

$$= 18/1$$

$$= \underline{18} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further in the system design. The shuttle bus portion of the RRT system will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/18) shows that a shuttle bus will run 53 cycles each day. Each bus will carry 53 passengers per cycle, or 2,809 passengers per day. The system's 18 shuttle buses can transport 50,562 passengers per day, which exceeds the expected 11,340 daily park visitors.

#### D.3.2.5 Total Number of Vehicles Required

$$\begin{aligned} \text{Total} &= \text{N} + \text{spares} \\ &= 18 + 1 \\ &= \underline{19} \text{ vehicles} \end{aligned}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

#### D.3.2.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$

$$= \frac{3,402}{0.9 * 53}$$

$$= 71.32$$

$$= \underline{72} \text{ vehicles per hour}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the shuttle buses is 72 vehicles per hour. Each bus carries 53 passengers, so the system can transport 3,816 park visitors during peak hour. This number exceeds the expected peak-hour load of 3,402 passengers.

## D.4 CAPITAL COST (Cc)

### D.4.1 Vehicle (Ccv)

#### D.4.1.1 Rail

The average capital cost of a rail rapid transit car was $1,230,000 in 1989 [3]. Using a 10% interest rate for five years, the compound-amount factor needed to find present value is 1.611 [21] Therefore, the capital cost of each rail car in 1994 dollars is $1,981,530 ($1,230,000 * 1.611).

$1,981,530 * 15 = <u>$29,722,950</u> capital cost of vehicles

#### D.4.1.2 Shuttle Bus

The average capital cost of a 40' conventional bus was $178,800 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each shuttle bus in 1994 dollars is $261,763 ($178,800 * 1.464).

$261,763 * 19 = $4,973,500 capital cost of shuttle buses

#### D.4.1.3 Total System

$29,722,950 capital cost of rail vehicles
<u>$ 4,973,500</u> capital cost of shuttle buses
<u>$34,696,450</u> total capital cost of vehicles

### D.4.2 Way (Ccw)

#### D.4.2.1 Rail

A 21-mile (33.81-kilometer) rail way will be built from the Vienna station to the park. The average cost of at-grade way was $2,850,000 per kilometer in the mid-1970's [10] Using a 10% interest rate for 19 years, the compound-amount factor needed to find present value is 6.116 [21]. Therefore the cost per kilometer in 1994 dollars is $17,430,600 ($2,850,000 * 6.116).

$17,430,600 * 33.81 km = <u>$589,328,586</u> capital cost of way

#### D.4.2.2 Shuttle Bus

The cost of providing the private road is the responsibility of the Walt Disney Company.

#### D.4.2.3 Total System

$589,328,586 capital cost of way - rail
0 capital cost of way - private road
$589,328,586 total cost of way

### D.4.3 Yard (Ccy)

#### D.4.3.1 Rail

The average cost per vehicle for a rail yard was $355,600 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost per vehicle for a rail yard in 1994 dollars is $520,598 ($355,600 * 1.464).

$520,598 * 15 = $7,808,976 capital cost of yard

#### D.4.3.2 Shuttle Bus

The average cost per vehicle for a bus depot is $107,289 [3].

$107,289 * 19 = $2,038,491 capital cost of depot

#### D.4.3.3 Total System

$7,808,976 capital cost of yard
$2,038,491 capital cost of depot
$9,847,467 total capital cost of yard/depot

### D.4.4 Station (Ccs)

#### D.4.4.1 Rail

The average capital cost of an at-grade station was $657,000 in 1990. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each station in 1994 dollars is $961,848 ($657,000 * 1.464).

Parking facilities will be provided at certain stations. These facilities may be high-rise garages or at-grade lots. Calculations to determine the number of parking spaces required, the cost of parking facilities, and the total station cost for the system are shown in the following subsections.

**D.4.4.1.1 Vienna Station.** The Vienna Metro station already exists. However, the parking facilities must be expanded to accommodate passengers to Disney's America. There will be 7,938 park visitors leaving from the Vienna station on peak days. It is assumed that 75% of the passengers going to the park will have boarded the Metro in the Washington area and thus will not have automobiles to park.

7,938 * 0.75 = 5,954 people will not have an automobile to park

7,938 - 5,954 = 1,984 people will have an automobile to park

It is also assumed that there will be two people in each automobile.

1,984/2 = 992 parking spaces are needed at Vienna station

There will be 300 parking spaces provided in a high-rise garage and 692 spaces provided in at-grade lots. It is assumed that the cost for each space in the high-rise garage is $10,000 and the cost for each space in the at-grade lots is $5,000 [10].

300 * $10,000 = $3,000,000 high rise
692 * $5,000 = $3,460,000 at-grade
$6,460,000 total parking cost at Vienna station

**D.4.4.1.2 Centreville Station.** There will be 1,701 people boarding at the Centreville station each day. It is assumed that there will be two people in each automobile.

1,701/2 = 851 parking spaces are needed at Centreville station

There are 300 parking spaces provided in a high-rise garage and 551 spaces provided in at-grade lots.

300 * $10,000 = $3,000,000 high rise
551 * $5,000 = $2,755,000 at-grade
$5,755,000 total parking cost at Centreville station

**D.4.4.1.3 Manassas Station.** Parking costs at the Manassas station are the same as costs at the Centreville station; i.e., $5,755,000.

**D.4.4.1.4 Disney Site.** No parking facilities are required at Disney's America.

**D.4.4.1.5 Rail Station Total.**

| | | |
|---|---|---|
| Vienna: | $ 6,460,000 | parking |
| | 0 | station |
| Centreville: | 5,755,000 | parking |
| | 961,848 | station |
| Manassas | 5,755,000 | parking |
| | 961,848 | station |
| Disney | 0 | parking |
| | 961,848 | station |
| Total | $20,855,544 | total rail station cost |

**D.4.4.2 Shuttle Bus**

One station will be required for the shuttle bus service. The station will be located near the park site. Parking facilities are not required. Assume that the cost of a station is $200,000 [10].

| | | |
|---|---|---|
| Disney | 0 | parking |
| | $200,000 | station |
| Total | $200,000 | total bus station cost |

**D.4.4.3 Total System**

| | |
|---|---|
| $20,855,544 | cost of rail stations |
| $ 200,000 | capital cost of bus station |
| $21,055,544 | total capital cost of stations |

**D.4.5 Power and Utility (Ccp)**

The cost of power and utility for an RRT system was $775,000 per kilometer in the mid-1970's [10]. Using a 10% interest rate for 19 years, the compound-amount factor needed to find present value is 6.116 [21]. Therefore, the cost per kilometer in 1994 dollars is $4,739,900. Twenty-one miles converts to 33.81 kilometers.

$4,739,900 * 33.81 = $160,256,019 capital cost of power and utility

### D.4.6 Command, Control, and Communication (Ccc)

The cost of command, control, and communications for an RRT system was $1,000,000 per kilometer in the mid-1970's [10]. Using a 10% interest rate for 19 years, the compound-amount factor needed to find present value is 6.116 [21]. Therefore, the cost per kilometer in 1994 dollars is $6,116,000.

$6,116,000 * 33.81 = $206,781,960 capital cost

### D.4.7 Engineering and Project Management (Cce)

The average cost of engineering and project management is 15% of the total capital cost of an RRT system [3]. The average total capital cost of the existing RRT system in Miami (with no underground segments) was $1,341,000,000 in 1988 dollars [3]. Using a 10% interest rate for six years, the compound-amount factor needed to find present value is 1.772 [21]. Therefore, the average total capital cost in 1994 dollars is $2,376,252,000.

$2,376,252,000 * 0.15 = $356,437,800 engineering and project management share of the total

Table 6 shows the capital cost for the RRT system.

## D.5 OPERATING AND MAINTENANCE COST (Co)

Operating and maintenance (O&M) cost items are based on cost per unit of service, where the unit of service may be platform hours, vehicle miles, or route miles. The units of service for the transit system must be determined before the O&M costs can be calculated.

Platform hours are the hours that the operator is in charge of the vehicle [23]. It is assumed that one operator is needed for each vehicle. There will be 18 RRT vehicles (not counting spares). Assuming that each operator is in charge of a vehicle for seven hours

Table 6. Rail Rapid Transit System Capital Cost

| Activity | Cost Category | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Capital Cost | Cc | | | |
| Vehicles | Ccv | 29,723 | 4,973 | 34,696 |
| Way | Ccw | 589,329 | | 589,329 |
| Yard/Depot | Ccy | 7,809 | 2,038 | 9,847 |
| Station | Ccs | 20,856 | 200 | 21,056 |
| Power & Utility | Ccp | 160,256 | | 160,256 |
| Command, Control, & Comm. | Ccc | 206,782 | | 206,782 |
| Engineering & Project Mgt. | Cce | 356,438 | | 356,438 |
| **TOTAL CAPITAL COST** | | **1,371,193** | **7,211** | **1,378,404** |

each day, the rail portion of the proposed RRT system involves 45,990 platform hours each year. There will also be 18 shuttle buses. The shuttle bus portion of the proposed RRT system involves 45,990 platform hours each year.

Vehicle miles are the miles that the vehicle travels. The system operates 16 hours a day, 365 days a year, for a total of 5,840 hours (or 350,400 minutes). The RRT vehicle requires 39.30 minutes to complete the 42-mile cycle. Dividing the total minutes by the cycle time and multiplying the result by 42 results in 374,472 RRT-vehicle miles per year. A shuttle bus requires 18 minutes to complete the 6-mile cycle. There will be 116,796 shuttle bus-vehicle miles per year.

Route miles represent the end-to-end mileage of the line [5]. The rail segment of the RRT system consists of 21 route miles, and the shuttle bus segment consists of 3 route miles.

Actual O&M cost data of the WMATA Metrorail for the year 1988 is used to estimate the O&M cost of the rail extension of the system. O&M data of the Chicago Sub Bus Division is used for the shuttle bus portion of the system. The source of the data is the O&M cost data base presented in DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems." The 1988 values have been converted to 1994 dollars. Table 7 shows the actual O&M cost for the RRT system.

Table 8 shows the RRT system costs and the percentage of total for each cost category.

Table 7. Rail Rapid Transit System Annual Operating and Maintenance Cost

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Annual Operations & Maintenance Cost | Co | | | |
| Vehicle Operations | Coo | | | |
| Operators | Coop | 1,983 | 1,742 | 3,725 |
| Fuel & Lube | Coof | | 25 | 25 |
| Tires & Tubes | Coot | | 6 | 6 |
| Electricity | Cooe | 385 | | 385 |
| Contract Service | Cooc | 12 | 10 | 22 |
| Other Labor | Cool | 2,792 | 295 | 3,087 |
| Other Nonlabor | Coon | 9 | 4 | 13 |
| Vehicle Maintenance | Com | | | |
| Labor | Coml | 518 | 99 | 617 |
| Contract Service | Comc | 7 | 19 | 25 |
| Fuel Lube/Service Veh. | Comf | 1 | 2 | 3 |
| Tires Tubes/Service Veh. | Comt | | | |
| Parts | Comp | 159 | 39 | 199 |
| Other Nonlabor | Comn | | | |
| Non-Vehicle Maintenance | Con | | | |
| Labor | Conl | 11,600 | 2 | 11,602 |
| Contract Service | Conc | 1,918 | 14 | 1,932 |
| Parts | Conp | 1,932 | 2 | 1,934 |
| Other Nonlabor | Conn | 229 | 1 | 231 |
| General Administration | Cog | | | |
| Labor | Cogl | 1,055 | 112 | 1,167 |
| Contract Service | Cogc | 73 | 68 | 141 |
| Supplier | Cogs | 246 | 8 | 254 |
| Insurance | Cogi | 106 | 48 | 154 |
| Other Nonlabor | Cogn | 212 | 39 | 252 |
| **TOTAL ANNUAL O&M COST** | | **23,236** | **2,536** | **25,772** |

# Table 8. Rail Rapid Transit System Costs

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System | % of Total |
|---|---|---|---|---|---|
| Capital | Cc | | | | |
| Vehicles | Ccv | 29,723 | 4,973 | 34,696 | 1.92% |
| Way | Ccw | 589,329 | | 589,329 | 32.67% |
| Yard/Depot | Ccy | 7,809 | 2,038 | 9,847 | 0.55% |
| Station | Ccs | 20,856 | 200 | 21,056 | 1.17% |
| Power & Utility | Ccp | 160,256 | | 160,256 | 8.88% |
| Command, Control, & Comm. | Ccc | 206,782 | | 206,782 | 11.46% |
| Engineering & Project Mgt. | Cce | 356,438 | | 356,438 | 19.76% |
| **TOTAL CAPITAL** | | **1,371,193** | **7,211** | **1,378,404** | 76.41% |
| Operations & Maintenance | Co | | | | |
| Vehicle Operations | Coo | | | | |
| Operators | Coop | 33,711 | 29,614 | 63,325 | 3.51% |
| Fuel & Lube | Coof | | 425 | 425 | 0.02% |
| Tires & Tubes | Coot | | 102 | 102 | 0.01% |
| Electricity | Cooe | 6,545 | | 6,545 | 0.36% |
| Contract Service | Cooc | 204 | 170 | 374 | 0.02% |
| Other Labor | Cool | 47,464 | 5,015 | 52,479 | 2.91% |
| Other Nonlabor | Coon | 153 | 68 | 221 | 0.01% |
| Vehicle Maintenance | Com | | | | |
| Labor | Coml | 8,806 | 1,683 | 10,489 | 0.58% |
| Contract Service | Comc | 119 | 323 | 442 | 0.02% |
| Fuel Lube/Service Veh. | Comf | 17 | 34 | 51 | 0.00% |
| Tires Tubes/Service Veh. | Comt | | | | |
| Parts | Comp | 2,703 | 663 | 3,366 | 0.19% |
| Other Nonlabor | Comn | | | | |
| Non-Vehicle Maintenance | Con | | | | |
| Labor | Conl | 197,200 | 34 | 197,234 | 10.93% |
| Contract Service | Conc | 32,606 | 238 | 32,844 | 1.82% |
| Parts | Conp | 32,844 | 34 | 32,878 | 1.82% |
| Other Nonlabor | Conn | 3,893 | 17 | 3,910 | 0.22% |
| General Administration | Cog | | | | |
| Labor | Cogl | 17,935 | 1,904 | 19,839 | 1.10% |
| Contract Service | Cogc | 1,241 | 1,156 | 2,397 | 0.13% |
| Supplier | Cogs | 4,182 | 136 | 4,318 | 0.24% |
| Insurance | Cogi | 1,802 | 816 | 2,618 | 0.15% |
| Other Nonlabor | Cogn | 3,604 | 663 | 4,267 | 0.24% |
| **TOTAL O&M** | | **395,029** | **30,549** | **425,578** | 24.29% |
| **GRAND TOTAL** | | | | **1,803,982** | 100.00% |

# APPENDIX E

# LIGHT RAIL TRANSIT SYSTEM

This section presents calculations related to the design of the LRT system. This alternative requires the construction of an LRT guideway from the Vienna Metrorail area to Disney's America. Shuttle buses are used to transport visitors from the LRT station to the east entrance of the park. Figure 11 shows the proposed LRT system.

