A Park For Exchange Place

Report No. 2: Transportation Alternatives

Prepared For:

THE JERSEY CITY OFFICE OF PLANNING

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February 29, 1980

The Hon. Thomas F.X.Smith
Mayor of the City of Jersey City
City Hall
Jersey City, New Jersey

Dear Mayor Smith:

The recommendations contained in this report are based on our evaluation that mass transit links between the proposed Exchange Place Riverside Park and Liberty State Park are desirable.

We are gratified by the interest in our proposals shown by Mr. John R. Weingart, Chief, Bureau of Coastal Planning and Development and Mr. Jerome J. McCabe, Chief, Bureau of Capital Planning and Improvements,- both bureaus of the New Jersey Department of Environmental Protection. Members of the New Jersey Greenacres Program have encouraged our studies.

Above all, we wish to recognize the creative participation and support of Mr. Jerome Killeen, Director of Planning and Mr. Charles E. Wyatt, Principal Planner of the Jersey City Division of Planning.

We believe the goals described in this report are realistic and required for the full utilization of the waterfront by the people of Jersey City and visitors to this area of great national significance.

Respectfully submitted,

Bernard J. Albin

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ALBIN ASSOCIATES

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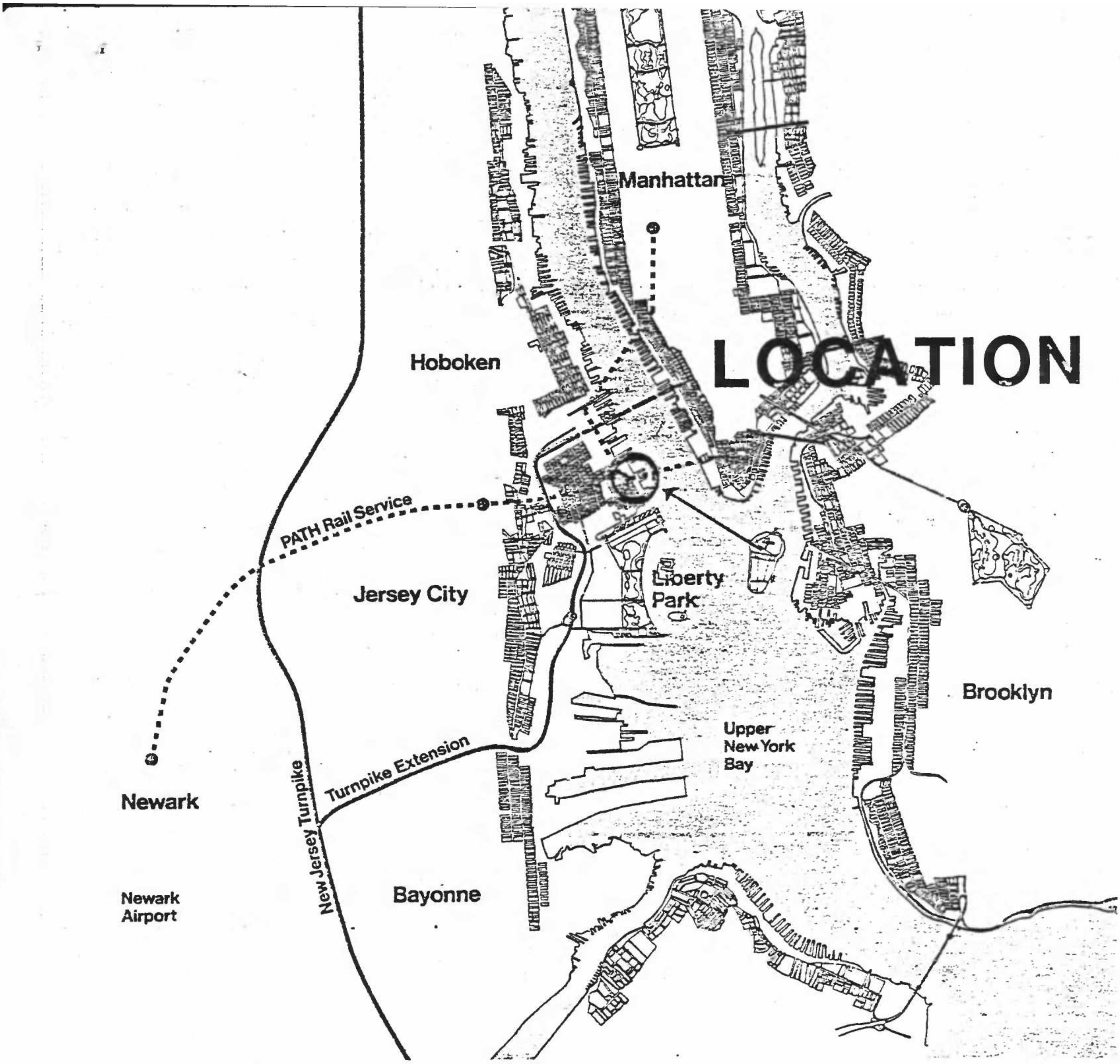
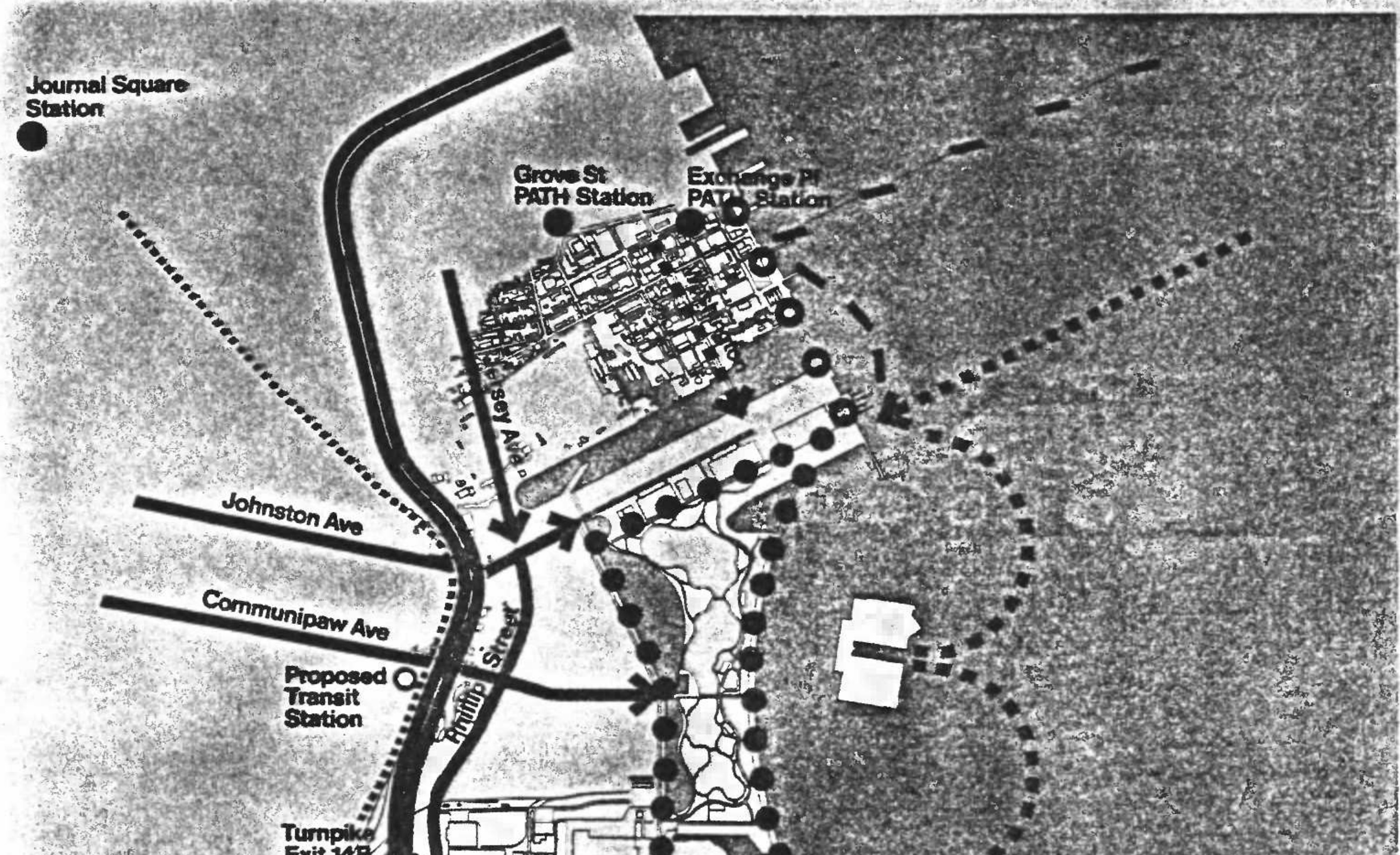


EXCHANGE PLACE RIVERFRONT PARK
JERSEY CITY, NEW JERSEY

ACCESS



Journal Square Station
Grove St PATH Station
Exchange Pl PATH Station
Jersey Ave
Johnston Ave
Communipaw Ave
Phillip Street
Proposed Transit Station
Turnpike Exit 14B
Bayview Ave
New Jersey Turnpike Extension
Proposed Route 169
Harbor Tour Boat Service

TRAMWAY

EXCHANGE PLACE RIVERFRONT PARK
JERSEY CITY, NEW JERSEY

Assessment of Alternate Transportation Systems:

PROBLEM: To Provide Convenient Mass Transportation Connections between Exchange Place, Jersey City and Liberty State Park.

THE RIVERFRONT ROUTE

The Morris Canal Basin creates a barrier to land based transportation links between Exchange Place and Liberty Park. For this reason a study was made to determine what transportation systems were available that could function with the required clearances for the water crossing of the canal basin. The designation of an exact height and horizontal distance for channel width requires the submission of plans and an actual application for construction permits to the United States Coast Guard, the agency with jurisdiction over the Morris Canal Basin.

The Coast Guard has provided preliminary design criteria. On this basis, the canal crossing has a height limitation of 100' clearance with a span of 900 feet. The footing for this span must be on land.

SYSTEMS STUDIED:

Two systems recommended in our preliminary report were evaluated in relation to the limitations created by the Morris Canal Basin criteria. These systems were the Roosevelt Island Tramway and the Automated Guideway Jetrail. In our first report based on an 80' clearance over the Morris Canal Basin, the Jetrails operational flexibility in allowing passengers to be carried to numerous places in Liberty Park gave this system an edge over the Roosevelt Island System. The criteria of a 900' clear span with a 100' minimum clearance caused a re-evaluation which clearly established the Tramway as the appropriate choice. The Jetrail System has a gradient limitation of 4%. Thus the 900' span reduces the distances available for change of grade and the required 100' clearance dictates more length than available north or south of the canal basin. An additional disadvantage is that supporting the span of rail over 900' between supports requires bridge construction which is far more expensive than the cable required to support the tramway system.

The straight line connecting the proposed Exchange Place Park with the terminal area in Liberty Park is ideal for the cable tramway system. We have used the Roosevelt Island installation to estimate construction costs and operating experience.

An Automated Guideway System should, in our opinion, be considered as the primary transportation system within the large area of Liberty Park. The Terminal Building in the park would make a suitable location for an interchange between the Cable Tramway and the Automated Guideway System.

A system that combines the performance characteristics of both the cable and guideway systems exists. This is the Mueller Aerobus System which was installed and operated for the Bundesgartenschau 1975, Mannheim, Germany. Although no installation exists in this country, an evaluation of this system was prepared for the United States Department of Transportation, Urban Mass Transportation Administration. We have used this report to evaluate the possible use of this system rather than the combined systems recommended above. The summary of our conclusions are followed by an appendix of supporting material taken from reports prepared for the United States Department of Transportation.

Our evaluation of the systems proposed was greatly assisted by David I. Ozerkis, P.E., branch manager for the VSL Corporation, the Roosevelt Island Tramway System manufacturer, Ira Greenbaum, Vice President of Design & Engineering for Titan PRT Systems, and George Scelzo of Titan. PRT Systems Corporation has modified the Jetrail vehicle used in Dallas Lovefield installation to improve performance and reliability. The modification involved replacing the original Jetrail power and propulsion system with a linear induction motor. This improved system is named "Astroglide" and is the system that is evaluated in this report.

THE ROOSEVELT ISLAND TRAMWAY:

During the development of the new community on Roosevelt Island, which lacked adequate transportation to Manhattan, the development corporation decided that a tramway system would provide the most economical solution for transportation to Manhattan. The important factors involved in this decision were the proven ability of tramway systems to bridge an obstacle such as the East River and the minimum land requirements for right-of-way, stations, and other facilities. The aerial tramway constructed was built with state-of the-art-aerial tramway technology. This fact combined with the availability of assessments of the installation and operational experience of the Roosevelt Island operation provide an excellent basis to evaluate the performance and applicability of this system to the Exchange Place Liberty Park requirements.

The precaution needed for all cable systems is to recognize that operation must be interrupted during high winds and electrical storms. In the case of the Roosevelt Island system, the average availability of the one-year period of March 5, 1977 to March 3, 1978, was found to be 98.3 percent. Of the total downtime, twenty-one and 3/10 percent (21.3%) were interruptions caused by the weather. This record of dependability, in our evaluation, qualifies this system for consideration for the Exchange Place -Liberty Park connection.

CABLEWAYS AND STATIONS

The Roosevelt Island Tramway system utilizes a system of steel cables to transport two passenger carrying suspended vehicles a distance of 3,143.2 ft. from Roosevelt Island across the East River to Manhattan. The system is classified as a bi-cable track tramway system with a double reversible mode. The two passenger vehicles travel simultaneously in opposite directions suspended from the two stationary paths of the cableway. Each path consists of two track cables. Motion is imparted to the 32-wheeled vehicle carriages by a haul rope which is driven by an electric motor in the Roosevelt Island Station.

The Roosevelt Island Station has at-grade loading and unloading platforms requiring no stairs or elevators for passenger access and exit. The Manhattan Station has loading and unloading platforms 18 ft. above the street level. Access to and from the street is by stairs. An elevator is provided for handicapped passengers.

The cables between the stations are supported by three steel pylons, one on Roosevelt Island and two in Manhattan. The middle pylon has a height of 250 ft. The vehicles will travel not lower than 18 ft. above Second Avenue and 140 ft. over the East River near the Roosevelt Island shore.

STATIONS

The two stations of the Roosevelt Island Tramway system are typical for most aerial tramways. The system has only two terminal stations and no intermediate stops. The Manhattan station which contains the counter weights, is located at the corner of 60th Street and Second Avenue. The Roosevelt Island

Station, which contains the drive installations and the central control provisions room, is located on Roosevelt Island beside the Queensboro Bridge and approximately 300 ft. from the East River. The stations are a combination of steel and concrete construction.

MAINTENANCE AND CENTRAL CONTROL FACILITIES

An aerial tramway has some unique characteristics compared with standard transit systems which result in different maintenance facility requirements. The system employs only two vehicles and any failure of one vehicle always results in system down time. Therefore, vehicle maintenance is performed with the vehicles remaining on-line and special vehicle maintenance facilities need not be provided.

The drive and control systems are stationary and their location is in the enclosed Roosevelt Island Station building. Consequently, the drive and control equipment is maintained at its installation location. All machinery such as motors, gear boxes, braking systems and drive wheels are installed so that they are easily accessible from all sides. The same applies for all control equipment.

The aerial tramway technology as applied for the Roosevelt Island system is based on proven technology as found at other aerial tramway systems in recreational facilities and mountain areas. The term "off-the-shelf technology" is truly applicable to this system. Also, since the Roosevelt Island system has now been in operation for over three years without any major problems, it may be looked upon as a mature system. This assumption is supported by the analysis of operational data in the United States Department of Transportation assessment.

The Roosevelt Island system is an urban transit system, located in the middle of Manhattan where an urban transportation problem needed to be solved. The occupants of the new Roosevelt Island residential development and the patients and employees of the hospitals on the same island needed to be provided with a convenient and dependable means of transportation to and from Manhattan. Private automobile traffic is virtually banned on the island. Transportation on the island is provided free, by means of electric buses. The aerial tramway system provides a direct connection from the island across the East River to the center of Manhattan. The Manhattan station is located at the corner of 60th Street and Second Avenue from where the other New York transit systems can be used. For many commuters between Manhattan and Roosevelt Island, the need to own a car and the parking problem are eliminated.

OPERATING STATISTICS

The Roosevelt Island Development Corporation has contracted with the VSL Corporation to actually operate and maintain the tramway system. During the one year of operation analyzed, the system accumulated 43,170 vehicle-miles. The system operates every day including weekends and holidays. Tha scheduled system operating hours are:

Sunday through Thursday	6:00 A.M. until 2:00 A.M.
Friday and Saturdays	6:00 A.M. until 3:00 A.M.

The peak hours are from 8:00 a.m. to 9:30 a.m., and from 4:00 p.m. to 7:00 p.m. During the peak hours, eight round trips (cycles per hour) are scheduled (i.e., a total of 16 vehicle trips, eight vehicle trips to Manhattan and eight vehicle trips to Roosevelt Island). During the off-peak hours four round trips (cycles) per hour are scheduled (i.e., a total of eight vehicle trips; four vehicle trips to Manhattan and four vehicle trips to Roosevelt Island).

The system is generally run in scheduled operation unless passenger demand exceeds scheduled capacity. Then additional trips are run to prevent waiting times in excess of 7.5 minutes during peak hours and 15 minutes during off-peak hours. Average trip time is 3.5 minutes. The average number of passengers carried per day was 5,058.

The Roosevelt Island system was designed for a single direction capacity of 1500 passengers per hour. The system fulfills this requirement. However, the operator has placed operational restrictions on the system, thereby reducing the actual operating capacity. Even in peak hours the tramway operates with longer scheduled headways (7.5 minutes) than the five minutes the system is capable of achieving. This results in a maximum operational peak-hour capacity of 1000 passengers per hour per direction- only two-thirds of the design capacity.

ENERGY CONSUMPTION

With the exception of the standby drive diesel engine, all energy consumed at the Roosevelt Island system is electrical. Energy is consumed for: Propulsion and vehicle heating

Station and maintenance facility housekeeping

Since the main drive is based on a dc motor-generator set, regenerative braking is used. However, at Roosevelt Island the recovered energy which is fed back to the power line is not credited. For future applications it should be studied whether this recovered electrical energy could be put to use at the system. Possible uses worth investigating would be resistor heating in stations, melting snow on walkways, and charging of batteries for emergencies.

The tramway operator keeps a record of weekly meter readings for system power consumption. While the consumption rates stay stable over the summer months, a significant increase can be observed for the winter months. This indicates that a significant proportion of the total energy consumption is needed for vehicle and station heating, and for lights during the colder seasons. Passenger areas in the stations are not heated, only the control room and the maintenance area.

Based on the recorded energy consumption data, the following statistics were derived:

Energy Consumption per Vehicle- mile	24.4 KwH
Average Power Consumption per Passenger-mile	0.99 KwH

Diesel fuel consumption for the standby drive is insignificant. The diesel engine is only run for a short time periodically, mainly for maintenance checks.

CAPITAL COSTS

A cost breakdown for system components is not necessary for an aerial tramway system capital cost analysis. Tramway systems are practically bought off-the-shelf and the cables, propulsion, and vehicles are integral system parts.

The cost for right-of-way may be considered negligible since the pylons require very little space and the system allows flexibility in their placement and design. For example, one tower of the Roosevelt Island system was built across a street without interfering with existing traffic. The land acquisition costs for the stations are comparable or less than those for at grade rail transit stations or bus terminals. The Manhattan station is a good example for value capture through good planning. This station was built with columns which, in the future, can support a 32-story building over the present station. The $2,000,000 in the cable system cost was for the turn-key tramway system without the structures (stations and pylons).

ROOSEVELT ISLAND TRAMWAY SYSTEM
CAPITAL COSTS IN 1976 US DOLLARS

COST CATEGORY	US DOLLARS
Vehicles, Cables, Cableway Saddles, Drive, C&C, other Hardware, Installation, Start-up and Acceptance Testing, Training of First Personnel.	2,000,000
Stations and Pylons	4,250,000
TOTAL	6,250,000

T-4

With the maximum single direction capacity of 1500 passengers per hour as demonstrated, the Roosevelt Island system may be classified as a high capacity aerial tramway system. For installations with cableway lengths comparable to the Roosevelt Island Tramway, somewhat higher capacities are possible. Headways at tramway systems are limited by operating speed and loading and unloading time. The two ways to increase capacities are higher operating speeds and larger vehicles. Only limited increases in maximum operating speeds are possible. The American National Standard Safety Requirements for Aerial Passenger Tramways limits the maximum speed at clear spans to 22.7 mph and across pylons to 17.1 mph. Tramway systems with capacities of up to approximately 150 passengers per vehicle are presently planned. However, at this time the largest vehicle which has been demonstrated has a capacity of 140 passengers. It may be concluded that present cableway technology allows construction of tramway systems similar to the Roosevelt Island application, with single direction capacities of up to approximately 1,800 passengers per hour.

The capital costs as expended for the Roosevelt Island Tramway may be seen as exemplary for similar urban applications. The same special requirements; e.g., one elevated station, provision for additional construction above one station (value capture), and special pylon designs may be anticipated again at other urban applications resulting in comparable capital costs. Also, no large cost deviations are expected to the tramway system cost excluding stations and pylons for a technically similar system with a comparable capacity, but cableway lengths longer or shorter of up to approximately 25 percent. The number of vehicles is fixed, the drive system and the control system are largely standardized, and the change in needed cable length would not impact the cost significantly.

CONNECTION BETWEEN EXCHANGE PLACE PARK AND LIBERTY STATE PARK

The installation of a cable tramway system between the Exchange Place Riverfront Park and Liberty Park would be similar to the Roosevelt Island system. The length of cable for the park connection would be less than 3000 feet. This would place the Liberty Park Station north of the existing ferry terminal building (assuming a straight line route is used parallel to the bulkhead line). A design predicated on station facilities within the present area of the ferry terminal building would require approximately 3200 feet of cable span. This is very close to the 3143 foot length of the Roosevelt Island installation.

Two terminal stations without intermediate stops is typical for most aerial tramways. However, an intermediate stop at a midpoint is possible. (to allow cars moving in opposite directions to be at the station simultanously). The proposed 3000 foot system would allow a station tower on the north side of the Morris Canal Basin. This could be combined with an observation facility. The required clearance of 100 feet for the Morris Canal Basin crossing would dictate a tower high enough to provide spectacular views of the New York skyline and the harbor views including a new perspective of the Statue of Liberty. Charges for tourist use of the observation facility, which could include a restaurant, would help offset capital and maintenance costs of the tramway facility.

A historic trail for bikes and pedestrians is suggested to connect the Exchange Place Riverfront Park with Liberty Park.

Direct links near the riverfront are not possible without bridge or pedestrian ferry crossing of the Morris Canal Basin. The construction and maintenance costs of a bridge or ferry must be evaluated against the costs and relative service of the tramway link proposed in this study.

Pedestrian and bicycle links should be established to Liberty State Park whether the tramway is programmed or not. However, the pedestrain and bicycle links could be planned for younger visitors and those seeking physical activity.

The PATH system serves Jersey City and Newark as well as midtown and lower Manhattan. Thus the suggested tramway link to Liberty Park would make this magnificent recreation resource more conveniently available to the great population centers of the metropolitan area without requiring dependence on energy intensive private automobiles.