## E.1 ASSUMPTIONS

In addition to the assumptions presented in section 3.3 regarding the transportation system in general, the following assumptions are relevant to the LRT system design.

### E.1.1 Rail

- Peak hour load is 3,402 passengers.
- $\alpha$ is 0.9.
- Acceleration rate is 3 feet/second/second.
- Deceleration rate is 4 feet/second/second.
- Average duration of standing at stations $t_s$ is 25 seconds.
- The LRT system operates at-grade.
- Stations are needed at Vienna, Centreville, Manassas, and the park site.
- Parking is available at the Vienna, Centreville, and Manassas stations.
- The one-way length of the rail segment of the route is 21 miles.
- Seating capacity of the vehicle is 64 people [10].
- Minimum scheduled headway in peak is 6 minutes [10].

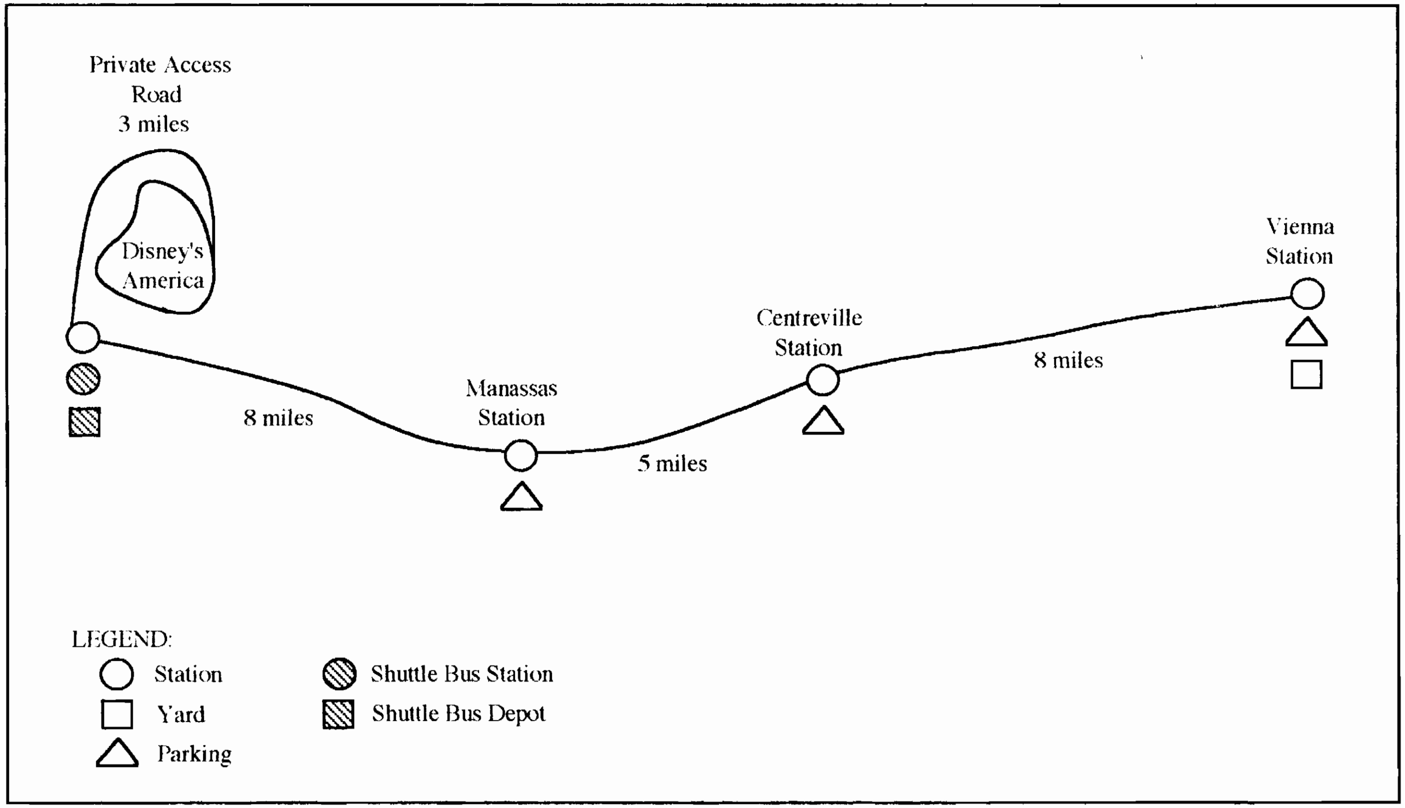



Figure 11. Light Rail Transit System

- Maximum operating speed is 51 mph [10].
- One rail yard is needed. Assume that the yard is at Vienna.

### E.1.2 Shuttle Bus

- The one-way length of the shuttle bus segment of the route is 3 miles.
- Conventional transit buses (40') will be used.
- The seating capacity of a shuttle bus is 53 passengers [3].
- The average operating speed on the private road is 45 mph.
- Peak hour load is 3,402 passengers.

## E.2 CALCULATION OF AVERAGE OPERATING SPEED--RAIL

### E.2.1 Average Operating Speed--Vienna to Centreville

The maximum speed possible as a function of station spacing is found by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$

$$= ((2*3*4*42{,}240)/(3 + 4))^{0.5}$$

$$= \underline{380.56} \text{ feet/second}$$

380.56 feet/second = 259.47 mph

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 42,240 feet (8 miles)

Travel time from Vienna to Centreville is determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$

$$= 42{,}240/74.8 + 74.8/2(1/3 + 1/4) + 25$$

$$= \underline{611.40} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (51 mph or 74.8 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 42,240 feet (8 miles)

Average speed from Vienna to Centreville is 69.09 feet/second (42,240/611.40) or 47 mph.

### E.2.2 Average Operating Speed--Centreville to Manassas

The maximum speed possible as a function of station spacing is found by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$

$$= ((2*3*4*26{,}400)/(3 + 4))^{0.5}$$

$$= \underline{300.86} \text{ feet/second}$$

300.86 feet/second = 205.13 mph

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 26,400 feet (5 miles)

Travel time from Centreville to Manassasis determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$

$$= 26{,}400/74.80 + 74.80/2(1/3 + 1/4) + 25$$

$$= \underline{399.63} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (51 mph or 74.8 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 26,400 feet (5 miles)

Average speed from Centreville to Manassas is 66.06 feet/second (26,400/399.63) or 45 mph.

### E.2.3 Average Operating Speed--Manassas to Disney

The average operating speed from Manassas to the Disney site is 47 mph (see above calculations for Vienna to Centreville).

## E.3 DESIGN CALCULATIONS

### E.3.1 Rail

#### E.3.1.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 64}{3,402}$$

$$= 1.01$$

= 1 minute, but minimum scheduled headway in peak hour is 6 minutes

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_V$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

#### E.3.1.2 Operating Time

From previous calculations, travel time ($T_S$) from Vienna to Centreville is 611.40 seconds or 10.19 minutes, travel time from Centreville to Manassas is 399.63 seconds or 6.66 minutes, and travel time from Manassas to Disney is 611.40 seconds or 10.19 minutes.

$$T_O = T_S = 10.19 + 6.66 + 10.19$$

$$= \underline{27.04} \text{ minutes}$$

where:

$T_O$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### E.3.1.3 Cycle Time

$$T = 2(T_O)$$

$$= 2(27.04)$$

$$= \underline{54.08} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_O$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### E.3.1.4 Number of Vehicles

$$N = T/h = 54.08/6 = 9.01 = \underline{10} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further in the system design. The LRT system will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/54.08) shows that a rail vehicle will run 17 cycles each day. Each vehicle will carry 64 passengers per cycle, or 1,088 passengers per day. The system can transport 10,880 passengers per day, which does not meet the expected volume of 11,340 daily park visitors. One additional rail vehicle is required to accommodate the 460 park visitors; therefore, the revised number of vehicles per cycle is 11 (N=11).

#### E.3.1.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares} = 11 + 1 = \underline{12} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

#### E.3.1.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$

$$= \frac{3{,}402}{0.9 * 64}$$

$$= 59.06$$

$$= \underline{60} \text{ vehicles per hour}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_V$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the LRT system is 60 vehicles per hour. Each vehicle carries 64 passengers, so the system can transport 3,840 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

### E.3.2 Shuttle Bus

#### E.3.2.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 53}{3{,}402}$$

$$= 1.04$$

$$= \underline{1} \text{ minute}$$

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

### E.3.2.2 Operating Time

$$T_o = d/r * 60$$

$$= 3/45 * 60$$

$$= \underline{4} \text{ minutes}$$

where:

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

d: distance (in miles)

r: rate (in mph)

### E.3.2.3 Cycle Time

$$T = 2(T_o + t_t)$$

$$= 2(4.0 + 5)$$

$$= \underline{18.0} \text{ minutes}$$

where:

- $T$: total round-trip time of a vehicle (in minutes) [10]
- $T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]
- $t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

#### E.3.2.4 Number of Vehicles

$$N = T/h$$
$$= 18/1$$
$$= \underline{18} \text{ vehicles}$$

where:

- $N$: the number of vehicles needed to serve peak hour passenger volume
- $T$: total round-trip time of a vehicle (in minutes) [10]
- $h$: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further. The shuttle bus service will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/18) shows that a bus will run 53 cycles per day. Each bus will carry 53 passengers, or 2,809 passengers per day. The system's 18 buses can transport 50,562 passengers per day, which exceeds the expected 3,402 daily park visitors.

### E.3.2.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares}$$
$$= 18 + 1$$
$$= \underline{19} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

### E.3.2.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$
$$= \frac{3{,}402}{0.9 * 53}$$
$$= 71.32$$
$$= \underline{72} \text{ vehicles per hour}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the shuttle bus portion of the LRT system is 72 vehicles per hour. Each vehicle carries 53 people, so the system can transport 3,816 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

## E.4 CAPITAL COST (Cc)

### E.4.1 Vehicle (Ccv)

#### E.4.1.1 Rail

The average capital cost of a light rail transit car was $1,580,000 in 1991 [3]. Using a 10% interest rate for three years, the compound-amount factor needed to find present value is 1.331 [21]. Therefore, the capital cost of each rail car in 1994 dollars is $2,102,980 ($1,580,000 * 1.331).

$2,102,980 * 12 = <u>$25,235,760</u> capital cost of vehicles

#### E.4.1.2 Shuttle Bus

The average capital cost of a 40' conventional bus was $178,800 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each shuttle bus in 1994 dollars is $261,763 ($178,800 * 1.464).

$261,783 * 19 = <u>$4,973,500</u> capital cost of shuttle buses

#### E.4.1.3 Total System

| | |
|---|---|
| $25,235,760 | capital cost of rail vehicles |
| <u>$ 4,973,500</u> | capital cost of shuttle buses |
| <u>$30,209,260</u> | total capital cost of vehicles |

### E.4.2 Way (Ccw)

#### E.4.2.1 Rail

A 21-mile rail way will be built from the Vienna station to the park. The average cost of way was $7,495,000 per route mile in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore the cost in 1994 dollars is $10,972,680 ($7,495,000 * 1.464).

$10,972,680 * 21 = <u>$230,426,280</u> capital cost of way

#### E.4.2.2 Shuttle Bus

The cost of providing the private road is the responsibility of the Walt Disney Company.

#### E.4.2.3 Total System

| | |
|---|---|
| $230,426,280 | capital cost of way - rail |
| 0 | capital cost of way - private road |
| $230,426,280 | total cost of way |

### E.4.3 Yard (Ccy)

#### E.4.3.1 Rail

The average cost per vehicle for a rail yard was $355,600 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost per vehicle for a rail yard in 1994 dollars is $520,598 ($355,600 * 1.464).

$520,598 * 12 = <u>$6,247,180</u> capital cost of yard

#### E.4.3.2 Shuttle Bus

The average cost per vehicle for a bus depot is $107,278 [3].

$107,278 * 19 = <u>$2,038,491</u> capital cost of depot

#### E.4.3.3 Total System

| | |
|---|---|
| $6,247,180 | capital cost of yard |
| $2,038,491 | capital cost of depot |
| $8,285,671 | total capital cost of yard/depot |

### E.4.4 Station (Ccs)

#### E.4.4.1 Rail

The average capital cost of an at-grade station was $657,000 in 1990. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each station in 1994 dollars is $961,848 ($657,000 * 1.464).

Parking facilities will be provided at certain stations. These facilities may be high-rise garages or at-grade lots. Calculations to determine the number of parking spaces required, the cost of parking facilities, and the total station cost for the system are shown in the following subsections.

**E.4.4.1.1 Vienna Station.** There will be 7,938 park visitors leaving from the Vienna station on peak days. It is assumed that 75% of the passengers going to the park will have boarded the Metro in the Washington area and thus will not have automobiles to park.

7,938 * 0.75 = 5,954 people will not have an automobile to park

7,938 - 5,954 = 1,984 people will have an automobile to park

It is also assumed that there will be two people in each automobile.

1,984/2 = 992 parking spaces are needed at Vienna station

There will be 300 parking spaces provided in a high-rise garage and 692 spaces provided in at-grade lots. It is assumed that the cost for each space in the high-rise garage is $10,000 and the cost for each space in the at-grade lots is $5,000 [10].

300 * $10,000 = $3,000,000 high rise
692 * $5,000 = $3,460,000 at-grade
$6,460,000 total parking cost at Vienna station

**E.4.4.1.2 Centreville Station.** There will be 1,701 people boarding at the Centreville station each day. It is assumed that there will be two people in each automobile.

1,701/2 = 851 parking spaces will be needed at Centreville station

There are 300 parking spaces provided in a high-rise garage and 551 spaces provided in at-grade lots.

| | | |
|---|---|---|
| 300 * $10,000 = | $3,000,000 | high rise |
| 551 * $5,000 = | $2,755,000 | at-grade |
| | $5,755,000 | total parking cost at Centreville station |

**E.4.4.1.3 Manassas Station.** Parking costs at the Manassas station are the same as costs at the Centreville station; i.e., $5,755,000.

**E.4.4.1.4 Disney Site.** No parking facilities are required at Disney's America.

**E.4.4.1.5 Rail Station Total**

| | | |
|---|---|---|
| Vienna | $ 6,460,000 | parking |
| | 961,848 | station |
| Centreville | 5,755,000 | parking |
| | 961,848 | station |
| Manassas | 5,755,000 | parking |
| | 961,848 | station |
| Disney | 0 | parking |
| | 961,848 | station |
| Total | $21,817,392 | capital cost |

**E.4.4.2 Shuttle Bus**

One station will be required for the shuttle bus service. The station will be located near the park site. Parking facilities are not required. Assume that the cost of a station is $200,000 [10].

| | | |
|---|---|---|
| Disney | 0 | parking |
| | $200,000 | station |
| Total | $200,000 | capital cost |

**E.4.4.3 Total System**

| | |
|---|---|
| $21,817,392 | capital cost of rail stations |
| $ 200,000 | capital cost of bus station |
| $22,017,392 | total capital cost of stations |

**E.4.5 Power and Utility (Ccp)**

The average cost of power and utility for an LRT system was $550,000 per kilometer in the mid-1970's [10]. Using a 10% interest rate and number of years equal to 19, the compound-amount factor needed to find present value is 6.116 [21]. Therefore, the cost per kilometer in 1994 dollars is $3,363,800. Twenty-one miles converts to 33.81 kilometers.