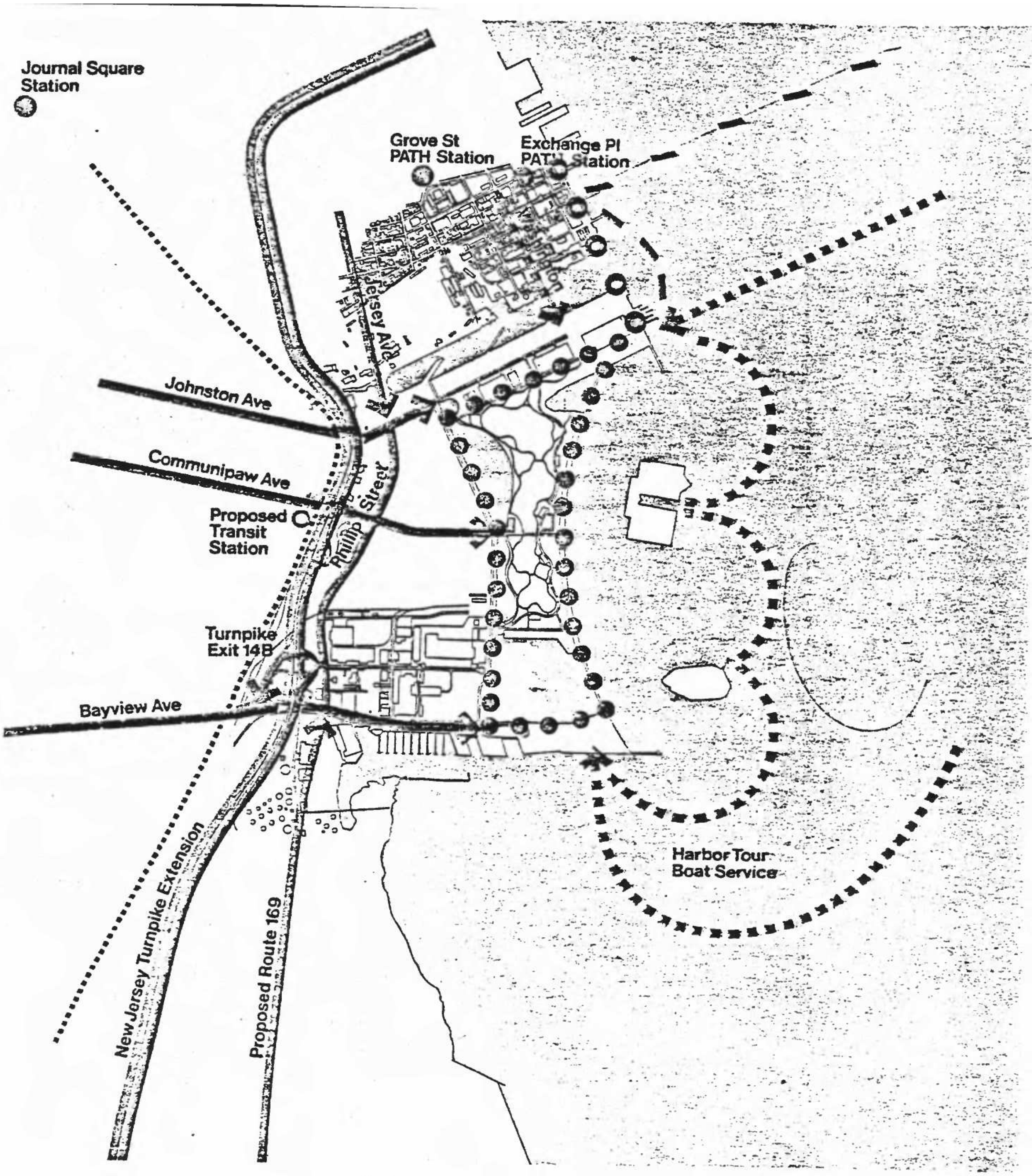
The energy conserving contribution of the cable tramway could be enhanced by its possible function as a park and ride facility. This would allow New York and other commuters to downtown Jersey City to use the parking facilities of the park during the off-peak midweek periods. The federal Department of Transportation, Urban Mass Transportation Administration is encouraging development of park and ride facilities. Our preliminary inquiry with the Urban Mass Transportation Office indicates an interest in the proposed concept of a link between PATH facilities at Exchange Place and the proposed parking areas at Liberty State Park. The energy conserving aspects of this concept combined with the improvements in air quality related to reduced auto use in the lower Manhattan area enhance the possibility of federal assistance for the proposed cable tramway.

The access diagram based on the Liberty State Park Master Plan indicates the new links that are proposed in this study. In addition to indicating the cable tramway link to Exchange Place Park, the diagram shows possible new boat service connections to Liberty State Park. The harbor service tour stop at Exchange Place Park would enhance the accessibility of boat tours for New Jersey residents who could use the PATH system to reach the proposed tour boat service.

ADDITIONAL DESIRABLE LINK TO PARK AND HARBOR FACILITIES

The access diagram indicates a proposed Automated Guideway Transit (AGT) system loop circulating within Liberty Park. This could be based on the characteristics of the "Astroglide" Jetrail system developed by Titan PRT Systems of Paramus, New Jersey. The diagram indicates the recommended direct link with the tramway station at the Central Railroad of New Jersey historic terminal building. An alternate to the dual system recommended is the use of a system based on the Mueller Aerobus system which was installed and operated for the Bundesgartenschau 1975, in Mannheim, Germany. This system could combine the cable tramway characteristics with the flexibility of the Guideway system. Further analysis of the Mueller system is in the appendix. It is derived from the Final Report, September 1979 on the assessment of the Mueller Aerobus system prepared for the United States Department of Transportation Urban Mass Transportation Administration.

The proposed linkages between the planned Exchange Place Riverfront Park and Liberty State Park will enhance the availability of this important recreational facility to local as well as regional and national visitors.



ACCESS DIAGRAM

Proposed Links

Exchange Place Park To Liberty State Park

Cable Tramway

Tour Boat Service (Possible New York Commuting)

Automated Guideway Transportation (AGT)

A P P E N D I X

Assessments Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Office of Socio-Economic and Special Projects

For The Following Projects:
Roosevelt Island Tramway System
Automated Guideway Systems-Jetrail
Mueller Aerobus System

ROOSEVELT ISLAND TRAMWAY SYSTEM ASSESSMENT.

Prepared for

U.S. Department Of Transportation / Urban Mass Transportation Administration
Office of Technology Development and Deployment

The findings reported in this subsection are based on system records for one operational year (1977-78) and interviews and observations during several site visits.

System Operation and Performance

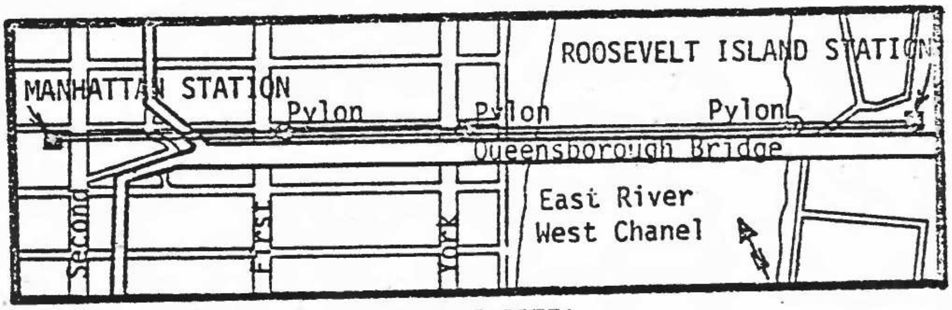
- The Roosevelt Island Tramway was designed for a single-direction capacity of 1500 passengers per hour. The system fulfills this requirement.

- Productivity measured in passenger-place-kilometers per man-hour and also in vehicle-kilometers per employee per month is poor compared to bus and rail systems. The system is operated with a total staff of 25 employees for two vehicles.

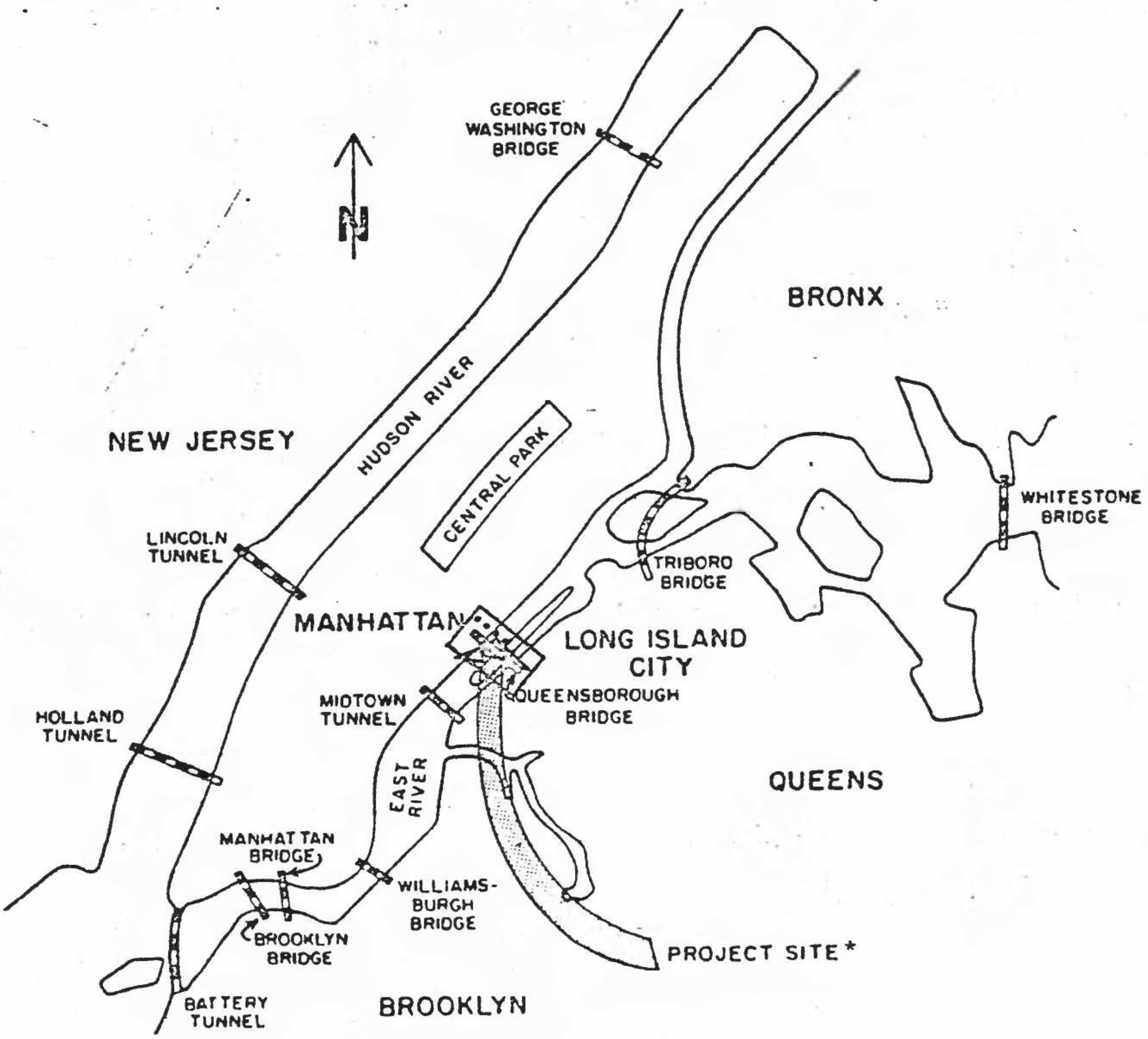
- High winds and electrical storms have a negative impact on system availability. High winds (72 km/h and higher) and lightning in close vicinity will always interrupt the service of a cable transportation system. However, as demonstrated at Roosevelt Island, a cable system may be still operable under ice and snow conditions which would hinder other transportation modes.

System Assurance

- No evidence of any significant start-up problems could be found, reinforcing the conclusion that the Roosevelt Island



PROJECT SITE*



ROOSEVELT ISLAND TRAMWAY LOCATION

Tramway system is based on mature technology using many off-the-shelf system components.

- Any vehicle downtime will always result in a system operation interruption. Both vehicles always have to be on-line, as opposed to conventional transit systems where back-up vehicles can be utilized.

- There is no redundance of the operating propulsion system (main drive and traction rope assembly), since the auxiliary drive is not designed for continuous service. However, because the propulsion system is located in enclosed buildings (except some parts of the traction rope assembly), it is well protected and maintenance is greatly facilitated.

- Some of the scheduled maintenance, such as electroscopic cable testing and rope shortening and splicing, can reduce system availability significantly. This impact can be reduced by scheduling such activities for periods when the system is not scheduled to operate.

Human Factors

- The Roosevelt Island Tramway is fully accessible for elderly and handicapped. The Roosevelt Island station has ramps and in the Manhattan station an elevator is provided. Vehicle loading is without steps.

- Measurement data regarding ride comfort and noise emissions are not available. Subjectively, the ride is judged as smooth and the noise emissions are exceptionally low. When vehicles enter the stations, they often bump against the guard rails necessitating that passengers always hold on to the handgrips, holding rails, and stanchions provided.

- The cable way with its pylons is aligned along the Queensborough Bridge structure. This has a camouflaging effect on the already slender guideway including the pylons.

Safety and Security

- Available data provide no evidence of any unusual safety risks inherent in cable systems of this type.

- There are two potential security hazards at the Manhattan station. The station exit stairs have areas hidden from outside view, also the elevator for elderly and handicapped cannot be observed by the station attendant. Closed circuit TV monitoring systems could be installed in these areas if operating experience indicated a need.

- Back-up systems, such as auxiliary drive, special equipment and operating procedures are designed to allow appropriate action in case of the different possible system failure or emergency situation. However, the emergency rescue vehicles are stored in a separate building and are not integrated in the Roosevelt Island station. Special lifting equipment and excessive time (approximately two hours) would be needed before passenger evacuation from stranded vehicles could begin with the use of the rescue vehicles. The rescue vehicles need to be installed so that they can be brought into action in the shortest time without having to bring other special equipment to the scene.

Costs

- General and administrative costs are significantly greater than all other operations and maintenance costs together. This is mainly caused by extremely high insurance costs which exceed even the labor cost. At the present time $95,000,000 of liability protection is carried. It may be desirable to consider alternative approaches to reduce this cost element.

- o Under present operating conditions, the system could break even if the load factor would increase from the present 20.0 percent to 68.9 percent, or if the present fare of $0.50 would be tripled. This includes recovery of the capital cost.

- o The total operating and maintenance cost per vehicle-kilometer (mile) is $29.65 (47.72). If the equivalent annual capital costs are included also, then the total cost per vehicle-kilometer (mile) is $39.38 (63.37).

2.4.2 Potential for Urban Applications

As has been demonstrated at Roosevelt Island, an aerial tramway system is uniquely qualified to transport people across artificial and natural obstacles. The cableway technology allows steep grades and long spans at almost any height, with great freedom for pylon placement and design. Waterbodies, moderately high construction, and existing traffic arterials are being by-passed with relatively low technical effort. Shuttle system operations with point-to-point transportation between two terminal stations are characteristics.

Aerial tramway installations with an intermediate station are operating in recreational areas. Systems with an intermediate station may also find applicability in urban transit. Such a station must be located halfway between the terminals so that both vehicles can stop at this point at the same time for loading and unloading. For longer systems, with two intermediate stations, the stations must be placed at equal distances to allow simultaneous station stops for both vehicles. One operational disadvantage of such systems with more than two stations would be that station dwell time is determined by the vehicle with the longest load and unload time. For example, even if one vehicle would not load or unload at an intermediate station, it would still have to stop until the other vehicle was ready to resume its trip. This would result in a performance decrease because of longer trip times and waiting times.

With the maximum single direction capacity of 1,500 passengers per hour as demonstrated, the Roosevelt Island system may be classified as a high capacity aerial tramway system. For installations with cableway lengths comparable to the Roosevelt Island Tramway, somewhat higher capacities are possible. Headways at tramway systems are limited by operating speed and loading and unloading time. The two ways to increase capacities are higher operating speeds and larger vehicles. Only limited increases in maximum operating speeds are possible. The American National Standard Safety Requirements for Aerial Passenger Tramways limits the maximum speed at clear spans to 36.6 km/h (22.7 mph) and across pylons to 27.4 km/h (17.1 mph). Tramway systems with capacities of up to approximately 150 passengers per vehicle are presently planned. However, at this time the largest vehicle which has been demonstrated has a capacity of 140 passengers. It may be concluded that present cableway technology allows construction of tramway systems similar to the Roosevelt Island application, with single direction capacities of up to approximately 1,800 passengers per hour.

Aerial tramway systems normally are constructed in a straight line to minimize eccentric forces on pylon saddles as well as wear due to friction. Even though straight line systems provide maximum safety, tramway systems that are not perfectly straight have been constructed by allowing a slight deviation at the pylons and may also be applicable for urban use. Another possible feature of aerial tramway systems is the integration of intermediate stations which accomplish a change of cableway direction (deviation station). Only low capacity systems with this feature have so far been demonstrated. The applicability for urban systems, where high capacities are needed, is questionable.

As the Roosevelt Island system shows, aerial tramways can be built according to the high ergonomic requirements of urban transit systems. The system as described in this report is fully accessible for elderly and handicapped. Since travel times are short, the low ratio of seats to standing places can be accepted. Ride comfort may be considered high and noise and sight pollution are extremely low.

The capital costs as expended for the Roosevelt Island Tramway may be seen as exemplary for similar urban applications. The same special requirements; e.g., one elevated station, provision for additional construction above one station (value capture), and special pylon designs may be anticipated again at other urban applications resulting in comparable capital costs. Also, no large cost deviations are expected to the tramway system cost excluding stations and pylons for a technically similar system with comparable capacity, but cableway lengths longer or shorter of up to approximately 25 percent. The number of vehicles is fixed, the drive system and the control system are largely standardized, and the change in needed cable length would not impact the cost significantly. Considerable change in acquisition costs would result if the number of required towers would change and/or if the required capacity (vehicle size) should increase or decrease significantly. The load changes resulting from a change of vehicle size would impact the sizing of drive system components and cables significantly and therefore impact acquisition costs.

A comparison shows that the operation and maintenance cost for the Roosevelt Island system, when insurance cost is excluded, is higher than for automated guideway systems, for bus systems, and for light rail transit systems. For future urban cableway applications, consideration should be given to unmanned stations with automated passenger admission processing. An automated fare collection system or an honor system and installation of closed circuit TV surveillance from central control could eliminate the need for station attendants and reduce operating costs significantly.

3.0 TECHNICAL SUBSYSTEM ASSESSMENT

This chapter presents the results of the assessment of technical subsystems. System operating performance, reliability and maintainability are discussed in Chapter 4. The basic technical design of the Roosevelt Island system is that of conventional tramway systems employed mainly to transport people in mountainous areas. These systems often bridge natural obstacles. The unique ability of tramway systems to cross obstacles with long spans and to negotiate extremely high grades has been made use of at Roosevelt Island. Here a river and other traffic arteries are crossed at considerable heights. The vehicle clears the ground at 68 m (220 ft) when it reaches the highest point in the system. A cable system could economically span the distance between the station location in Manhattan and on Roosevelt Island without interference with existing buildings, street traffic, and river traffic. Figure 3.1 shows the vehicle crossing the East River.

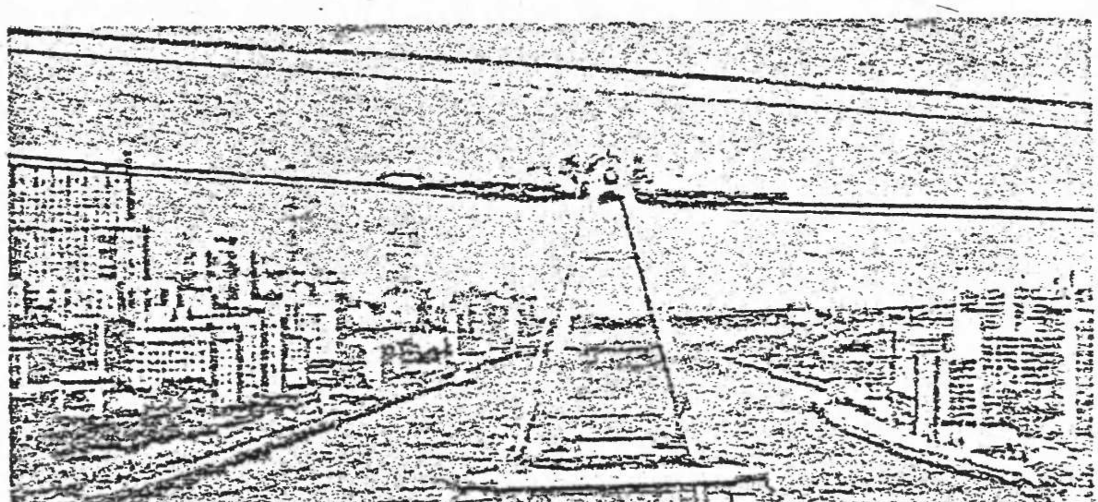


FIGURE 3.1: VEHICLE CROSSING EAST RIVER

3.1 VEHICLES

The system has a total of two vehicles operating suspended from the overhead cableway. The vehicle consists of three basic components: the passenger module, the hanger, and the carriage. The passenger module provides a capacity for 125 passengers plus one attendant. The hanger connects the passenger module to the carriage which rides on the carrying cables. The carriage contains an independent emergency braking system and connects to the haul rope and the counter rope. A side and front view of the Roosevelt Island Tramway vehicle is provided in Figure 3.2. The major dimensions are given on the same figure in mm.

3.1.1 Passenger Module, Hanger, and Carriage

The passenger module structure is of light weight aluminum construction consisting basically of a welded framework with an enclosure. As can be seen in Figure 3.3, approximately half of the wall surfaces all around the module consists of windows. On each side a bi-parting sliding door is located. The following lists some pertinent vehicle data. Additional data is given in the respective subsections and in Appendix A, Roosevelt Island Tramway Assessment Measures.

Overall Length	7600 mm (24.93 ft)
Overall Width	3900 mm (12.80 ft)
Overall Height (passenger module only)	2950 mm (9.68 ft)
Overall Height (incl. hanger & carriage)	9490 mm (31.13 ft)
Headroom, Standing Area	2250 mm (7.38 ft)
Empty Weight (passenger module only)	2280 kg (6,284 lbs)
Gross Weight (passenger module only)	9690 kg (21,340 lbs)
Design Capacity	125 passengers plus one attendant
Seated	10 passengers
Standing	115 passengers