$3,363,800 * 33.81 = <u>$113,730,078</u> capital cost of power and utility

### E.4.6 Command, Control, and Communication (Ccc)

The average cost of command, control, and communications for an LRT system was $262,500 per kilometer in the mid-1970's [10]. Using a 10% interest rate for 19 years, the compound-amount factor needed to find present value is 6.116 [21]. Therefore, the cost per kilometer in 1994 dollars is $1,605,450.

$1,605,450 * 33.81 = <u>$54,280,264</u> capital cost

### E.4.7 Engineering and Project Management (Cce)

The average cost of engineering and project managment is $5,581,000 per route mile in 1990 dollars [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the average total capital cost in 1994 dollars is $8,170,584.

$8,170,584 * 21 = <u>$171,582,264</u> engineering and project management share of the total

Table 9 shows the capital cost of the LRT system.

## E.5 OPERATING AND MAINTENANCE COST (Co)

It is assumed that one operator is needed for each LRT vehicle. There will be 11 LRT vehicles (not counting spares). Assuming that each operator is in charge of a vehicle for seven hours each day, the rail portion of the LRT system involves 28,105

Table 9. Light Rail Transit System Capital Cost

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Capital Cost | Cc | | | |
| Vehicles | Ccv | 25,236 | 4,973 | 30,209 |
| Way | Ccw | 230,426 | | 230,426 |
| Yard/Depot | Ccy | 6,247 | 2,038 | 8,285 |
| Station | Ccs | 22,017 | 200 | 22,217 |
| Power & Utility | Ccp | 113,730 | | 113,730 |
| Command, Control, & Comm. | Ccc | 54,280 | | 54,280 |
| Engineering & Project Mgt. | Cce | 171,582 | | 171,582 |
| **TOTAL CAPITAL COST** | | **623,518** | **7,211** | **630,729** |

platform hours each year. There will also be 18 shuttle buses. The shuttle bus portion of the proposed LRT system also involves 45,990 platform hours each year.

An LRT vehicle requires 54.08 minutes to complete 42-mile cycle. Dividing the total minutes by the cycle time and multiplying the result by 42 results in 272,118 LRT-vehicle miles per year for the LRT system. A shuttle bus requires 18 minutes to complete the 6-mile cycle. There will be 116,796 shuttle bus-vehicle miles per year.

Route miles represent the end-to-end mileage of the line [5]. The rail segment of the LRT system consists of 21 route miles, and the shuttle bus segment consists of 3 route miles.

Actual O&M cost data of the Santa Clara Rapid Transit District (SCCTD) for the year 1988 is used to estimate the O&M cost of the rail portion system. O&M data of the Chicago Sub Bus Division is used the for shuttle bus portion of the system. The source of the data is the O&M cost data base presented in DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems." The 1988 values have been converted to 1994 dollars. Table 10 shows the actual O&M cost of the LRT system.

Table 11 shows the LRT system costs and the percentage of total for each cost category.

Table 10. Light Rail Transit System Annual Operating and Maintenance Cost

| Activity | Cost Category | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Annual Operating & Maintenance Cost | Co | | | |
| Vehicle Operations | Coo | | | |
| Operators | Coop | 2,247 | 1,742 | 3,989 |
| Fuel & Lube | Coof | | 25 | 25 |
| Tires & Tubes | Coot | | 6 | 6 |
| Electricity | Cooe | 564 | | 564 |
| Contract Service | Cooc | | 10 | 10 |
| Other Labor | Cool | 1,763 | 295 | 2,058 |
| Other Nonlabor | Coon | 236 | 4 | 240 |
| Vehicle Maintenance | Com | | | |
| Labor | Coml | 18,998 | 99 | 19,097 |
| Contract Service | Comc | 241 | 19 | 260 |
| Fuel Lube/Service Veh. | Comf | 5 | 2 | 7 |
| Tires Tubes/Service Veh. | Comt | | | |
| Parts | Comp | 24 | 39 | 63 |
| Other Nonlabor | Comn | 627 | | 627 |
| Non-Vehicle Maintenance | Con | | | |
| Labor | Conl | 2,122 | 2 | 2,124 |
| Contract Service | Conc | 67 | 14 | 81 |
| Parts | Conp | 208 | 2 | 210 |
| Other Nonlabor | Conn | 5 | 1 | 6 |
| General Administration | Cog | | | |
| Labor | Cogl | 1,823 | 112 | 1,935 |
| Contract Service | Cogc | 207 | 68 | 275 |
| Supplier | Cogs | 2 | 8 | 10 |
| Insurance | Cogi | 694 | 48 | 742 |
| Other Nonlabor | Cogn | 1,099 | 39 | 1,138 |
| **TOTAL ANNUAL O&M COST** | | **30,934** | **2,535** | **33,469** |

## Table 11. Light Rail Transit System Costs

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System | % of Total |
|---|---|---|---|---|---|
| Capital | Cc | | | | |
| Vehicles | Ccv | 25,236 | 4,973 | 30,209 | 2.52% |
| Way | Ccw | 230,426 | | 230,426 | 19.21% |
| Yard/Depot | Ccy | 6,247 | 2,038 | 8,285 | 0.69% |
| Station | Ccs | 22,017 | 200 | 22,217 | 1.85% |
| Power & Utility | Ccp | 113,730 | | 113,730 | 9.48% |
| Command, Control, & Comm. | Ccc | 54,280 | | 54,280 | 4.52% |
| Engineering & Project Mgt. | Cce | 171,582 | | 171,582 | 14.30% |
| **TOTAL CAPITAL** | | **623,518** | **7,211** | **630,729** | 52.57% |
| Operations & Maintenance | Co | | | | |
| Vehicle Operations | Coo | | | | |
| Operators | Coop | 38,199 | 29,614 | 67,813 | 5.65% |
| Fuel & Lube | Coof | | 425 | 425 | 0.04% |
| Tires & Tubes | Coot | | 102 | 102 | 0.01% |
| Electricity | Cooe | 9,588 | | 9,588 | 0.80% |
| Contract Service | Cooc | | 170 | 170 | 0.01% |
| Other Labor | Cool | 29,971 | 5,015 | 34,986 | 2.92% |
| Other Nonlabor | Coon | 4,012 | 68 | 4,080 | 0.34% |
| Vehicle Maintenance | Com | | | | |
| Labor | Coml | 322,966 | 1,683 | 324,649 | 27.06% |
| Contract Service | Comc | 4,097 | 323 | 4,420 | 0.37% |
| Fuel Lube/Service Veh. | Comf | 85 | 68 | 153 | 0.01% |
| Tires Tubes/Service Veh. | Comt | | | | |
| Parts | Comp | 408 | 663 | 1,071 | 0.09% |
| Other Nonlabor | Comn | 10,659 | | 10,659 | 0.89% |
| Non-Vehicle Maintenance | Con | | | | |
| Labor | Conl | 36,074 | 34 | 36,108 | 3.01% |
| Contract Service | Conc | 1,139 | 238 | 1,377 | 0.11% |
| Parts | Conp | 3,536 | 34 | 3,570 | 0.30% |
| Other Nonlabor | Conn | 85 | 17 | 102 | 0.01% |
| General Administration | Cog | | | | |
| Labor | Cogl | 30,991 | 1,904 | 32,895 | 2.74% |
| Contract Service | Cogc | 3,519 | 1,156 | 4,675 | 0.39% |
| Supplier | Cogs | 34 | 136 | 170 | 0.01% |
| Insurance | Cogi | 11,798 | 816 | 12,614 | 1.05% |
| Other Nonlabor | Cogn | 18,683 | 663 | 19,346 | 1.61% |
| **TOTAL O&M** | | **525,844** | **43,129** | **568,973** | 47.43% |
| **GRAND TOTAL** | | | | **1,199,702** | 100.00% |

# APPENDIX F

# COMMUTER RAIL TRANSIT SYSTEM

This section presents calculations related to the use of a commuter rail transit system. Two options are available for taking advantage of the existing VRE commuter rail service:

- **Option 1: Extend Commuter Rail .** This option involves extending the existing VRE commuter rail service from Manassas to Disney's America. Shuttle buses are used to transport visitors from the rail station located at Disney's America to the east entrance of the park. Figure 12 shows the proposed commuter rail and shuttle bus transit system.
- **Option 2: Bus way From Commuter Rail Station**. The existing commuter rail system is not extended; instead, an exclusive busway is constructed from VRE's Manassas rail station to Disney's America. Express buses (i.e., non-stop) transport visitors from the Manassas rail station directly to the east park entrance. Figure 13 shows the proposed express bus service.

## F.1 OPTION 1: EXTEND COMMUTER RAIL

### F.1.1 Assumptions

#### F.1.1.1 Rail

In addition to the assumptions presented in section 3.3 regarding the transportation system in general, the following assumptions are relevant to Option 1:

- System peak hour load is 3,402 passengers; these passengers will board at various existing stations along the VRE Manassas line.
- $\alpha$ is 0.9.

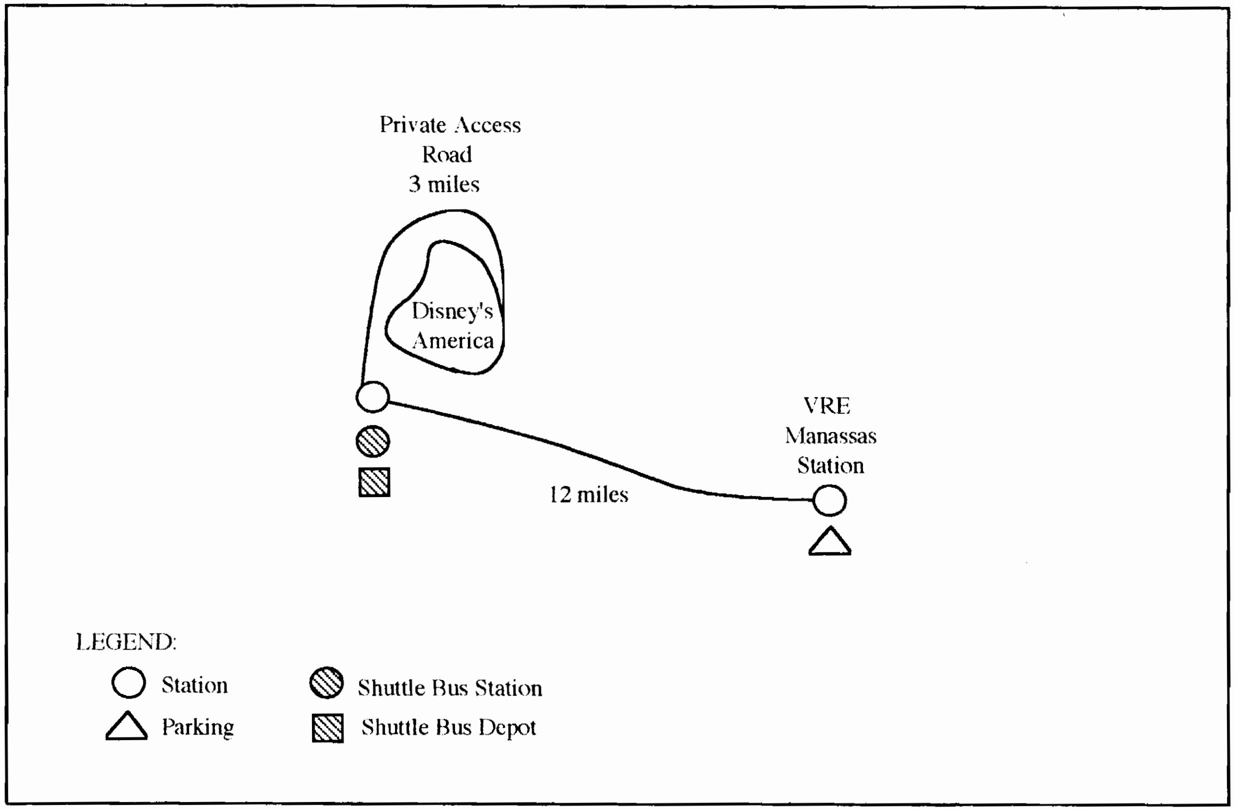



Figure 12. Commuter Rail Transit System
Option 1: Extend Commuter Rail

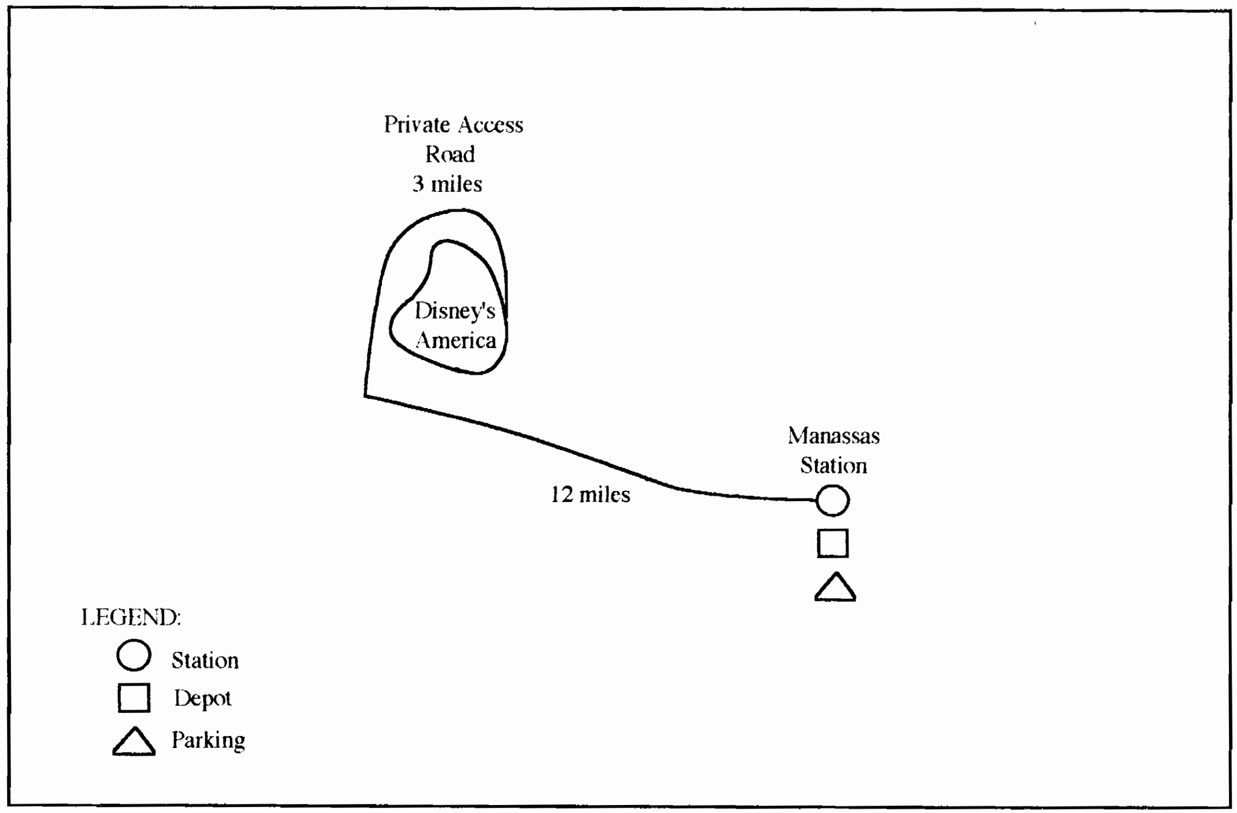



Figure 13. Commuter Rail Transit System
Option 2: Busway from Commuter Rail Station

- Acceleration rate is 3 feet/second/second.
- Deceleration rate is 4 feet/second/second.
- Average duration of standing at stations $t_s$ is 25 seconds.
- The existing VRE commuter rail service cannot handle the volume of Disney visitors without adding rail vehicles.
- A rail yard already exists, but it must be expanded to accommodate the additional vehicles needed to transport Disney visitors. Assume that the yard is in the Manassas area.
- Parking spaces must be added to the existing parking facilities at Manassas to accommodate Disney visitors who drive to the station.
- A station is needed at the park site.
- Parking is not needed at the park site.
- The one-way length of the rail segment of the route is 12 miles.
- Seating capacity of the vehicle is 124 people [10].
- Minimum scheduled headway is 20 minutes [10].
- Maximum operating speed is 81 mph [10].