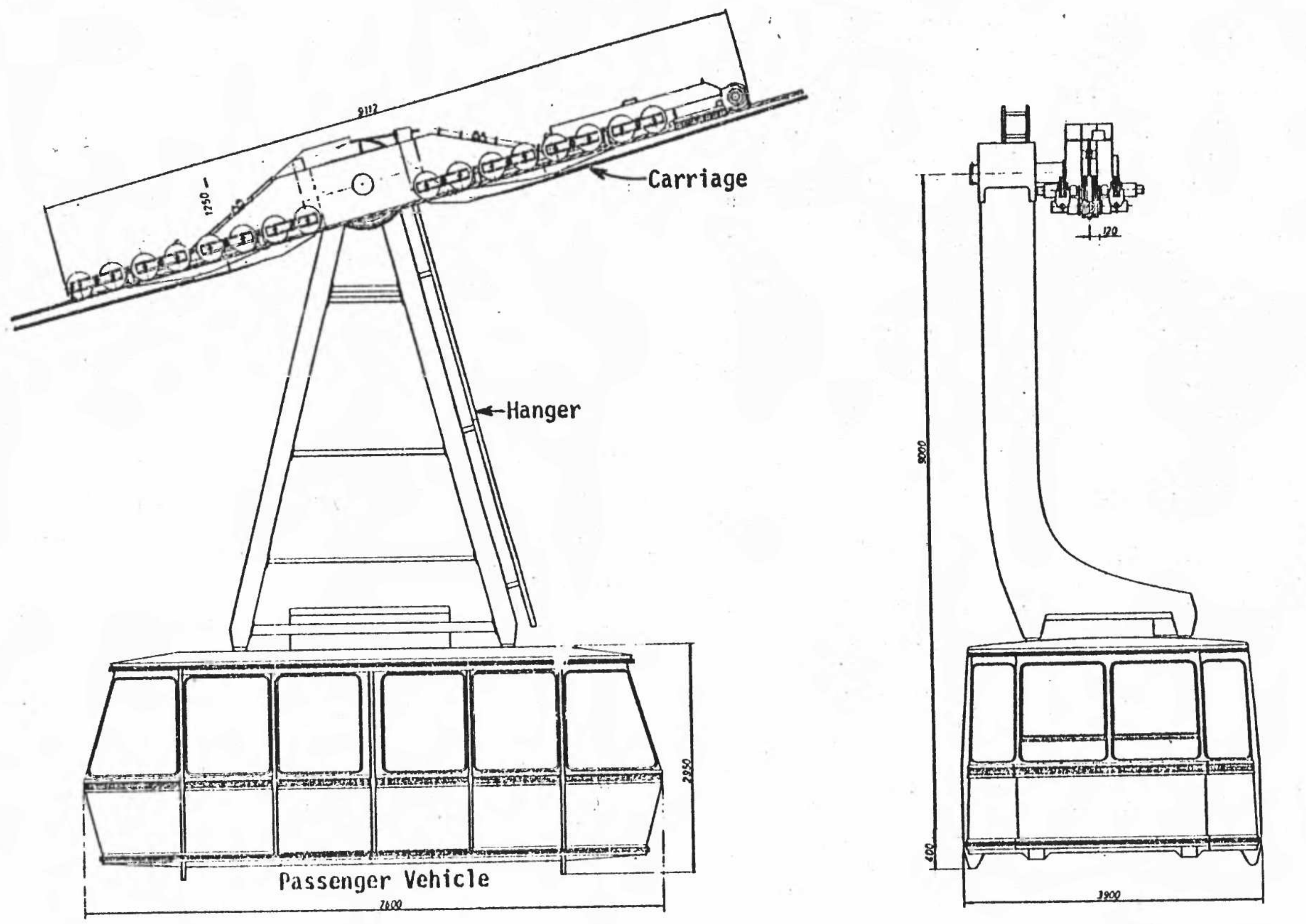


FIGURE 3.2: ROOSEVELT ISLAND VEHICLE SIDE AND FRONT VIEW WITH MAJOR DIMENSIONS (mm)

The vehicles were designed with heater thermostat controls which are adjustable from 13^{o} to $31^{o}C$ (55^{o} to $88^{o}F$). However, these have never been used since the system was put into service and may not be operable. During site visits for this assessment it was observed that during cold weather the heater was run at full capacity and the attendant controlled the temperature by manually limiting the door opening time and also by opening the doors only partially. The trip time of 210 seconds is too short to allow cooling of the passenger compartment to objectional temperatures. The capacity of the heaters is sufficient to make up for heat loss during the trip even though heating occurs only during station stop.

Four overhead lights illuminate the passenger compartment to a sufficient level for safe passenger movement. The lights are powered from the 24 volt battery circuit. Two speakers are provided for announcements by the attendant.

3.1.4 Vehicle Overall Performance

The American National Standard Safety Requirements for Aerial Passenger Tramways (ANSI B77.1-1976) allows a maximum speed of 36.6 km/h (22.7 mph) over clear spans and 27.4 km/h (17.1 mph) across pylons for tramway systems. The Roosevelt Island Tramway system operates with a maximum speed of 26.3 km/h (16.3 mph) and a service acceleration and deceleration of 0.25 m/s^2 (0.82 ft/sec^2). As described in section 3.2, Control and Communication, the system is equipped with continuous approach speed control for entering the stations. This enhances ride comfort by avoiding jerks during acceleration and deceleration. In case of breakdown of the main drive, the system can operate with the stand-by drive. Then the maximum vehicle speed is 3.0 km/h (1.9 mph) and velocity control is manual.

3.2 CONTROL AND COMMUNICATION

The Roosevelt-Island Aerial Tramway is a so-called bi-cable track system in the double (two vehicles) reversible mode. Two vehicles travel simultaneously in opposite directions on two twin-track stationary cable paths connecting the Manhattan station with the Roosevelt-Island station. The vehicles are propelled by a continuous-loop traction rope (haul and counter rope) which is driven by two bullwheels in the Roosevelt-Island station (see Figure 3.18 and traction rope assembly description in subsection 3.3.1). Thus vehicle speed is primarily controlled from the Roosevelt-Island station where the speeds versus traveling distance characteristics are controlled by programmers geared to the traction rope deviation sheaves. The operator at the system control desk may reduce speed with the speed selector potentiometer. In addition, either vehicle attendant may reduce speed by pushing the "slower" button on the vehicle control desk or he may restore speed again to the preselected value by pushing the "faster" button.

Communication (service telephone system) is provided between both stations and vehicles inductively via the insulated continuous-loop traction rope. An additional telephone link between the two stations operates directly over the traction rope of the rescue system. Walkie-talkies are available for standby communication. A tramway safety system is provided for continuous supervision of the main and rescue traction rope systems and for transmission of control and safety signals to and from both vehicles and the control room at the Roosevelt-Island station.

The system has an automated continuous wind monitoring and warning system. System personnel interrupt service when electrical storms are observed in close proximity.

3.4 CABLEWAYS AND STATIONS

The Roosevelt Island Tramway system utilizes a system of steel cables to transport two passenger carrying suspended vehicles a distance of 958.0 m (3,143.2 ft) from Roosevelt Island across the East River to Manhattan. The system is classified as a bi-cable track tramway system with a double reversible mode. The two passenger vehicles travel simultaneously in opposite directions suspended from the two stationary paths of the cableway. Each path consists of two track cables. Motion is imparted to the 32-wheeled vehicle carriages by a haul rope which is driven by an electric motor in the Roosevelt Island station.

The Roosevelt Island Station has at-grade loading and unloading platforms requiring no stairs or elevators for passenger access and exit. The Manhattan Station has loading and unloading platforms 5.5 m (18 ft) above the street level. Access to and from the street is by stairs. An elevator is provided for handicapped passengers.

The cables between the stations are supported by three steel pylons, one on Roosevelt Island and two in Manhattan. The middle pylon has a height of 76.2 m (250 ft). The vehicles will travel not lower than 5.5 m (18 ft) above Second Avenue and 42.7 m (140 ft) over the East River near the Roosevelt Island shore. The profile and alignment of the cableway are shown in Figure 3.27.

3.4.1 Cableways

The track cable assembly consists of four track cables - two for each track - two track cable anchors, two track cable roller chains and two track cable tension weights (Figure 3.19).

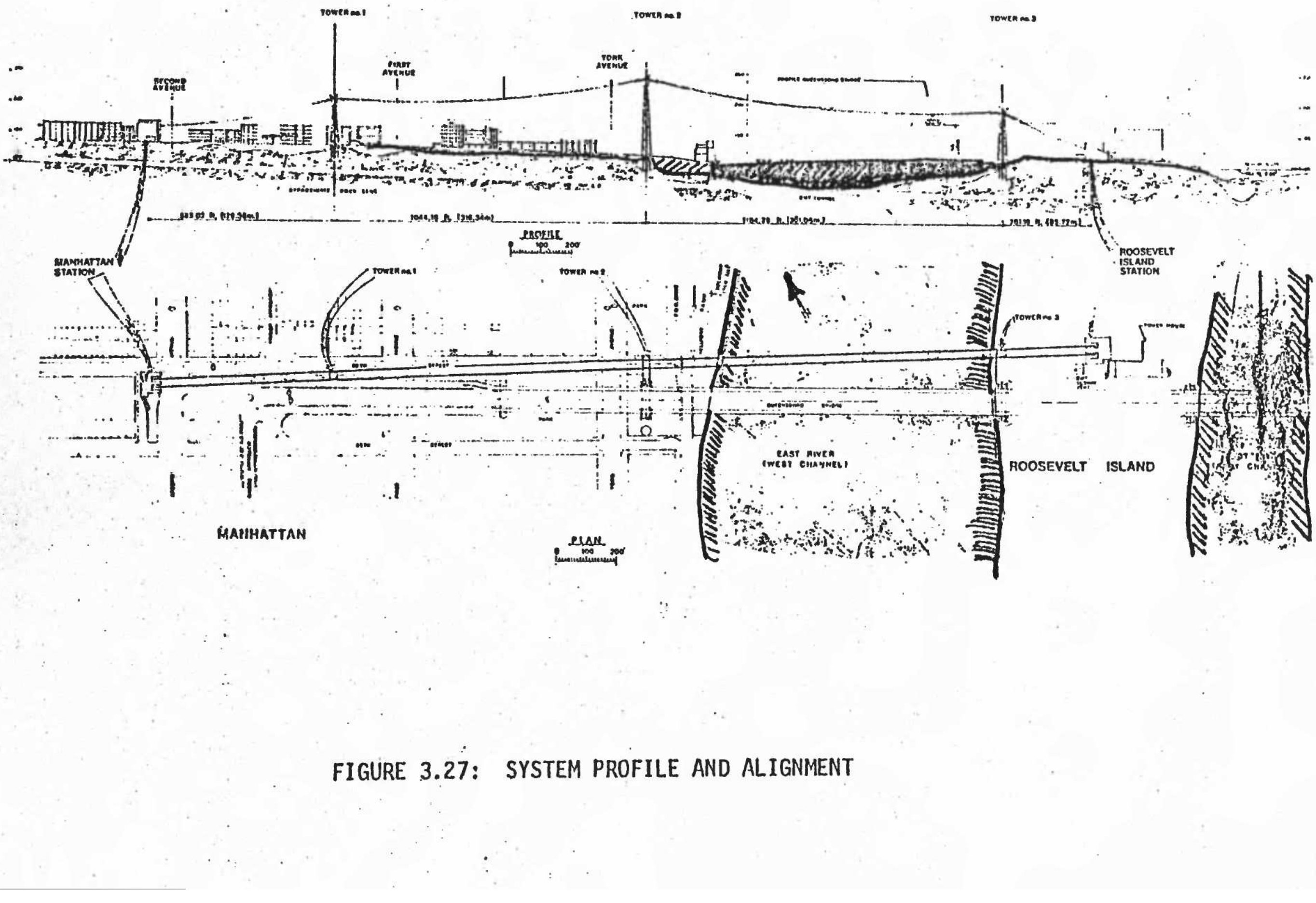


FIGURE 3.27: SYSTEM PROFILE AND ALIGNMENT

A summary of the distribution of system downtime events by major subsystems is given in Table 4.3. Of the subsystems shown, the Control and Safety system caused the highest percentage of downtime events, followed by the Drive and Vehicles. It is interesting to note that, by far, the highest number of downtime events was caused by weather (high winds and/or lightning). Of the total downtime, 21.3 percent was due to operating interruptions because of weather. Since this results in a system unavailability of 0.4 percent, the highest availability the system could have achieved without any other system failures would have been 99.6 percent.

Figure 4.10 is a histogram of time periods between system failures and their frequency of occurrence over the investigated operating year. The normal operating day of 20 hours provided the basis for the final interval of time between downtime events of 20 hours and more. The 20 hour operating day has been subdivided into eight intervals of 2.5 hours each. Half of the MTBF (Mean Time Between Failures, i.e., operating interruptions) fall into the first interval (0 to 2.5 hours). However, almost 40 percent of the times between downtime events are longer than 20 hours and the Mean Time Between Failure for the year was calculated to be 54.5 hours.

The Mean Time to Restore (MTTR) was calculated to be 1.1 hours for the operating year as shown in Figure 4.11. The time intervals chosen to illustrate the distributions of the frequency of time durations to restore the system after a downtime event are those used by UMTA for the Advanced GRT program.

The greatest frequency of downtime events, 50 percent, occurred in the interval of 3 to 24 minutes. The broken lines in the intervals show a finer distribution in seven minute increments. From this downtime duration distribution histogram it can be concluded that the majority of downtimes exceed the scheduled waiting times.

TABLE 4.3: DISTRIBUTION OF SYSTEM DOWNTIME EVENTS BY MAJOR SUBSYSTEMS

SUBSYSTEM	NUMBER OF DOWNTIME EVENTS	PERCENT OF TOTAL EVENTS
DRIVE (main and auxiliary)	9	10.8
VEHICLES, including carriages	9	10.8
GUIDEWAY, including anchors, tension weights, sheaves, roller chains, and tower saddles	5	6.0
CONTROL AND SAFETY SYSTEM	17	20.5
COMMUNICATIONS	2	2.4
WEATHER	25	30.1
OTHERS OR UNDETERMINED	16	19.3
TOTAL	83	100

4.4 SAFETY AND SECURITY

This section discusses safety of cableways, specifications and regulations, safety experience at Roosevelt Island and safety aspects with regard to passengers, employees, and the public.