#### F.1.1.2 Shuttle Bus

- The one-way length of the shuttle bus segment of the route is 3 miles.
- Conventional transit buses (40') will be used.
- The seating capacity of a shuttle bus is 53 passengers [3].
- The average operating speed on the private road is 45 mph.
- Peak hour load is 3,402 passengers.

### F.1.2 Calculation of Average Operating Speed--Rail

The maximum speed possible traveling from Manassas to Disney's America as a function of station spacing is found by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$
$$= ((2*3*4*63{,}360)/(3 + 4))^{0.5}$$
$$= \underline{466.08} \text{ feet/second}$$

466.08 feet/second = 317.78 mph

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 63,360 feet (12 miles)

Travel time from Manassas to Disney's America is determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$
$$= 63{,}360/118.80 + 118.80/2(1/3 + 1/4) + 25$$
$$= \underline{592.78} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (81 mph or 118.80 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 63,360 feet (12 miles)

Average speed from Manassas to Disney's America is 106.89 feet/second (63,360/592.78) or 72 mph.

### F.1.3 Design Calculations

#### F.1.3.1 Rail

##### F.1.3.1.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 124}{3{,}042}$$

$$= 1.97$$

= 1 minute, but minimum scheduled headway in peak hour is 20 minutes

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

##### F.1.3.1.2 Operating Time

From previous calculations, travel time ($T_s$) from Manassas to Disney's America is 592.78 seconds or 9.88 minutes.

$$T_o = T_s = 9.88 \text{ minutes}$$

where:

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### F.1.3.1.3 Cycle Time

$$T = 2(T_o)$$
$$= 2(9.88)$$
$$= \underline{19.76} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### F.1.3.1.4 Number of Vehicles

$$N = T/h$$
$$= 19.76/20$$
$$= 0.99$$
$$= \underline{1} \text{ vehicle}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further. The commuter rail service will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/19.76) shows that a commuter rail vehicle will run 48 cycles per day. Each vehicle will carry 124 passengers, or 5,952 passengers per day. The system's one vehicle can transport 5,952 passengers per day, which does not meet the expected volume of 11,340 daily park visitors. One additional rail vehicle is required to accommodate the 5,388 park visitors; therefore, the revised number of vehicles per cycle is 2 (N=2).

#### F.1.3.1.5 Total Number of Vehicles Required

$$\begin{aligned} \text{Total} &= N + \text{spares} \\ &= 2 + 0 \\ &= \underline{2} \text{ vehicles} \end{aligned}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

Since this alternative proposes the extension of existing commuter rail service and only two additional vehicles are required, it is assumed that the existing fleet will already contain a spare vehicle that could be used to cover the proposed service extension.

#### F.1.3.1.6 Frequency of Service

$$\begin{aligned} f &= \frac{P}{\alpha * C_v} \\ &= \frac{3{,}402}{0.9 * 124} \\ &= 30.48 \\ &= \underline{31} \text{ vehicles per hour} \end{aligned}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the commuter rail transit system is 31 vehicles per hour. Each vehicle carries 124 passengers, so the system can transport 3,844 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

### F.1.3.2 Shuttle Bus

#### F.1.3.2.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 53}{2,673}$$

$$= 1.07$$

$$= \underline{1} \text{ minute}$$

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$ : load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

#### F.1.3.2.2 Operating Time

$$T_o = d/r * 60$$
$$= 3/45 * 60$$
$$= \underline{4} \text{ minutes}$$

where:

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

d: distance (in miles)

r: rate (in mph)

#### F.1.3.2.3 Cycle Time

$$T = 2(T_o + t_t)$$
$$= 2(4.0 + 5)$$
$$= \underline{18.0} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

$t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

#### F.1.3.2.4 Number of Vehicles

$$N = T/h$$
$$= 18/1$$
$$= \underline{18} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further. The shuttle bus segment of the commuter rail service will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/18) shows that a commuter rail vehicle will run 53 cycles per day. Each vehicle will carry 53 passengers, or 2,809 passengers per day. The system's 18 buses can transport 50,562 passengers per day, which exceeds the expected volume of 11,340 daily park visitors.

#### F.1.3.2.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares}$$
$$= 18 + 1$$
$$= \underline{19} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

#### F.1.3.2.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$

$$= \frac{3{,}402}{0.9 * 53}$$

$$= 71.32$$

$= \underline{72}$ vehicles per hour

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the shuttle bus portion of the commuter rail transit system is 72 vehicles per hour. Each vehicle carries 53 passengers, so the system can transport 3,816 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

#### F.1.4. Capital Cost (Cc)

#### F.1.4.1 Vehicle (Ccv)

##### F.1.4.1.1 Rail

The average capital cost of a commuter rail transit car was $2,520,000 in 1991 [3]. Using a 10% interest rate for three years, the compound-amount factor needed to find present value is 1.331 [21]. Therefore, the capital cost of each rail car in 1994 dollars is $3,354,120 ($2,520,000* 1.331).

$3,354,120 * 2 = <u>$6,708,240</u> capital cost of vehicles

##### F.1.4.1.2 Shuttle Bus

The average capital cost of a 40' conventional bus was $178,800 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each shuttle bus in 1994 dollars is $261,763 ($178,800 * 1.464).

$261,763 * 19 = <u>$4,973,500</u> capital cost of vehicles

##### F.1.4.1.3 Total System

| | |
|---|---|
| $ 6,708,240 | capital cost of rail vehicles |
| <u>$ 4,973,500</u> | capital cost of shuttle buses |
| $<u>11,681,740</u> | total capital cost of vehicles |

#### F.1.4.2 Way (Ccw)

##### F.1.4.2.1 Rail

The length of the proposed commuter rail extension is 12 miles, and the cost of way is $3,940,298 per mile [4].

$3,940,298 * 12 = $47,283,576 capital cost of way

##### F.1.4.2.2 Shuttle Bus

The cost of providing the private road is the responsibility of the Walt Disney Company.

#### F.1.4.2.3 Total System

| | |
|---|---|
| $47,283,576 | capital cost of way - rail |
| 0 | capital cost of way - private road |
| $47,283,576 | total cost of way |

### F.1.4.3 Yard (Ccy)

#### F.1.4.3.1 Rail

The average cost per vehicle for a rail yard was $355,600 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost per vehicle for a rail yard in 1994 dollars is $520,598 ($355,600 * 1.464).

$520,598 * 2 = $1,041,196 capital cost of yard

#### F.1.4.3.2 Shuttle Bus

The average cost per vehicle for a bus depot is $107,278 [3].

$107,278 * 19 = $2,038,491 capital cost of depot

#### F.1.4.3.3 Total System

| | |
|---|---|
| $1,041,196 | capital cost of yard |
| $2,038,491 | capital cost of depot |
| $3,079,687 | total capital cost of yard/depot |

### F.1.4.4 Station (Ccs)

#### F.1.4.4.1 Rail

The average capital cost of an at-grade station was $657,000 in 1990. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each station in 1994 dollars is $961,848 ($657,000 * 1.464).

- **Manassas Station**. A commuter rail station exists at Manassas, but parking at the station must be expanded to accommodate the 1,701 travelers to Disney who will board there (see Appendix B for calculations). It is assumed that there will be two people in each automobile.

1,701/2 = 851 parking spaces are needed

There are 300 parking spaces provided in a high-rise garage and 551 spaces provided in at-grade lots.

| | | | |
|---|---|---|---|
| 300 * $10,000 | = | $3,000,000 | high rise |
| 551 * $ 5,000 | = | $2,755,000 | at-grade |
| | | $5,755,000 | total parking cost at Manassas |

- **Disney Site**. A new rail station must be built at the Disney's America site, but parking facilities will not be provided.
- **Rail Station Total.**

| | | |
|---|---|---|
| Manassas | 5,755,000 | parking |
| | 0 | station |
| Disney | 0 | parking |
| | 961,848 | station |
| Total | $ 6,716,848 | capital cost |

### F.1.4.4.2 Shuttle Bus

One station will be required for the shuttle bus service. The station will be located near the park site. Parking facilities are not required. Assume that the cost of a station is $200,000 [10].

| | | |
|---|---|---|
| Disney | 0 | parking |
| | $200,000 | station |
| Total | $200,000 | capital cost |

### F.1.4.4.3 Total System

| | |
|---|---|
| $6,716,848 | capital cost of rail stations |
| $ 200,000 | capital cost of bus station |
| $6,916,848 | total capital cost of stations |

#### F.1.4.5 Power and Utility (Ccp)

The capital cost of power and utility for a commuter rail transit system is assumed to be the same as for an RRT system.

The cost of power and utility for a commuter rail transit system was $775,000 per kilometer in the mid-1970's [10]. Using a 10% interest rate for 19 years, the compound-amount factor needed to find present value is 6.116 [21]. Therefore, the cost per kilometer in 1994 dollars is $4,739,900. Twenty-one miles converts to 33.81 kilometers.

$4,739,900 * 33.81 = $160,256,019 capital cost of power and utility

#### F.1.4.6 Command, Control, and Communication (Ccc)

The capital cost of command, control, and communication for a commuter rail transit system is assumed to be the same as for an RRT system.

The cost of command, control, and communications for a commuter rail transit system was $1,000,000 per kilometer in the mid-1970's [3]. Using a 10% interest rate for 19 years, the compound-amount factor needed to find present value is 6.116 [21]. Therefore, the cost per kilometer in 1994 dollars is $6,116,000.

$6,116,000 * 33.81 = $206,781,960 capital cost

#### F.1.4.7 Engineering and Project Management (Cce)

The capital cost of engineering and project management for a commuter rail transit system is assumed to be the same as for an RRT system.

The average cost of engineering and project managment is 15% of the total capital cost of the system [3]. The average total capital cost of an existing RRT system in Miami (with no underground segments) was $1,341,000,000 in 1988 dollars [3]. Using a 10%

interest rate for six years, the compound-amount factor needed to find present value is 1.772 [21]. Therefore, the average total capital cost in 1994 dollars is $2,376,252,000.

$2,376,252,000 * 0.15 = $356,437,800 engineering and project management share of the total

Table 12 shows the capital cost for the commuter rail transit system (option 1).

### F.1.5 Operating and Maintenance Cost (Co)

It is assumed that one operator is needed for each commuter rail vehicle. There will be two commuter rail vehicle (not counting spares). Assuming that each operator is in charge of a vehicle for seven hours each day, the rail portion of the transit system involves 5,110 platform hours each year. There will also be 18 shuttle buses. The shuttle bus portion of the system involves 45,990 platform hours each year.

The rail vehicle requires 19.76 minutes to complete 24-mile cycle. Dividing the total minutes by the cycle time and multiplying the result by 24 results in 425,568 rail-vehicle miles per year for the commuter rail transit system. A shuttle bus requires 18 minutes to complete the 6-miles cycle. There will be 116,796 shuttle bus-vehicle miles per year.

Route miles represent the end-to-end mileage of the line [5]. The rail segment of the system consists of 12 route miles, and the shuttle bus segment consists of 3 route miles.

Actual O&M cost data of the Staten Island Rapid Transit Operating Authority for the year 1988 is used to estimate the O&M cost of the rail portion system. O&M data of the Chicago Sub Bus Division is used for the shuttle bus portion of the system. The source of the data is the O&M cost data base presented in DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems." The 1988 values have been

Table 12. Commuter Rail Transit System Capital Cost: Option 1

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Capital Cost | Cc | | | |
| Vehicles | Ccv | 6,708 | 4,973 | 11,681 |
| Way | Ccw | 47,284 | | 47,284 |
| Yard/Depot | Ccy | 1,041 | 2,038 | 3,079 |
| Station | Ccs | 6,717 | 200 | 6,917 |
| Power & Utility | Ccp | 160,256 | | 160,256 |
| Command, Control, & Comm. | Ccc | 206,782 | | 206,782 |
| Engineering & Project Mgt. | Cce | 356,438 | | 356,438 |
| **TOTAL CAPITAL COST** | | **785,226** | **7,211** | **792,437** |

converted to 1994 dollars. Table 13 shows the actual O&M cost of the commuter rail extension.

Table 14 shows the commuter rail transit system costs (option 1) and the percentage of total of each cost category.

## F.2 OPTION 2: BUSWAY FROM COMMUTER RAIL STATION

### F.2.1 Assumptions

In addition to the assumptions presented in section 3.3 regarding the transportation system in general, the following assumptions are relevant to Option 2:

- LRT could be used to transport visitors from the existing commuter rail station in Manassas to the shuttle bus station at Disney's America. However,it is assumed that users of the transportation system will want the convenience of minimal transfers, and LRT will require an additional transfer; i.e., commuter rail=>LRT=>shuttle bus. Therefore, an LRT segment is not used in the design.
- The busway is exclusive; buses only.
- The busway is two lanes, one in each direction.
- The cost of constructing the two-lane busway is $10 million per mile [10].
- The one-way length of the busway is 12 miles.
- The one-way length of the entire route is 15 miles.
- Articulated buses (60') will be used.
- Seating capacity of articulated buses is 73 passengers [3].
- Terminal time ($t_t$) is 5 minutes.

Table 13. Commuter Rail Transit System Annual Operating and Maintenance Cost: Option 1

| Activity | Cost Category | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Annual Operating & Maintenance Cost | Co | | | |
| Vehicle Operations | Coo | | | |
| Operators | Coop | 27,125 | 1,742 | 28,867 |
| Fuel & Lube | Coof | | 25 | 25 |
| Tires & Tubes | Coot | | 6 | 6 |
| Electricity | Cooe | 98 | | 98 |
| Contract Service | Cooc | | 10 | 10 |
| Other Labor | Cool | | 295 | 295 |
| Other Nonlabor | Coon | 1,207 | 4 | 1,211 |
| Vehicle Maintenance | Com | | | |
| Labor | Coml | 739 | 99 | 838 |
| Contract Service | Comc | | 19 | 19 |
| Fuel Lube/Service Veh. | Comf | | 2 | 2 |
| Tires Tubes/Service Veh. | Comt | | | |
| Parts | Comp | 60 | 39 | 99 |
| Other Nonlabor | Comn | 23 | | 23 |
| Non-Vehicle Maintenance | Con | | | |
| Labor | Conl | 3,222 | 2 | 3,224 |
| Contract Service | Conc | | 14 | 14 |
| Parts | Conp | 289 | 2 | 291 |
| Other Nonlabor | Conn | 113 | 1 | 114 |
| General Administration | Cog | | | |
| Labor | Cogl | 1,395 | 112 | 1,507 |
| Contract Service | Cogc | | 68 | 68 |
| Supplies | Cogs | 121 | 8 | 129 |
| Insurance | Cogi | | 48 | 48 |
| Other Nonlabor | Cogn | 45 | 39 | 84 |
| **TOTAL ANNUAL O&M COST** | | **34,437** | **2,535** | **36,972** |

Table 14. Commuter Rail Transit System Costs: Option 1

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System | % of Total |
|---|---|---|---|---|---|
| Capital | Cc | | | | |
| Vehicles | Ccv | 6,708 | 4,973 | 11,681 | 0.82% |
| Way | Ccw | 47,284 | | 47,284 | 3.33% |
| Yard/Depot | Ccy | 1,041 | 2,038 | 3,079 | 0.22% |
| Station | Ccs | 6,717 | 200 | 6,917 | 0.49% |
| Power & Utility | Ccp | 160,256 | | 160,256 | 11.28% |
| Command, Control, & Comm. | Ccc | 206,782 | | 206,782 | 14.55% |
| Engineering & Project Mgt. | Cce | 356,438 | | 356,438 | 25.08% |
| **TOTAL CAPITAL** | | **785,226** | **7,211** | **792,437** | 55.77% |
| Operations & Maintenance | Co | | | | |
| Vehicle Operations | Coo | | | | |
| Operators | Coop | 461,125 | 29,614 | 490,739 | 34.54% |
| Fuel & Lube | Coof | | 425 | 425 | 0.03% |
| Tires & Tubes | Coot | | 102 | 102 | 0.01% |
| Electricity | Cooe | 1,666 | | 1,666 | 0.12% |
| Contract Service | Cooc | | 170 | 170 | 0.01% |
| Other Labor | Cool | | 5,015 | 5,015 | 0.35% |
| Other Nonlabor | Coon | 20,519 | 68 | 20,587 | 1.45% |
| Vehicle Maintenance | Com | | | | |
| Labor | Coml | 12,563 | 1,683 | 14,246 | 1.00% |
| Contract Service | Comc | | 323 | 323 | 0.02% |
| Fuel Lube/Service Veh. | Comf | | 34 | 34 | 0.00% |
| Tires Tubes/Service Veh. | Comt | | | | |
| Parts | Comp | 1,020 | 663 | 1,683 | 0.12% |
| Other Nonlabor | Comn | 391 | | 391 | 0.03% |
| Non-Vehicle Maintenance | Con | | | | |
| Labor | Conl | 54,774 | 34 | 54,808 | 3.86% |
| Contract Service | Conc | | 238 | 238 | 0.02% |
| Parts | Conp | 4,913 | 34 | 4,947 | 0.35% |
| Other Nonlabor | Conn | 1,921 | 17 | 1,938 | 0.14% |
| General Administration | Cog | | | | |
| Labor | Cogl | 23,715 | 1,904 | 25,619 | 1.80% |
| Contract Service | Cogc | | 1,156 | 1,156 | 0.08% |
| Supplier | Cogs | 2,057 | 136 | 2,193 | 0.15% |
| Insurance | Cogi | | 816 | 816 | 0.06% |
| Other Nonlabor | Cogn | 765 | 663 | 1,428 | 0.10% |
| **TOTAL O&M** | | **585,429** | **43,095** | **628,524** | 44.23% |
| **GRAND TOTAL** | | | | **1,420,961** | 100.00% |

- Average operating speed is 50 mph on the busway and 45 mph on the private road.
- Minimum headway is 3 seconds [10].
- A new station is needed at Manassas. An area for boarding and unloading at Disney's America will already exist.
- Parking is available at the Manassas station.
- One bus depot is needed, and it will be located at Manassas.

## F.2.2 Design Calculations

### F.2.2.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 73}{3{,}402}$$

$$= 1.16$$

$$= \underline{1} \text{ minute}$$

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

### F.2.2.2 Operating Time

$$T_o = (d/r) * 60$$
$$= (12/50) * 60 + (3/45) * 60$$
$$= 14.40 + 4.0$$
$$= \underline{18.40} \text{ minutes}$$

where:

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

d: distance

r: rate

### F.2.2.3 Cycle Time

$$T = 2(T_o + t_t)$$
$$= 2(18.40 + 5)$$
$$= \underline{46.80} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_o$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

$t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

#### F.2.2.4 Number of Vehicles

$$N = T/h$$
$$= 46.80/1$$
$$= 46.80$$
$$= \underline{47} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further. The buses will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/46.80) shows that a bus will run 20 cycles per day. Each vehicle will carry 73 passengers, or 1,460 passengers per day. The system's 47 buses can transport 68,620 passengers per day, which exceeds the expected volume of 11,340 daily park visitors.

#### F.2.2.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares}$$
$$= 47 + 4$$
$$= \underline{51} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

#### F.2.2.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$

$$= \frac{3,402}{0.9 * 73}$$

$$= 51.78$$

$$= \underline{52} \text{ vehicles per hour}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the buses is 52 vehicles per hour. Each vehicle carries 73 passengers, so the system can transport 3,796 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

### F.2.3 Capital Cost (Cc)

#### F.2.3.1 Vehicle (Ccv)

The average capital cost of a 60' articulated bus was $279,900 in 1990 dollars [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each articulated bus in 1994 dollars is $409,773 ($279,900 * 1.464).

$409,773 * 51 = $20,898,453 capital cost of vehicles

### F.2.3.2 Way (Ccw)

A 12-miles busway will be built from the Manassas commuter rail station to the park. The Walt Disney Company is responsible for the cost of the three-mile private access road.

$10,000,000 * 12 = $120,000,000 capital cost of way

### F.2.3.3 Depot (Ccy)

The average cost per vehicle for a bus facility without indoor vehicle storage was $91,700 in 1990 dollars [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost per vehicle for a bus depot in 1994 dollars is $134,248 ($91,700 * 1.464).

$134,248 * 51 buses = $6,846,648 capital cost of depot

### F.2.3.4 Station (Ccs)

A new bus station must be built at Manassas. The cost of a bus station is assumed to be $200,000 [10]. Parking facilities will be provided for the 1,701 travelers to Disney who will board at Manassas (see Appendix B for calculations). It is assumed that there will be two people in each automobile.

1,701/2 = 851 parking spaces are needed

There are 300 parking spaces provided in a high-rise garage and 551 spaces provided in at-grade lots.

300 * $10,000 = $3,000,000 high rise
551 * $ 5,000 = $2,755,000 at-grade
200,000 station
$5,955,000 total station cost

### F.2.3.5 Power and Utility (Ccp)

This item is not a major cost contributor for buses and is not addressed [9].

#### F.2.3.6 Command, Control, and Communication (Ccc)

Command, control, and communication for a bus system consists of two-way voice radios and silent alarms [9]. This cost item is insignificant for buses and is not addressed.

#### F.2.3.7 Engineering and Project Management (Cce)

This item is not a major cost contributor for buses and is not addressed [9].

Table 15 shows the capital cost of the commuter rail transit system (option 2).

### F.2.4 Operating and Maintenance Cost (Co)

It is assumed that one operator is needed for each bus. There are 47 buses (not counting spares). Assuming that each operator is in charge of a vehicle for seven hours each day, the busway extension to the existing commuter rail system involves 120,085 platform hours each year.

The bus requires 46.80 minutes to complete 30-mile cycle. Dividing the total minutes by the cycle time and multiplying the result by 30 results in 224,610 vehicle miles per year for the busway extension to the commuter rail transit system.

Route miles represent the end-to-end mileage of the line [5]. The busway consists of 15 route miles.

Actual O&M cost data of the Chicago Sub Bus Division for the year 1988 is used to estimate the O&M cost of the bus extension. The source of the data is the O&M cost data base presented in DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems." The 1988 values have been converted to 1994 dollars. Table 16 shows the actual O&M cost of the busway from the commuter rail station.

Table 17 shows the commuter rail transit system costs (option 2).

Table 15. Commuter Rail Transit System Capital Cost: Option 2

| Activity | Cost Category | Actual Cost (1000 $) |
|---|---|---|
| Capital Cost | Cc | |
| Vehicles | Ccv | 20,898 |
| Way | Ccw | 120,000 |
| Yard/Depot | Ccy | 6,847 |
| Station | Ccs | 5,955 |
| Power & Utility | Ccp | |
| Command, Control, & Comm. | Ccc | |
| Engineering & Project Mgt. | Cce | |
| **TOTAL CAPITAL COST** | | **153,700** |

Table 16. Commuter Rail Transit System Annual Operating and Maintenance Cost: Option 2

| Activity | Cost Category | Actual Cost (1000 $) |
|---|---|---|
| Annual Operating & Maintenance Cost | Co | |
| Vehicle Operations | Coo | |
| Operators | Coop | 4,549 |
| Fuel & Lube | Coof | 48 |
| Tires & Tubes | Coot | 12 |
| Electricity | Cooe | |
| Contract Service | Cooc | 26 |
| Other Labor | Cool | 770 |
| Other Nonlabor | Coon | 11 |
| Vehicle Maintenance | Com | |
| Labor | Coml | 191 |
| Contract Service | Comc | 36 |
| Fuel Lube/Service Veh. | Comf | 3 |
| Tires Tubes/Service Veh. | Comt | |
| Parts | Comp | 76 |
| Other Nonlabor | Comn | |
| Non-Vehicle Maintenance | Con | |
| Labor | Conl | 3 |
| Contract Service | Conc | 28 |
| Parts | Conp | 4 |
| Other Nonlabor | Conn | 28 |
| General Administration | Cog | |
| Labor | Cogl | 215 |
| Contract Service | Cogc | 131 |
| Supplies | Cogs | 16 |
| Insurance | Cogi | 92 |
| Other Nonlabor | Cogn | 76 |
| **TOTAL ANNUAL O&M COST** | | **6,315** |

## Table 17. Commuter Rail Transit System Costs: Option 2

| Activity | Cost Category | Actual Cost (1000 $) | % of Total |
|---|---|---|---|
| Capital | Cc | | |
| Vehicles | Ccv | 20,898 | 7.88% |
| Way | Ccw | 120,000 | 45.25% |
| Yard/Depot | Ccy | 6,847 | 2.58% |
| Station | Ccs | 5,955 | 2.25% |
| Power & Utility | Ccp | | |
| Command, Control, & Comm. | Ccc | | |
| Engineering & Project Mgt. | Cce | | |
| **TOTAL CAPITAL** | | **153,700** | 57.96% |
| Operations & Maintenance | Co | | |
| Vehicle Operations | Coo | | |
| Operators | Coop | 77,333 | 29.16% |
| Fuel & Lube | Coof | 816 | 0.31% |
| Tires & Tubes | Coot | 204 | 0.08% |
| Electricity | Cooe | | |
| Contract Service | Cooc | 4,556 | 1.72% |
| Other Labor | Cool | 13,090 | 4.94% |
| Other Nonlabor | Coon | 187 | 0.07% |
| Vehicle Maintenance | Com | | |
| Labor | Coml | 3,247 | 1.22% |
| Contract Service | Comc | 612 | 0.23% |
| Fuel Lube/Service Veh. | Comf | 51 | 0.02% |
| Tires Tubes/Service Veh. | Comt | | |
| Parts | Comp | 1,292 | 0.49% |
| Other Nonlabor | Comn | | |
| Non-Vehicle Maintenance | Con | | |
| Labor | Conl | 51 | 0.02% |
| Contract Service | Conc | 476 | 0.18% |
| Parts | Conp | 68 | 0.03% |
| Other Nonlabor | Conn | 476 | 0.18% |
| General Administration | Cog | | |
| Labor | Cogl | 3,655 | 1.38% |
| Contract Service | Cogc | 2,227 | 0.84% |
| Supplier | Cogs | 272 | 0.10% |
| Insurance | Cogi | 1,564 | 0.59% |
| Other Nonlabor | Cogn | 1,292 | 0.49% |
| **TOTAL O&M** | | **111,469** | 42.04% |
| **GRAND TOTAL** | | **265,169** | 100.00% |

# APPENDIX G

# AUTOMATED GUIDEWAY TRANSIT SYSTEM

This section presents calculations related to the design of the AGT system. The AGT alternative requires the construction of a guideway from the Vienna Metro station to Disney's America. Shuttle buses transport visitors from the AGT station located at Disney's America to the east entrance of the park via Disney's private access road. Figure 14 shows the proposed AGT system.

## G.1 ASSUMPTIONS

### G.1.1 Rail

In addition to the assumptions presented in section 3.3 regarding the transportation system in general, the following assumptions are relevant to the AGT system design:

- Peak hour load is 3,402 passengers.
- $\alpha$ is 0.9.
- Acceleration rate is 3 feet/second/second.
- Deceleration rate is 4 feet/second/second.
- Average duration of standing at stations $t_s$ is 25 seconds.
- A rail yard is needed; assume that the yard is at Vienna.
- Stations are needed at Vienna, Centreville, Manassas, and the park site.
- Parking is available at the Vienna, Centreville, and Manassas stations.
- The one-way length of the rail segment of the route is 21 miles.
- Seating capacity of the vehicle is 12 people (average) [3].
- Minimum scheduled headway in peak is 2 minutes [10].
- Maximum operating speed is 28 mph [3].