4.4.1 Safety of Cable Systems

Cable technology for transporting people and goods has evolved over a long time span. Today, cable technology is at a mature state because of a long, evolutionary development process. Over the years and in a wide variety of applications, transportation systems based on cable technology have established an impressive safety record.

In Table 4.5, Swiss safety statistics of cable systems, measured by passenger injuries or fatalities, are compared with rail systems which are generally accepted as safe. While the overall rate of passenger injuries and death for aerial tramways is slightly higher than on rail systems, the death rate alone on rail systems is 50 percent higher than on aerial tramways. In addition, it should be noted that in the accident statistics for railways, intercity rail passengers are included and that generally the trip length on rail systems is longer than on aerial tramway systems. Conversely, the environment in which aerial tramways generally operate is more severe than for rail systems.

The potential for fire on-board a tramway vehicle is judged to be low. No case of on-board fire at any of these cable systems has been reported to date. Very little material is used on the vehicles which could be potentially flammable. The vehicles are usually of aluminum construction. Most important, because tramway systems do not employ on-board propulsion, fire hazards resulting from high voltage equipment are eliminated from the vehicles. Only low voltage signal currents are to be found. At the Roosevelt Island system smoking on-board the vehicles is prohibited.

5.1 CAPITAL COSTS

5.1.1 Amounts Expended

The capital costs as cited herein were provided by the operator. Costs for individual cost categories such as vehicles, cableways, control and communications, power and utilities, maintenance and support facilities and equipment, and engineering and project management were not made available for this assessment. A cost breakdown for system components is not necessary for an aerial tramway system capital cost analysis. Tramway systems are practically bought off-the-shelf and the cables, propulsion, and vehicles are integral system parts.

Costs for right-of-way and ground for station acquisition are not included in the capital costs as reported here. This cost for right-of-way may be considered negligible since the pylons require very little space and the system allows flexibility in their placement and design. For example, one tower of the Roosevelt Island system was built across a street without interfering with existing traffic. The land acquisition costs for the stations are comparable or less than those for at grade rail transit stations or bus terminals. The Manhattan station is a good example for value capture through good planning. This station was built with columns which, in the future, can support a 32-story building over the present station.

Table 5.1 deliniates the capital costs for the Roosevelt Island system. The $2,000,000 in the cable system cost category was expended for the turn-key tramway system without the structures (stations and pylons).

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16. Abstract

This is an assessment and evaluation of Jetrail, the first operational completely automated, demand-responsive, group rapid, intra-airport transportation system. It was installed by Braniff International Airlines at Love Field in Dallas, Texas, for their passengers and guests.

It connects a parking lot at the entrance to Love Field and the Braniff terminal with three-quarters of a mile of double-lane monorail and has ten suspended vehicles, a maintenance facility, and three stations.

The system was intended to retain passengers in the face of increased congestion at Love Field. It operated successfully from April 1970 to January 1974, at which time Braniff moved to the new Dallas-Ft. Worth Regional Airport.

Over six million passengers were carried 1.3 million miles over a four-year period without a fatality or major mishap. The system did this in spite of the engineering novelty and early, low reliability of the propulsion and control systems.

The Jetrail system continues to be used as an engineering test-bed for a prototype linear induction motor propulsion system. This latter system, called Astroglide, is being developed by PRT Systems Inc. Since the motor has no moving parts, it is markedly simpler than the rotary motor and drive train of the Jetrail system.

This report provides information on the Jetrail operational experience and the Astroglide prototype for transportation planners, designers, developers, and operators of automated transit systems for intra-airport, urban, recreational, and freight applications.

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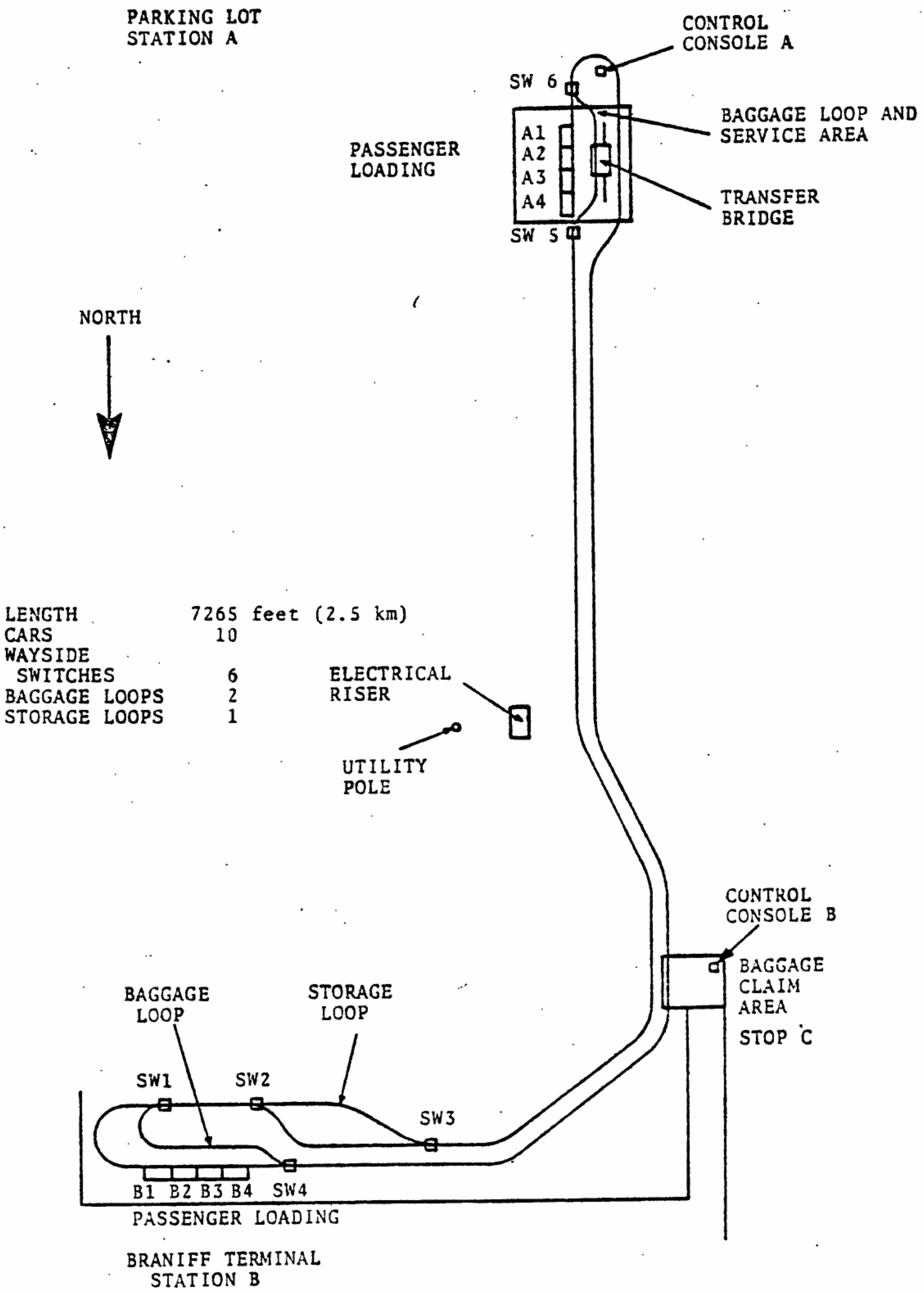


FIGURE 3.1.4. SCHEMATIC OF THE JETRAIL SYSTEM

Automatic system operation is achieved by means of a hard-wired system of relays which operates as a redundant block control system. The system is demand-operated in either a low- or high-flow mode.

Although design provisions were made for two baggage vehicles, they were never incorporated into the system. Baggage was moved between stations by automotive trucks.

3.1.1 System Characteristics

The Jetrail vehicles operate at four discrete nominal speeds.

	(mph)	(km/hr)	(ft/sec)	(m/sec)
Speed 1	1.5	2.4	2.2	0.67
Speed 2	4.5	7.2	6.6	2.0
Speed 3	9.0	14.5	13.2	4.0
Speed 4	15.0	24.0	22.0	6.7

The speed sequence over the guideway is shown in Figure 3.4.1.

The average speed is 11.8 mph (17.3 ft/sec, 19 m/sec), requiring 3.5 min. to travel the 3632 ft (0.7 mile, 1.1 km) between stations A and B, or 7.0 minutes to complete the 1.38-mile (2.2 km) loop. Assuming that the unloading of passengers at the aft-most loading bay, the relocation of the vehicle to the foremost loading bay, and the loading of passengers requires 55 seconds, the maximum theoretical one-way capacity of the system is 1358 passengers/hour. This is based on ten vehicles with a maximum design capacity of ten passenters. However, with a maximum crush-load of 14 passengers (eight seated and six standees), the system will have an increased theoretical capacity of 1902 passengers/hour. The maximum practical one-way capacity is considered to be about 80% of the theoretical maximum, or 1086 passenter/hour.

The Jetrail system could theoretically accommodate up to 21 vehicles on the guideway simultaneously (based on a 20-second headway and an average speed of 11.8 mph, 19 km/hr), indicating a further potential increase in passenger capacity. However, to accept the added vehicles loading and unloading facilities would have to be doubled.

The maximum operating capacity experienced was reported by Braniff to be approximately half the theoretical, or 600 passengers per hour. This is not based on an actual count but on a sample estimate made on the basis of 2.2 passengers per car entering parking lot A. Over the life of the system (April 1970-January 1974) it carried an estimated six million passengers with no fatalities.

The Jetrail System Operational Characteristics

System Performance:

max. theoretical one-way capacity	1358 pass./hr.
max. practical one-way capacity	600 pass./hr. (est. Braniff)
max. practical one-way capacity	1086 pass./hr (80% theor.)
min. theoretical headway	approx. 7.3. sec.
headway	20 sec.
availability	on demand, 24 hr./day
type service	point-to-point, demand-responsive collection and dist.
type network	loop
traveling unit	single vehicles
interior noise	71 dBA
exterior noise	72 dBA

Vehicle Performance:

average velocity	11.8 mph (19 km/hr)
max. velocity	15 mph (24 km/hr)
max. grade	4%
average acceleration/deceleration	3.2 ft/sec^2 (0.97 m/sec^2)
max. jerk	-
emergency deceleration	3.5 ft/sec^2 (1.1 m/sec^2)
stopping precision in station	-
degradation if guideway is wet	none
degradation for ice and snow	inoperative
vehicle design capacity	6 seated, 4 standees
vehicle crush capacity	8 seated, 6 standees
energy consumption	-

Stations:

type	on-line, 3-berth, platoon loading
type boarding	level
ticket & fare collection	free service
security	none
boarding capacity	1028 pass./berth/hr
debarking capacity	1440 pass./berth/hr
max. wait time	3.8 min.
vehicle in-station dwell time	20-55 sec.
station spacing (principal)	0.7 mile (1.1 km)

Individual Service:

privacy	multiple party
transfers	none
stops	at baggage claim (Sta. C) from Braniff terminal (Sta. B)
accommodations	seated and standing
security	none
instruction	auditory and signs
passenger articles	small packages & luggage
comfort	heating, ventilation, and air conditioning

Cargo Capability:

luggage	from parking lot (Sta. A) to aircraft by truck - 2 Jetrail baggage cars never implemented.

Reliability and Safety:

fail-safe features	two levels of control redundancy without use of vital relays
strategy for passenger evacuation	knotted rope
strategy for removal of failed vehicles	push with trailing vehicle or tow from ground
system lifetime	design goal 15 yrs.
vehicle	design goal 7 yrs.

operational life	4 years
system Mean Time Before Failure (MTBF)	113 hrs. (approx.)
system restore time after failure	variable-usually <15 minutes
system availability	99.7 - 99.9% (approx.)
vehicle MTBF (single)	52 hours (approx.)
guideway MTBF	12,000 hours (approx.)
command and control MTBF	3,000 hours (approx.)

Personnel Requirements:

Vehicles & stations are unmanned. Personnel are required at one central control facility, maintenance, and administration.

The Jetrail System Physical Description

Vehicle:

length, overall	11.25 ft (3.4 m)
height, clear inside	6.5 ft (2 m)
width, clear inside	5.25 ft (1.6 m)
weight, empty	6000 lbs (2700 kg)

Suspension:

type	Vehicle suspended by 8 solid-rubber tired wheels. 4 drivers and 4 idlers running on a steel I-beam flange
lateral guidance	16 solid-rubber tires wheels
sway (roll)	4 shock absorbers

Propulsion & Braking:

type & no. of motors	2 rotary induction
motor rating	7.5 HP each (5.6 kW)
type drive	Electromagnetic eddy-current transmission providing positive and negative torque coupled with a mechanical differential and gear train for final drive of wheels. 2 driving wheels per truck.

type power	480 Vac, 3ϕ, 60 Hz
power collection	Sliding contact shoes on galvanized steel power rails
type service brakes	eddy-current 2 per vehicle
type emergency brakes	mechanical/electro-magnetic

Switching:

type	Lateral transfer of inter-connecting guideway elements
switch time (lock-to-lock)	6 sec
speed thru switch	4.5 mph (speed 2)

Guideway:

type	mono-rail, standard I-beam
supports	cylindrical steel columns
width (center-to-center)	12.1 ft (3.7 m)
total length including storage, turnouts, and maint.	8400 ft (2.5 km)
length, shuttle-loop	7265 ft (2.2 km)
average height of vehicle floor above ground	16 ft (4.9 m)
max. grade	4%
min. turn radius	15 ft (4.5 m)

3.2 VEHICLES

3.2.1 Body

The vehicle is a fiberglass shell attached to a steel frame, having windows in the upper half and a door on the right side. Polyurethane foam insulation lines the inside of the fiberglass. The general features of the vehicle exterior are shown in Figure 3.2.1.

The welded steel frame structure is attached to the two trucks which contain the suspension, lateral restraint, and anti-sway systems. The weight is carried by eight solid-rubber (four driving) wheels, which ride on the supper surface of the lower flange of the I-beam. The truck is inherently constrained to the guideway in a

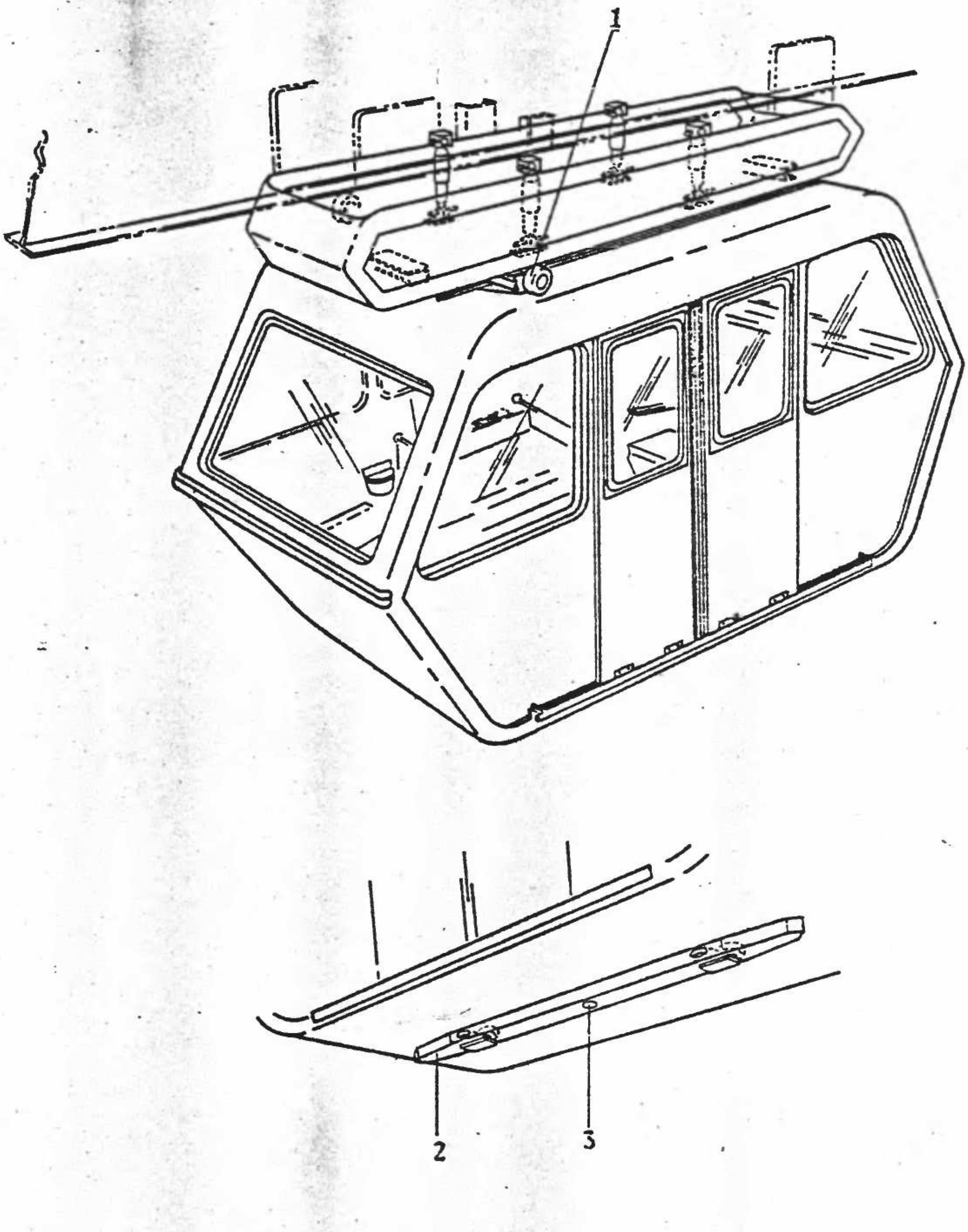


FIGURE 3.2.1. SOME DETAILS OF JETRAIL VEHICLE AND SUSPENSION

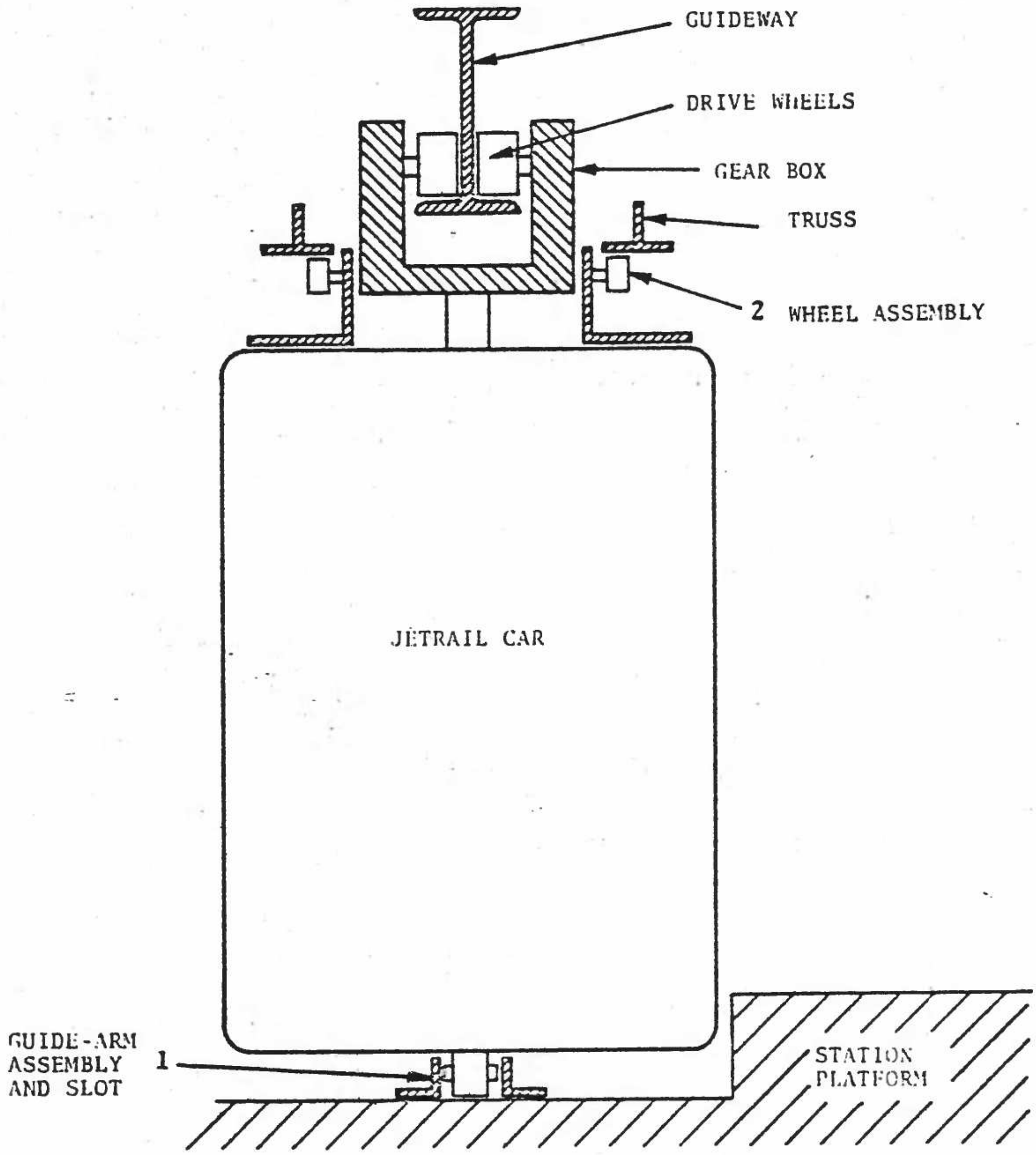


FIGURE 3.2.2. SCHEMATIC OF JETRAIL GUIDING AND SUSPENSION

3.10 ASTROGLIDE

The Jetrail vehicle operational experience resulted in a relatively large number of propulsion and vehicle control system failures which required a significant maintenance effort to keep the system operational (see Section 4.3.3). In order to eliminate these failures and minimize the required maintenance, PRT Systems Inc., made modifications to the Jetrail vehicle Number 10 by removing the eddy-current transmission propulsion system and incorporating a mechanically simpler linear-induction-motor (LIM) propulsion and control system.

The LIM system consists of two single-sided motors, one mounted on each vehicle truck and a control system currently mounted in the vehicle (see Figures 3.10.1, -2, and -3). The HVAC system was removed and the motor control system was mounted in a vertical cabinet to facilitate maintenance during the prototype development test phase. This is shown in Figure 3.10.4. This equipment is expected to be repackaged and mounted on top of the vehicle in the production model.

The differentials and gear boxes were eliminated reducing the vehicle weight by 2600 pounds (1200 kg) to 4400 pounds (2200 kg). The original drive and support which rolled on the upper surface of the lower flange are no longer used for traction but are only used as idler support wheels. The lower face of the I-beam flange is used as a reaction rail by the LIM.

The linear induction motor is the basic electrical machine used to provide the propulsion for the vehicle. The linear induction motor is analogous to the rotary induction motor in that they both produce output, thrust (linear) or torque (rotary), through the interaction of an exciting magnetic field and an induced secondary magnetic field. In each case the excitation is produced by multi-phase windings which are located in the stator. For the linear induction motor the induced secondary magnetic field occurs in the reaction rail which for the Astroglide system is the guide rail. In a linear machine the synchronous speed of the traveling magnetic field is related to the operating frequency and pole spacing, p. For a machine operating at 60 Hz with a given pole spacing, the velocity of the moving field is 2 x 60 x p. For the Astroglide system, with a 15-cm pole spacing, the synchronous velocity is 64.5 km/hr.