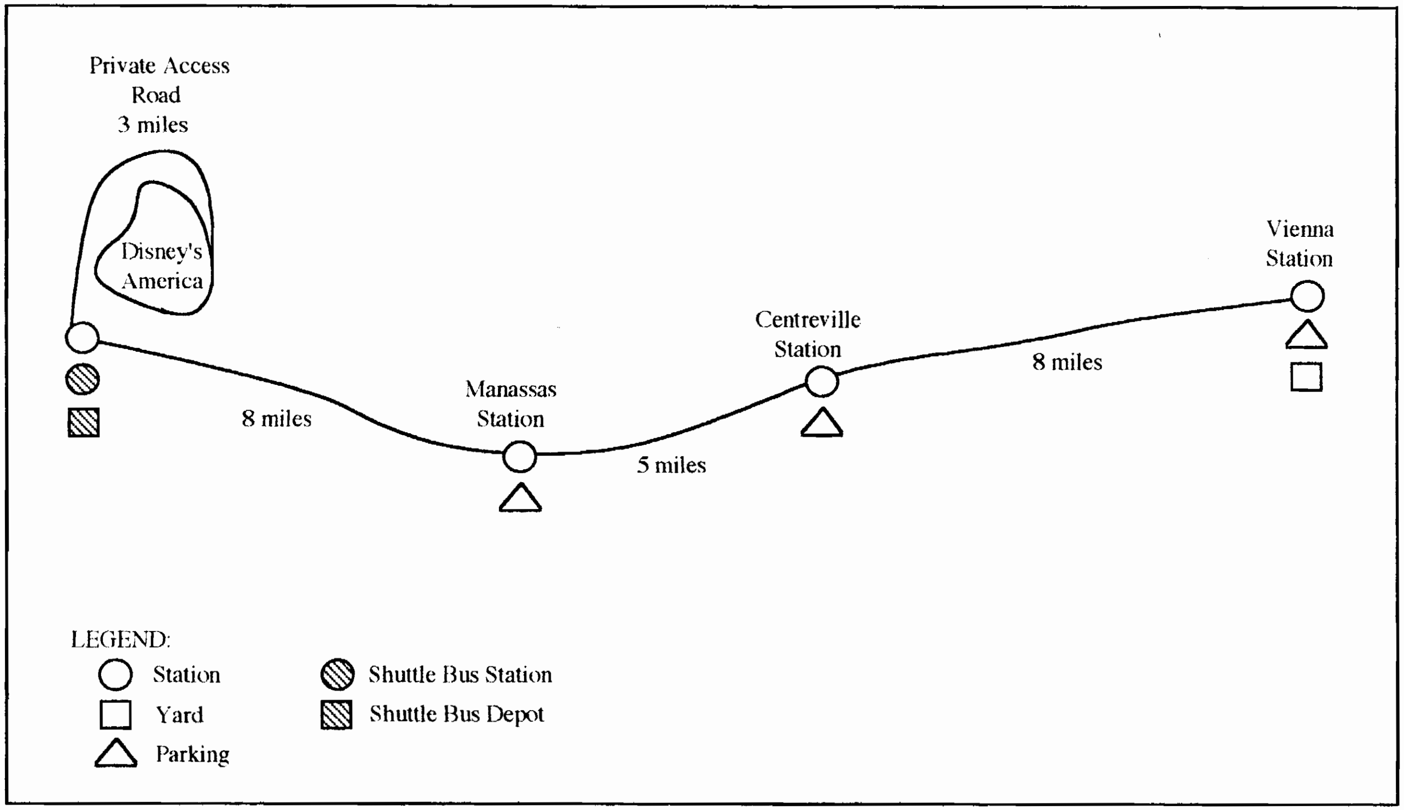



Figure 14. Automated Guideway Transit System

### G.1.2 Shuttle Bus

- The one-way length of the shuttle bus segment of the route is 3 miles.
- Conventional transit buses (40') will be used.
- The seating capacity of a shuttle bus is 53 passengers [3].
- The average operating speed on the private road is 45 mph.
- Peak hour load is 3,402 passengers.

## G.2 CALCULATION OF AVERAGE OPERATING SPEED--RAIL

### G.2.1 Average Operating Speed--Vienna to Centreville

The maximum speed possible as a function of station spacing is found by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$

$$= ((2*3*4*42{,}240)/(3 + 4))^{0.5}$$

$$= \underline{380.56} \text{ feet/second}$$

380.56 feet/second = 259.47 mph

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 42,240 feet (8 miles)

Travel time is determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$

$$= 42{,}240/41.07 + 41.07/2(1/3 + 1/4) + 25$$

$$= \underline{1{,}101.13} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (28 mph or 41.07 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 42,240 feet (8 miles)

Average speed from Vienna to Centreville is 38.36 feet/second (42,240/1,103.13) or 26 mph.

### G.2.2 Average Operating Speed--Centreville to Manassas

The maximum speed possible as a function of station spacing is found by the following formula [10]:

$$v' = ((2abS)/(a + b))^{0.5}$$

$$= ((2*3*4*26{,}400)/(3 + 4))^{0.5}$$

$$= \underline{300.86} \text{ feet/second}$$

300.86 feet/second = 205.13 mph

where:

v': maximum speed possible as a function of station spacing (feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 26,400 feet (5 miles)

Travel time from Centreville to Manassas is determined using the following formula [10]:

$$T_s = S/V_{max} + V_{max}/2(1/a + 1/b) + t_s$$

$$= 26{,}400/41.07 + 41.07/2(1/3 + 1/4) + 25$$

$$= \underline{679.71} \text{ seconds}$$

where:

$T_s$: travel time (in seconds)

$V_{max}$: maximum operating speed (28 mph or 41.07 feet/second)

a: acceleration is 3 feet/second/second

b: deceleration 4 feet/second/second

S: station spacing 26,400 feet (5 miles)

Average speed from Centreville to Manassas is 38.84 feet/second (26,400/679.71) or 26 mph.

### G.2.3 Average Operating Speed--Manassas to Disney

The average operating speed from Manassas to the Disney site is 26 mph, the same as Vienna to Centreville.

## G.3 DESIGN CALCULATIONS

### G.3.1 Rail

#### G.3.1.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 12}{3,402}$$

$= 0.19$ minute, but minimum scheduled headway in peak hour is 2 minutes

where:

h: headway--the time between two successive departures of vehicles (in minutes) [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_V$: vehicle capacity (seating only, no standees) [10]

P: maximum load of passengers per hour [10]

#### G.3.1.2 Operating Time

From previous calculations, travel time ($T_S$) from Vienna to Centreville is 1,101.13 seconds or 18.35 minutes, travel time from Centreville to Manassas is 679.71 seconds or 11.33 minutes, and travel time from Manassas to Disney is 1,101.13 seconds or 18.35 minutes.

$$T_o = T_s = 18.35 + 11.33 + 18.35$$
$$= \underline{48.03} \text{ minutes}$$

where:

$T_O$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### G.3.1.3 Cycle Time

$$T = 2(T_O)$$
$$= 2(48.03)$$
$$= \underline{96.06} \text{ minutes}$$

where:

T: total round-trip time of a vehicle (in minutes) [10]

$T_O$: time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10]

#### G.3.1.4 Number of Vehicles

$$N = T/h = 96.06/2 = 48.03 = \underline{49} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further in the system design. The AGT system will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/96.06) shows that an AGT vehicle will run 9 cycles each day. Each vehicle will carry 12 passengers per cycle, or 108 passengers per day. The system's 49 vehicles can transport 5,292 passengers per day, which does not meet the expected volume of 11,340 daily park visitors. Fifty-six additional AGT vehicles are required to accommodate the remaining 6,048 park visitors; therefore, the revised number of vehicles is 105 (N=105).

#### G.3.1.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares} = 105 + 10 = \underline{115} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

#### G.3.1.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$

$$= \frac{3{,}402}{0.9 * 12}$$

$$= \underline{315} \text{ vehicles per hour}$$

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the AGT system is 315 vehicles per hour. Each vehicle carries 12 passengers, so the system can transport 3,780 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

### G.3.2 Shuttle Bus

#### G.3.2.1 Headway

$$h = \frac{60 * \alpha * C_v}{P}$$

$$= \frac{60 * 0.9 * 53}{3{,}402}$$

$$= 1.04$$

$$= \underline{1} \text{ minute}$$

where:

| | |
|---|---|
| h: | headway--the time between two successive departures of vehicles (in minutes) [10] |
| $\alpha$: | load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10] |
| $C_V$: | vehicle capacity (seating only, no standees) [10] |
| P: | maximum load of passengers per hour [10] |

### G.3.2.2 Operating Time

$$T_o = d/r * 60$$
$$= 3/45 * 60$$
$$= \underline{4} \text{ minutes}$$

where:

| | |
|---|---|
| $T_o$: | time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10] |
| d: | distance (in miles) |
| r: | rate (in mph) |

### G.3.2.3 Cycle Time

$$T = 2(T_o + t_t)$$
$$= 2(4.0 + 5)$$
$$= \underline{18.0} \text{ minutes}$$

where:

| | |
|---|---|
| T: | total round-trip time of a vehicle (in minutes) [10] |
| $T_o$: | time between the departure of a vehicle from one terminal and its arrival at another terminal on the route (in minutes) [10] |

$t_t$: terminal time--the time that a vehicle spends at a terminal beyond that required for boarding and unloading of passengers (in minutes); dwell time [10]

### G.3.2.4 Number of Vehicles

$$N = T/h$$
$$= 18/1$$
$$= \underline{18} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

T: total round-trip time of a vehicle (in minutes) [10]

h: headway--the time between two successive departures of vehicles (in minutes) [10]

It is important to check that daily ridership demand is met before proceeding further. The shuttle bus service will operate 16 hours per day, or 960 minutes. Dividing the total operating minutes by the cycle time (960/18) shows that a bus will run 53 cycles per day. Each bus will carry 53 passengers, or 2,809 passengers per day. The system's18 buses can transport 50,562 passengers per day, which exceeds the expected 3,402 daily park visitors.

### G.3.2.5 Total Number of Vehicles Required

$$\text{Total} = N + \text{spares}$$
$$= 18 + 1$$
$$= \underline{19} \text{ vehicles}$$

where:

N: the number of vehicles needed to serve peak hour passenger volume

spares: 10% of N, rounded down

### G.3.2.6 Frequency of Service

$$f = \frac{P}{\alpha * C_v}$$

$$= \frac{3{,}402}{0.9 * 53}$$

$$= 71.32$$

= <u>72</u> vehicles per hour

where:

f: frequency of service--number of transit trips passing a point on the line (per hour)

P: maximum load of passengers per hour [10]

$\alpha$: load factor--the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]

$C_v$: vehicle capacity (seating only, no standees) [10]

It is important to check that peak-hour ridership demand is met. The frequency of service for the shuttle bus portion of the AGT system is 72 vehicles per hour. Each bus carries 53 people, so the system can transport 3,816 park visitors during peak hour. This exceeds the expected peak-hour load of 3,402 passengers for the system.

## G.4 CAPITAL COST (Cc)

### G.4.1 Vehicle (Ccv)

#### G.4.1.1 Rail

The average capital cost of an AGT vehicle was $830,437 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each rail car in 1994 dollars is $1,215,759 ($830,437 * 1.464).

$1,215,759 * 115 = $139,812,285 capital cost of vehicles

#### G.4.1.2 Shuttle Bus

The average capital cost of a 40' conventional bus was $178,800 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each shuttle bus in 1994 dollars is $261,763 ($178,800 * 1.464).

$261,763 * 19 = $4,973,500 capital cost of vehicles

#### G.4.1.3 Total System

| | |
|---|---|
| $139,812,285 | capital cost of rail vehicles |
| $ 4,973,500 | capital cost of shuttle buses |
| $144,785,785 | total capital cost of vehicles |

### G.4.2 Way (Ccw)

#### G.4.2.1 Rail

A 21-mile guideway will be built from the Vienna station to the park. The average cost of guideway per lane mile was $7,435,250 in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore the cost per mile in 1994 dollars is $10,885,206 ($7,435,250 * 1.464).

$10,885,206 * 21 = $228,589,326 capital cost of way

#### G.4.2.2 Shuttle Bus

The cost of providing the private road is the responsibility of the Walt Disney Company.

#### G.4.2.3 Total System

$228,589,326 capital cost of way - rail
0 capital cost of way - private road
$228,589,326 total cost of way

### G.4.3 Yard (Ccy)

#### G.4.3.1 Rail

The average cost per vehicle for a light rail transit yard was $355,600 in 1990 [3]. It is assumed that the cost per vehicle for AGT vehicles is the same. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost per vehicle for a rail yard in 1994 dollars is $520,598 ($355,600 * 1.464).

$520,598 * 115 = $59,868,770 capital cost of yard

#### G.4.3.2 Shuttle Bus

The average cost per vehicle for a bus depot is $107,278 [3].

$107,278 * 19 = $2,038,491 capital cost of depot

#### G.4.3.3 Total System

$59,868,770 annual capital cost of yard
$ 2,038,491 annual capital cost of depot
$61,907,261 total annual capital cost of yard/depot

### G.4.4 Station (Ccs)

#### G.4.4.1 Rail

The average capital cost of an AGT station was $956,500 in 1990. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the capital cost of each station in 1994 dollars is $1,400,316 ($956,500 * 1.464).

Parking facilities will be provided at certain stations. These facilities may be high-rise garages or at-grade lots. Calculations to determine the number of parking spaces required, the cost of parking facilities, and the total station cost for the system are shown in the following subsections.

**G.4.4.1.1 Vienna Station.** There will be 7,938 park visitors leaving from the Vienna station on peak days. It is assumed that 75% of the passengers going to the park will have boarded the Metro in the Washington area and thus will not have automobiles to park.

7,938 * 0.75 = 5,954 people will not have an automobile to park

7,938 - 5,954 = 1,984 people will have an automobile to park

It is also assumed that there will be two people in each automobile.

1,984/2 = 992 parking spaces will be needed at Vienna station

There will be 300 parking spaces provided in a high-rise garage and 692 spaces provided in at-grade lots. It is assumed that the cost for each space in the high-rise garage is $10,000 and the cost for each space in the at-grade lots is $5,000 [10].

300 * $10,000 = $3,000,000 high rise
692 * $5,000 = $3,460,000 at-grade
$6,460,000 total parking cost at Vienna station

**G.4.4.1.2 Centreville Station.** There will be 1,701 people boarding at the Centreville station each day. It is assumed that there will be two people in each automobile.

1,701/2 = 851 parking spaces will be needed at Centreville station

There will be 300 spaces provided in a high-rise garage and 551 spaces provided in at-grade lots.

300 * $10,000 = $3,000,000 high rise
551 * $5,000 = $2,755,000 at-grade
$5,755,000 total parking cost at Centreville station

**G.4.4.1.3 Manassas Station.** Parking costs at the Manassas station are the same as costs at the Centreville station; i.e., $5,755,000.

**G.4.4.1.4 Disney Site.** No parking facilities are required at Disney's America.

**G.4.4.1.5 Rail Station Total**

| | | |
|---|---|---|
| Vienna: | $ 6,460,000 | parking |
| | 1,400,316 | station |
| Centreville: | 5,755,000 | parking |
| | 1,400,316 | station |
| Manassas | 5,755,000 | parking |
| | 1,400,316 | station |
| Disney | 0 | parking |
| | 1,400,316 | station |
| Total | $23,571,264 | capital cost |

**G.4.4.2 Shuttle Bus**

One station is required for the shuttle bus service. The station is located near the park site. Parking facilities are not required. Assume that the cost of a station is $200,000 [10].

| | | |
|---|---|---|
| Disney | 0 | parking |
| | $200,000 | station |
| Total | $200,000 | capital cost |

**G.4.4.3 Total System**

| | |
|---|---|
| $23,571,264 | capital cost of rail stations |
| $ 200,000 | capital cost of bus station |
| $23,771,264 | total capital cost of stations |

## G.4.5 Power and Utility (Ccp)

The average cost of power and utility for an AGT system was $1,774,133 per lane mile in 1990 [10]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the cost in 1994 dollars is $2,597,330.

$2,597,330 * 21 = $54,543,930 capital cost of power and utility

### G.4.6 Command, Control, and Communication (Ccc)

The average cost of command, control, and communications for an AGT system was $3,855,705 per lane mile in 1990 [10]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the cost in 1994 dollars is $5,644,752.

$5,644,752 * 21 = $118,539,794 capital cost

### G.4.7 Engineering and Project Management (Cce)

The average cost of engineering and project management for an AGT system was $5,269,823 per lane mile in 1990 [3]. Using a 10% interest rate for four years, the compound-amount factor needed to find present value is 1.464 [21]. Therefore, the cost in 1994 dollars is $7,715,020.

$7,715,020 * 21 = $162,015,420

Table 18 shows the capital cost of the AGT system.

## G.5 OPERATING AND MAINTENANCE COST (Co)

DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems," does not contain data related to AGT systems. Therefore, the average O&M costs of the Detroit, Miami, and Vancouver AGT systems is used to estimate the O&M costs of the proposed AGT system. The 1988 values have been converted to 1994 dollars.

The shuttle bus portion of the system requires the determination of platform hours, vehicle miles, and route miles. There will be 18 buses; the bus portion of the proposed AGT system involves 45,990 platform hours each year.

A shuttle bus requires 18 minutes to complete the 6-mile cycle. There will be 116,796 shuttle bus-vehicle miles per year.

Table 18. Automated Guideway Transit System Capital Cost

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Capital Cost | Cc | | | |
| Vehicles | Ccv | 139,812 | 4,973 | 144,785 |
| Way | Ccw | 228,589 | | 228,589 |
| Yard/Depot | Ccy | 59,869 | 2,038 | 61,907 |
| Station | Ccs | 23,571 | 200 | 23,771 |
| Power & Utility | Ccp | 54,544 | | 54,544 |
| Command, Control, & Comm. | Ccc | 118,540 | | 118,540 |
| Engineering & Project Mgt. | Cce | 162,015 | | 162,015 |
| **TOTAL CAPITAL COST** | | **786,940** | **7,211** | **794,151** |

Route miles represent the end-to-end mileage of the line [5]. The shuttle bus segment of the AGT system consists of 3 route miles.

Actual O&M cost data of the Chicago Sub Bus Division for the year 1988 is used to estimate the O&M cost of the bus portion of the AGT system. The source of the data is the O&M cost data base presented in DOT-T-93-21, "Estimation of Operating and Maintenance Costs for Transit Systems." The 1988 values have been converted to 1994 dollars. Table 19 shows the actual O&M cost of the AGT system.

Table 20 shows the AGT system costs and the percentage of total for each cost category.

Table 19. Automated Guideway Transit System Annual Operating & Maintenance Cost

| Activity | Cost Category | Actual Cost (1000 $) Rail | Shuttle | Total System |
|---|---|---|---|---|
| Annual Operating & Maintenance Cost | Co | | | |
| Vehicle Operations | Coo | | | |
| Operators | Coop | | 1,742 | |
| Fuel & Lube | Coof | | 25 | |
| Tires & Tubes | Coot | | 6 | |
| Electricity | Cooe | | | |
| Contract Service | Cooc | | 10 | |
| Other Labor | Cool | | 295 | |
| Other Nonlabor | Coon | | 4 | |
| Vehicle Maintenance | Com | | | |
| Labor | Coml | | 99 | |
| Contract Service | Comc | | 19 | |
| Fuel Lube/Service Veh. | Comf | | 2 | |
| Tires Tubes/Service Veh. | Comt | | | |
| Parts | Comp | | 39 | |
| Other Nonlabor | Comn | | | |
| Non-Vehicle Maintenance | Con | | | |
| Labor | Conl | | 2 | |
| Contract Service | Conc | | 14 | |
| Parts | Conp | | 2 | |
| Other Nonlabor | Conn | | 1 | |
| General Administration | Cog | | | |
| Labor | Cogl | | 112 | |
| Contract Service | Cogc | | 68 | |
| Supplies | Cogs | | 8 | |
| Insurance | Cogi | | 48 | |
| Other Nonlabor | Cogn | | 39 | |
| **TOTAL ANNUAL O&M COST** | | **20,437** | **2,535** | **22,972** |

## Table 20. Automated Guideway Transit System Costs

| Activity | Cost Cate-gory | Actual Cost (1000 $) Rail | Shuttle | Total System | % of Total |
|---|---|---|---|---|---|
| Capital | Cc | | | | |
| Vehicles | Ccv | 139,812 | 4,973 | 144,785 | 12.22% |
| Way | Ccw | 228,589 | | 228,589 | 19.30% |
| Yard/Depot | Ccy | 59,869 | 2,038 | 61,907 | 5.23% |
| Station | Ccs | 23,571 | 200 | 23,771 | 2.01% |
| Power & Utility | Ccp | 54,544 | | 54,544 | 4.60% |
| Command, Control, & Comm. | Ccc | 118,540 | | 118,540 | 10.01% |
| Engineering & Project Mgt. | Cce | 162,015 | | 162,015 | 13.68% |
| **TOTAL CAPITAL** | | **786,940** | **7,211** | **794,151** | 67.04% |
| Operations & Maintenance | Co | | | | |
| Vehicle Operations | Coo | | | | |
| Operators | Coop | | 29,614 | | |
| Fuel & Lube | Coof | | 425 | | |
| Tires & Tubes | Coot | | 102 | | |
| Electricity | Cooe | | | | |
| Contract Service | Cooc | | 170 | | |
| Other Labor | Cool | | 5,015 | | |
| Other Nonlabor | Coon | | 68 | | |
| Vehicle Maintenance | Com | | | | |
| Labor | Coml | | 1,683 | | |
| Contract Service | Comc | | 323 | | |
| Fuel Lube/Service Veh. | Comf | | 34 | | |
| Tires Tubes/Service Veh. | Comt | | | | |
| Parts | Comp | | 663 | | |
| Other Nonlabor | Comn | | | | |
| Non-Vehicle Maintenance | Con | | | | |
| Labor | Conl | | 34 | | |
| Contract Service | Conc | | 238 | | |
| Parts | Conp | | 34 | | |
| Other Nonlabor | Conn | | 17 | | |
| General Administration | Cog | | | | |
| Labor | Cogl | | 1,904 | | |
| Contract Service | Cogc | | 1,156 | | |
| Supplier | Cogs | | 136 | | |
| Insurance | Cogi | | 816 | | |
| Other Nonlabor | Cogn | | 663 | | |
| **TOTAL O&M** | | **347,429** | **43,095** | **390,524** | |
| **GRAND TOTAL** | | | | **1,184,675** | |

# APPENDIX H

# DO NOTHING

The "do nothing" option, i.e., visitors use their automobiles to reach Disney's America, is not considered as an alternative in this project for two reasons: (1) automobiles are private transportation, not public transportation [9], and (2) I-66 does not have the capacity to accommodate the park-generated traffic.

However, one aspect of doing nothing does merit inclusion as a point of comparison for the public transportation modes--automobile emissions. A summary of the air pollutants generated by each transit alternative, as well as automobiles in the do-nothing option, is shown in Appendix I.

# APPENDIX I

# AIR POLLUTION CALCULATIONS

This section presents calculations related to the amount of air pollutants generated by each transit design alternative, as well as the do-nothing option. It addresses non-methane hydrocarbons (NMHC), carbon monoxide (CO), and oxides of nitrogen (NOX). The emission factors are used to determine the amount (in grams per mile) of NMHC, CO, and NOX that is generated by buses and automobiles are found in "Characteristics of Urban Transportation Systems," Table 4-17 [3]. The emission factors for the rail vehicles are assumed to be 0.9 for CO and NMHC, and zero for NOX [10].

## I.1 BUS TRANSIT SYSTEM

The one-way route length is 24 miles, so a cycle is 48 miles. Each bus runs 10 cycles a day (see Appendix C for calculation).

48 * 10 = 480 miles a day, each bus

480 * 365 = 175,200 miles a year, each bus

175,200 * 30 buses = 5,256,000 miles a year, all buses

CO: 5,256,000 * 21.75 = <u>114,318,000</u> grams each year

NMHC: 5,256,000 * 3.83 = <u>20,130,480</u>

NOX: 5,256,000 * 16.06 = <u>84,411,360</u>

## I.2 RAIL RAPID TRANSIT SYSTEM

### I.2.1 Rail

The one-way route length is 21 miles, so a cycle is 42 miles. Each rail vehicle runs 24 cycles a day (see Appendix D for calculation).

42 * 24 = 1,008 miles a day, each vehicle

1,008 * 365 = 367,920 miles a year, each vehicle

367,920 * 14 vehicles = 5,150,880 miles a year, all vehicles

CO: 5,150,880 * 0.9 = 4,635,792 grams each year

NMHC: 5,150,880 * 0.9 = 4,635,792

NOX: 5,150,880 * 0 = 0

### I.2.2 Shuttle Bus

The one-way route length is 3 miles, so a cycle is 6 miles. Each bus runs 53 cycles a day (see Appendix D for calculation).

6 * 53 = 318 miles a day, each vehicle

318 * 365 = 116,070 miles a year, each vehicle

116,070 * 18 vehicles = 2,089,260 miles a year, all vehicles

CO: 2,089,260 * 21.80 = 45,545,868 grams each year

NMHC: 2,089,260 * 4.00 = 8,357,040

NOX: 2,089,260 * 14.97 = 31,276,222

### I.2.3 Total RRT System

CO: 4,635,792 + 45,545,868 = 50,181,660 grams

NMHC: 4,635,792 + 8,357,040 = 12,992,832 grams

NOX: 0 + 31,276,222 = 31,276,222 grams

## I.3 LIGHT RAIL TRANSIT SYSTEM

### I.3.1 Rail

The one-way route length is 21 miles, so a cycle is 42 miles. Each rail vehicle runs 17 cycles a day (see Appendix E for calculation).

42 * 17 = 714 miles a day, each vehicle

714 * 365 = 260,610 miles a year, each vehicle

260,610 * 11 vehicles = 2,866,710 miles a year, all vehicles

CO: 2,866,710 * 0.9 = 2,580,039 grams each year

NMHC: 2,866,710 * 0.9 = 2,580,039

NOX: 2,866,710 * 0 = 0

### I.3.2 Shuttle Bus

The one-way route length is 3 miles, so a cycle is 6 miles. Each bus runs 53 cycles a day (see Appendix E for calculation).

6 * 53 = 318 miles a day, each vehicle

318 * 365 = 116,070 miles a year, each vehicle

116,070 * 18 vehicles = 2,089,260 miles a year, all vehicles

CO: 2,089,260 * 21.80 = 45,545,868 grams each year

NMHC: 2,089,260 * 4.00 = 8,357,040

NOX: 2,089,260 * 14.97 = 31,276,222

### I.3.3 Total LRT System

CO: 2,580,039 + 45,545,868 = 48,125,907 grams

NMHC: 2,580,039 + 8,357,040 = 11,223,750 grams

NOX: 0 + 31,276,222 = 31,276,222 grams

## I.4 COMMUTER RAIL TRANSIT SYSTEM: OPTION 1

### I.4.1 Rail

The one-way route length is 12 miles, so a cycle is 24 miles. Each rail vehicle runs 48 cycles a day (see Appendix F for calculation).

24 * 48 = 1,152 miles a day, each vehicle

1,152 * 365 = 420,480 miles a year, each vehicle

420,480 * 2 vehicles = 840,960 miles a year, all vehicles

CO: 840,960 * 0.9 = 756,864 grams each year

NMHC: 840,960 * 0.9 = 756,864

NOX: 840,960 * 0 = 0

### I.4.2 Shuttle Bus

The one-way route length is 3 miles, so a cycle is 6 miles. Each bus runs 53 cycles a day (see Appendix F for calculation).

6 * 53 = 318 miles a day, each vehicle

318 * 365 = 116,070 miles a year, each vehicle

116,070 * 18 vehicles = 2,089,260 miles a year, all vehicles

CO: 2,089,260 * 21.80 = 45,545,868 grams each year

NMHC: 2,089,260 * 4.00 = 8,357,040

NOX: 2,089,260 * 14.97 = 31,276,222

### I.4.3 Total Commuter Rail Transit System: Option 1

CO: 756,864 + 45,545,868 = 46,302,732 grams

NMHC: 756,864 + 8,357,040 = 9,113,904 grams

NOX: 0 + 31,276,222 = 31,276,222 grams

## I.5 COMMUTER RAIL TRANSIT SYSTEM: OPTION 2

The one-way route length is 15 miles, so a cycle is 30 miles. Each bus runs 20 cycles a day (see Appendix F for calculation).

30 * 20 = 600 miles a day, each vehicle

600 * 365 = 219,000 miles a year, each vehicle

219,000 * 47 vehicles = 10,293,000 miles a year, all vehicles

CO: 10,293,000 * 21.75 = <u>223,872,750</u> grams each year

NMHC: 10,293,000 * 3.83 = <u>39,422,190</u>

NOX: 10,293,000 * 16.06 = <u>165,305,580</u>

## I.6 AUTOMATED GUIDEWAY TRANSIT SYSTEM

### I.6.1 Rail

The one-way route length is 21 miles, so a cycle is 42 miles. Each rail vehicle runs 9 cycles a day (see Appendix G for calculation).

42 * 9 = 378 miles a day, each vehicle

378 * 365 = 137,970 miles a year, each vehicle

137,970 * 105 vehicles = 14,486,850 miles a year, all vehicles

CO: 14,486,850 * 0.9 = <u>13,038,165</u> grams each year

NMHC: 14,486,850 * 0.9 = <u>13,038,165</u>

NOX: 14,486,850 * 0 = <u>0</u>

### I.6.2 Shuttle Bus

The one-way route length is 3 miles, so a cycle is 6 miles. Each bus runs 53 cycles a day (see Appendix G for calculation).

6 * 53 = 318 miles a day, each vehicle

318 * 365 = 116,070 miles a year, each vehicle

116,070 * 18 vehicles = 2,089,260 miles a year, all vehicles

CO: 2,089,260 * 21.80 = 45,545,868 grams each year

NMHC: 2,089,260 * 4.00 = 8,357,040

NOX: 2,089,260 * 14.97 = 31,276,222

### I.6.3 Total AGT System

CO: 13,038,165 + 45,545,868 = 58,584,033 grams

NMHC: 13,038,165 + 8,357,040 = 21,395,205 grams

NOX: 0 + 31,276,222 = 31,276,222 grams

## I.7 DO NOTHING

There will be approximately 30,000 park visitors daily. It is assumed that there will be 2 passengers in each vehicle, so 15,000 vehicles will travel to the park each day. For comparison purposes, it is also assumed that the one-way route length is 24 miles, so a cycle is 48 miles.

48 * 15,000 = 720,000 miles a day

720,000 * 365 = 262,800,000 miles a year

CO: 262,800,000 * 11.75 = 3,087,900,000 grams each year

NMHC: 262,800,000 * 2.46 = 646,488,000

NOX: 262,800,000 * 1.56 = 409,968,000

Table 21 shows a summary of the air pollutants generated by each design alternative.

Table 21. Air Pollutant Summary

| System | Grams Per Year CO | NMHC | NOX |
|---|---|---|---|
| Bus Transit System | 114,318,000 | 20,130,480 | 84,411,360 |
| Rail Rapid Transit System | 50,181,660 | 12,992,832 | 31,276,222 |
| Light Rail Transit System | 48,125,907 | 11,223,750 | 31,276,222 |
| Commuter Rail Transit System-Option 1 | 46,302,732 | 9,113,904 | 31,276,222 |
| Commuter Rail Transit System-Option 2 | 223,872,750 | 39,422,190 | 165,305,580 |
| Automated Guideway Transit System | 58,584,033 | 21,395,205 | 31,276,222 |
| Do Nothing (Automobiles) | 3,087,900,000 | 646,488,000 | 409,968,000 |

# APPENDIX J

# LIFE-CYCLE COST ANALYSIS

The following assumptions are relevant to the financing of the PTS:

- The state will issue bonds at the current market rate (assume 10%) for 20 years in order to finance the transportation project. The annual capital cost of the project is the amount of interest paid.
- Tax revenues and other revenues generated by the park, such as hotel taxes and state tax on admission ticket, are used to retire the bonds.
- Buses have a life of 10 years. Another bond issuance is done after 10 years to finance the purchase of new buses. The interest rate is 10%.
- Rail vehicles and all facilities have a life of 20 years.
- Phaseout and disposal cost is not addressed; it is assumed that the cost will be insignificant. The operation of the system could be extended beyond the system life proposed for this project: rail vehicles could be renovated, track could be replaced, and stations could be remodeled.
- Construction time required to prepare the ROW, build stations and yards, etc., is three years.

Table 22 shows the cost allocation by program year for the PTS.

Table 22. Cost Allocation By Program Year

| Activity | Cost Category | Cost By Program Year (1000 $) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BUS SYSTEM** | | | | | | | | | | | | | |
| Capital | Cc | 28,732 | 28,732 | 28,732 | 28,732 | 28,732 | 28,732 | 28,732 | 28,732 | 28,732 | 28,732 | 45,541 | 45,541 |
| Operating & Maintenance | Co | | | | 14,166 | 14,166 | 14,166 | 14,166 | 14,166 | 14,166 | 14,166 | 14,166 | 14,166 |
| Total Actual Cost | C | 28,732 | 28,732 | 28,732 | 42,898 | 42,898 | 42,898 | 42,898 | 42,898 | 42,898 | 42,898 | 59,707 | 59,707 |
| Total Present Cost | C(10%) | 26,120 | 23,747 | 21,586 | 29,299 | 26,635 | 24,216 | 22,015 | 20,012 | 18,193 | 16,541 | 20,927 | 19,023 |
| **RAIL RAPID TRANSIT SYSTEM** | | | | | | | | | | | | | |
| Capital | Cc | 137,840 | 137,840 | 137,840 | 137,840 | 137,840 | 137,840 | 137,840 | 137,840 | 137,840 | 137,840 | 139,729 | 139,729 |
| Operating & Maintenance | Co | | | | 25,772 | 25,772 | 25,772 | 25,772 | 25,772 | 25,772 | 25,772 | 25,772 | 25,772 |
| Total Actual Cost | C | 137,840 | 137,840 | 137,840 | 163,612 | 163,612 | 163,612 | 163,612 | 163,612 | 163,612 | 163,612 | 165,501 | 165,501 |
| Total Present Cost | C(10%) | 125,310 | 113,925 | 103,559 | 111,747 | 101,587 | 92,359 | 83,966 | 76,325 | 69,388 | 63,089 | 58,008 | 52,729 |
| **LIGHT RAIL TRANSIT SYSTEM** | | | | | | | | | | | | | |
| Capital | Cc | 63,073 | 63,073 | 63,073 | 63,073 | 63,073 | 63,073 | 63,073 | 63,073 | 63,073 | 63,073 | 64,962 | 64,962 |
| Operating & Maintenance | Co | | | | 33,469 | 33,469 | 33,469 | 33,469 | 33,469 | 33,469 | 33,469 | 33,469 | 33,469 |
| Total Actual Cost | C | 63,073 | 63,073 | 63,073 | 96,542 | 96,542 | 96,542 | 96,542 | 96,542 | 96,542 | 96,542 | 98,431 | 98,431 |
| Total Present Cost | C(10%) | 57,340 | 52,130 | 47,387 | 65,938 | 59,943 | 54,498 | 49,545 | 45,037 | 40,943 | 37,227 | 34,500 | 31,360 |
| **COMMUTER RAIL TRANSIT SYSTEM: OPTION 1** | | | | | | | | | | | | | |
| Capital | Cc | 79,244 | 79,244 | 79,244 | 79,244 | 79,244 | 79,244 | 79,244 | 79,244 | 79,244 | 79,244 | 81,133 | 81,133 |
| Operating & Maintenance | Co | | | | 36,972 | 36,972 | 36,972 | 36,972 | 36,972 | 36,972 | 36,972 | 36,972 | 36,972 |
| Total Actual Cost | C | 79,244 | 79,244 | 79,244 | 116,216 | 116,216 | 116,216 | 116,216 | 116,216 | 116,216 | 116,216 | 118,105 | 118,105 |
| Total Present Cost | C(10%) | 72,041 | 65,495 | 59,536 | 79,376 | 72,159 | 65,604 | 59,642 | 54,215 | 49,287 | 44,813 | 41,396 | 37,628 |
| **COMMUTER RAIL TRANSIT SYSTEM: OPTION 2** | | | | | | | | | | | | | |
| Capital | Cc | 15,370 | 15,370 | 15,370 | 15,370 | 15,370 | 15,370 | 15,370 | 15,370 | 15,370 | 15,370 | 23,307 | 23,307 |
| Operating & Maintenance | Co | | | | 6,315 | 6,315 | 6,315 | 6,315 | 6,315 | 6,315 | 6,315 | 6,315 | 6,315 |
| Total Actual Cost | C | 15,370 | 15,370 | 15,370 | 21,685 | 21,685 | 21,685 | 21,685 | 21,685 | 21,685 | 21,685 | 29,622 | 29,622 |
| Total Present Cost | C(10%) | 13,973 | 12,703 | 11,547 | 14,811 | 13,464 | 12,241 | 11,129 | 10,116 | 9,197 | 8,362 | 10,383 | 9,438 |
| **AUTOMATED GUIDEWAY TRANSIT SYSTEM** | | | | | | | | | | | | | |
| Capital | Cc | 79,415 | 79,415 | 79,415 | 79,415 | 79,415 | 79,415 | 79,415 | 79,415 | 79,415 | 79,415 | 81,304 | 81,304 |
| Operating & Maintenance | Co | | | | 22,972 | 22,972 | 22,972 | 22,972 | 22,972 | 22,972 | 22,972 | 22,972 | 22,972 |
| Total Actual Cost | C | 79,415 | 79,415 | 79,415 | 102,387 | 102,387 | 102,387 | 102,387 | 102,387 | 102,387 | 102,387 | 104,276 | 104,276 |
| Total Present Cost | C(10%) | 72,196 | 65,636 | 59,664 | 69,930 | 63,572 | 57,797 | 52,545 | 47,764 | 43,422 | 39,480 | 36,549 | 33,222 |

Table 22. Cost Allocation By Program Year (Concluded)

| Activity | Cost Category | Cost By Program Year (1000 $) 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Total Cost (1000 $) |
|---|---|---|---|---|---|---|---|---|---|---|
| **BUS SYSTEM** | | | | | | | | | | |
| Capital | Cc | 45.541 | 45.541 | 45.541 | 45.541 | 45.541 | 45.541 | 45.541 | 45.541 | 742.730 |
| Operating & Maintenance | Co | 14.166 | 14.166 | 14.166 | 14.166 | 14.166 | 14.166 | 14.166 | 14.166 | 240.822 |
| Total Actual Cost | C | 59.707 | 59.707 | 59.707 | 59.707 | 59.707 | 59.707 | 59.707 | 59.707 | 983.552 |
| Total Present Cost | C(10%) | 17.297 | 15.721 | 14.294 | 12.992 | 11.816 | 10.741 | 9.762 | 8.878 | **369,815** |
| **RAIL RAPID TRANSIT SYSTEM** | | | | | | | | | | |
| Capital | Cc | 139.729 | 139.729 | 139.729 | 139.729 | 139.729 | 139.729 | 139.729 | 139.729 | 2.775.697 |
| Operating & Maintenance | Co | 25.772 | 25.772 | 25.772 | 25.772 | 25.772 | 25.772 | 25.772 | 25.772 | 438.124 |
| Total Actual Cost | C | 165.501 | 165.501 | 165.501 | 165.501 | 165.501 | 165,501 | 165.501 | 165.501 | 3.213.821 |
| Total Present Cost | C(10%) | 47.946 | 43.576 | 39.621 | 36.013 | 32,753 | 29.774 | 27.059 | 24.610 | **1,333,344** |
| **LIGHT RAIL TRANSIT SYSTEM** | | | | | | | | | | |
| Capital | Cc | 64.962 | 64.962 | 64.962 | 64.962 | 64.962 | 64.962 | 64.962 | 64.962 | 1.280.347 |
| Operating & Maintenance | Co | 33.469 | 33.469 | 33.469 | 33.469 | 33.469 | 33.469 | 33.469 | 33.469 | 568.973 |
| Total Actual Cost | C | 98.431 | 98.431 | 98.431 | 98.431 | 98.431 | 98.431 | 98.431 | 98.431 | 1.849.320 |
| Total Present Cost | C(10%) | 28.515 | 25.917 | 23.564 | 21.419 | 19.479 | 17.708 | 16.093 | 14.637 | **743,180** |
| **COMMUTER RAIL TRANSIT SYSTEM: OPTION 1** | | | | | | | | | | |
| Capital | Cc | 81.133 | 81.133 | 81.133 | 81.133 | 81.133 | 81.133 | 81.133 | 81.133 | 1.603.763 |
| Operating & Maintenance | Co | 36.972 | 36.972 | 36.972 | 36.972 | 36.972 | 36.972 | 36.972 | 36.972 | 628.524 |
| Total Actual Cost | C | 118.105 | 118.105 | 118.105 | 118.105 | 118.105 | 118.105 | 118.105 | 118.105 | 2.232.287 |
| Total Present Cost | C(10%) | 34.215 | 31.097 | 28.274 | 25.700 | 23.373 | 21.247 | 19.310 | 17.562 | **901,970** |
| **COMMUTER RAIL TRANSIT SYSTEM: OPTION 2** | | | | | | | | | | |
| Capital | Cc | 23.307 | 23.307 | 23.307 | 23.307 | 23.307 | 23,307 | 23.307 | 23.307 | 386.772 |
| Operating & Maintenance | Co | 6.315 | 6.315 | 6.315 | 6.315 | 6.315 | 6.315 | 6.315 | 6.315 | 107.355 |
| Total Actual Cost | C | 29.622 | 29.622 | 29.622 | 29.622 | 29.622 | 29.622 | 29.622 | 29.622 | 494.127 |
| Total Present Cost | C(10%) | 8.581 | 7.799 | 7.092 | 6.446 | 5.862 | 5.329 | 4.843 | 4.405 | **187,721** |
| **AUTOMATED GUIDEWAY TRANSIT SYSTEM** | | | | | | | | | | |
| Capital | Cc | 81.304 | 81.304 | 81.304 | 81.304 | 81.304 | 81.304 | 81.304 | 81.304 | 1.607.191 |
| Operating & Maintenance | Co | 22.972 | 22.972 | 22.972 | 22.972 | 22.972 | 22.972 | 22.972 | 22.972 | 390.524 |
| Total Actual Cost | C | 104.276 | 104.276 | 104.276 | 104.276 | 104.276 | 104.276 | 104.276 | 104.276 | 1.997.715 |
| Total Present Cost | C(10%) | 30.209 | 27.456 | 24.964 | 22.690 | 20.636 | 18.759 | 17.049 | 15.506 | **819,046** |

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# GLOSSARY

## Acronyms

| | |
|---|---|
| ADA | Americans with Disabilities Act |
| AGT | Automated Guideway Transit |
| BART | Bay Area Rapid Transit |
| COTS | Commercial-Off-The-Shelf |
| CTA | Chicago Transit Authority |
| DOT | Department of Transportation |
| LIRR | Long Island Rail Road |
| LRT | Light Rail Transit |
| MARC | Maryland Rail Commuter |
| MARTA | Metropolitan Atlanta Rapid Transit Authority |
| MBTA | Massachusetts Bay Transportation Authority |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time to Repair |
| NJT | New Jersey Transit |
| O&M | Operating and Maintenance |
| PRT | Personal Rapid Transit |
| ROW | Right of Way |
| RRT | Rail Rapid Transit |
| SEPTA | Southeastern Pennsylvania Transportation Authority |
| VRE | Virginia Railway Express |
| WMATA | Washington Metropolitan Area Transit Authority |

## Terms

| | |
|---|---|
| Alpha ($\alpha$) | Alpha is the load factor; i.e., the ratio of the number of passengers in a vehicle to the vehicle's capacity [10]. |
| Articulated Bus | An articulated bus is long (55 feet or 60 feet) and bends in the middle [3]. |

| | |
|---|---|
| Corrective Maintenance | Corrective maintenance is unscheduled maintenance that is performed to restore a system to desired performance following a failure [2]. |
| Mean Time Between Maintenance | Mean time between maintenance is the average time between maintenance actions, both preventive and corrective [2]. |
| Off-Line | Stations that are off-line are located to the side of the guideway or busway so that other moving vehicles are not affected by passengers boarding and alighting the stopped vehicle [9]. |
| Operational Availability | The operational availability of a system is the probability that the system will perform satisfactorily when used under stated conditions in its operational environment [2]. |
| Preventive Maintenance | Preventive maintenance is scheduled maintenance that is performed to keep a system functioning at a desired level of performance [2]. |