A S S E S S M E N T O F T H E M U E L L E R A E R O B U S S Y S T E M

Prepared for

U.S. Department of Transportation / Urban Mass Transportation Administration

2.1.1 The Transportation Problem and its Solution in Mannheim

In 1969, the City Council of Mannheim accepted the offer to host the Bundesgartenschau 1975 (Federal Garden Show) in the City of Mannheim. Two distant sites were selected to locate the garden show. These two locations, on opposite sides of the Neckar River, needed to be connected with a well functioning visitor transportation service. It was determined that the existing transportation systems could not provide the additional capacity needed to ensure fast and convenient visitor transportation service between the two activity centers. The Neckar River with its bottlenecks at the bridges posed an additional problem.

The Mueller Aerobus was selected to provide the transportation link between the two Bundesgartenschau sites. Important in this decision was the system's potential to be implemented with little disruption to the existing urban structure; making use of existing right-of-ways, passing over traffic arteries and bridging the Neckar River. It was also felt that the novel technological solution would attract the visitors.

2.1.2 System Development

The Aerobus system is based on cable technology. The development goal was a new urban transportation system based on cable technology using a very light guideway and utilizing space above existing structures to bridge natural and other obstacles with long spans.

The Aerobus development history to date can be defined in three stages as follows:

- First generation system - An engineering test system which was first constructed and tested at Smerikon in Switzerland and later sold and installed in St. Anne, P. Q., Canada. This system is expected to start operation in 1979.

- Second generation system - The Mannheim Aerobus installation, operating from April 18, 1975 to October 10, 1975.

- Third generation system - Further development and improvements started during the Mannheim demonstration for future installations.

2.2 SYSTEM DESCRIPTION

The Mannheim installation was the first application of the Mueller Aerobus system for public transportation. Its essential features are summarized in this section. More comprehensive technical information concerning system design and function is provided in the appropriate sections of Chapters 3 and 4 of this report.

2.2.1 System Layout and Operational Concept

The Mannheim Aerobus system connected the two parts of the Bundesgartenschau 1975 as illustrated in Figure 2.1. The L-shaped Aerobus guideway connected the station in Herzogenriedpark with the station in Luisenpark and had two parallel cableways connected with fixed-rail sections in curves and at switches. A 90 degree turn led to a river crossing. The whole guideway was elevated resulting in a complete system segregation from existing traffic patterns. The guideway was fully integrated in an urban environment. Parts of it ran above a double-track electric high speed railway, while other parts ran at an approximately 4.6 m (15 ft) clearance above street level, crossing major traffic junctions. The total route length was 2,951 m (9,679 ft).

The system had eight vehicles. They were bi-directional and could not be connected in trains. The vehicles were manually driven with safe headway and speed limits enforced by an Automatic Train Protection System.

The two terminal stations were each located at the periphery of the two parts of the Bundesgartenschau. The Fernmeldeturm station was at-grade and the Herzogenriedpark station was elevated with the loading platform approximately 3.50 m (11.5 ft) above ground. The elevated station was entered by stairways, and exited over a ramp. The elevation of the station exit side was not as high as the entrance side.

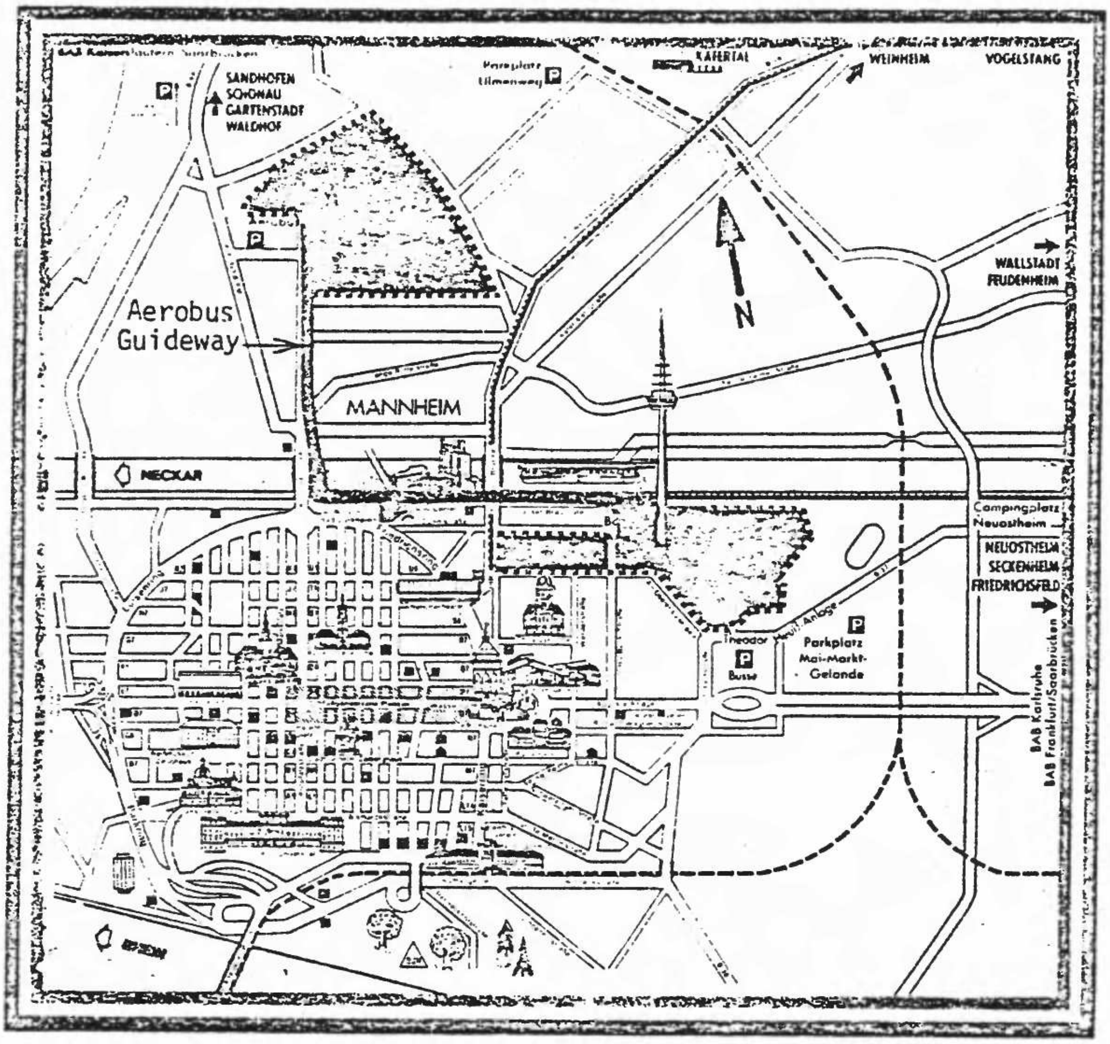


FIGURE 2.1: MANNHEIM CITY MAP WITH L-SHAPED AEROBUS GUIDEWAY

The maintenance facility was built in close proximity to the Herzogenriedpark terminal station. An approximately 200 m (600 ft) single lane fixed-rail section with a 90 degree curve connected the maintenance building with the end station. The maintenance building also provided parking space for all eight vehicles.

The operation was a shuttle service generally operated in a scheduled mode. However, in cases of high demand during off-peak periods, some unscheduled trips were made. Operating hours coincided with the Bundesgartenschau, from 9:00 am to 7:00 pm. Minimum operational headway was 210 seconds.

2.2.2 Vehicles

The Aerobus vehicles operated suspended from the overhead cableway with its fixed-rail sections in curves and at switches. The articulated vehicle consisted of nine articulated body sections, each with its own carriage mounted on the roof. Even though the vehicles were bi-directional, only one driver position was provided, located on one side in the mid-section.

The passenger compartment was spacious for the design capacity of 100 passengers. Seating space for 48 passengers was provided on simple, vinyl covered, upholstered benches along the vehicle walls. Large windows around the entire vehicle allowed a view in all directions. Air conditioning was not provided.

Each vehicle had three plug doors on each side, pneumatically operated and electrically controlled. Pressure sensitive edges were employed, which in case of a blocked passageway, interrupted the closing function and returned the door to its opened position.

The vehicle propulsion system consisted of eight 300 volt, 9.5 Kw, series-type traction motors with conventional resistor/cam control.

2.3.4 System Dependability

For the 185 days duration of system operation (1,814 system operating hours), a total of 36.3 downtime hours resulting from 18 system downtime events were recorded. The mean time between failures (MTBF) for the six months was 95.3 hours. Dividing the total uptime by the total scheduled time (i.e., uptime plus downtime), yields a system availability of 98.0 percent. While for the first 44 days of operation the average system availability only reached 93.1 percent, it increased to 99.6 percent in the period of June to October.

The greatest cause of downtime resulted from power rail problems. Correction of this problem during the initial phase of operation increased system dependability greatly. Second greatest were wind gusts exceeding the imposed 58 km/h (36 mph) limit, followed by vehicle problems which ranked third.

2.3.5 Safety and Security

The safety and security of an Aerobus system may be compared to that of other conventional transit systems where vehicles travel on elevated guideways. An important factor ensuring the personal safety and security of passengers was the continuous presence of station and vehicle attendants.

The Mannheim Aerobus system provides a limited operating experience in the areas of safety and security, since it only operated for six months. The experience was too short to be used as evidence to establish a statistical basis for the prediction of the safety performance of future systems.

No serious accidents were recorded for the duration of the Mannheim operation.

A special area of concern with elevated systems are emergency evacuation procedures for passengers in stranded vehicles. The most preferable method for the Aerobus system would be to push or pull the stranded vehicle into the next station. For the cases where pushing or pulling was not feasible, a gangway was provided, to evacuate passengers from a stranded vehicle through the emergency exit at the end sections, or through a door to an empty Aerobus vehicle at the side, front, or rear position. However, passenger evacuation with another vehicle may not be possible when the power distribution system is shut down because of failure or power loss. In case a failed vehicle cannot be brought to a station and its position is not too high above the ground, use of an extension ladder may be the proper rescue method. The maintenance vehicle built for Mannheim was driven by a gasoline engine and could be used when electric power was not available. If a stranded vehicle is high above the ground and evacuation with another vehicle is not possible, the stranded passengers might be lowered to the ground by using rope resuce trousers.

The Aerobus vehicle was evaluated and tested by the Mannheim operator for fire safety. According to the operator, the vehicles fullfilled the fire safety requirements of the German construction and operating codes for transit vehicles. All critical electrical conductors were insulated with fire resistant silicon. The space between the exterior and interior walls was filled with a type of polyurethane foam which was tested and found acceptable. Three fire extinguishers were provided in each vehicle.

2.4 ASSESSMENT FINDINGS

Significant findings which resulted from this assessment are summarized below. The main sections of the report provide detailed discussions of all system aspects.

2.4.1 The Mueller Aerobus System as Installed in Mannheim

The findings reported in this subsection are based on Mannheim system records and interviews and observations during several site visits.

System Operation and Performance

- o The Aerobus system operation in Mannheim reached a high level of performance after a relatively short break-in time, but was not able to meet peak passenger demands. System availability reached a maximum after 1-1/2 months duration.

  - Average wait times of 20 minutes in peak hours as reported by the operator, must be considered too high.

  - The reported eight minutes average waiting times for off-peak operation should have been the minimum goal for peak hour operation.

  - Urban application of a third generation Aerobus system should be preceded by demonstration of safe operation with maximum speed, minimum headway, and maximum vehicle capacity to achieve a line capacity, satisfying expected demand and waiting times.

- Weather conditions that adversely affect an Aerobus system operation are high wind and lightning. Depending on the climate, special measures for ice and snow may be necessary. In Mannheim, the average system unavailability caused by weather was 0.29 percent. However, the maximum wind criteria was set lower than is reported for cable tramway systems.

System Assurance

- According to the records available to the assessment team, system acquisition occurred without the benefit of detailed technical specifications and well defined specification verification procedures. Only a short general performance specification was contractually agreed upon. The maximum system capacity, as stated in the procurement contract, was never achieved in Mannheim.

- Problems causing system downtimes were not related to the basic system concept. The significant problems which caused failures (i.e., power rail expansion, air compressor failures, etc.), should be correctable by proper design and installation.

- The guideway structure and vehicles as delivered to Mannheim showed some serious deficiencies (see subsection 4.4.3). Parts of the vehicle carriage frame and wheel hubs had casting failures. Gas bubbles were found in the bells which supported the running cables. Also, a design failure caused nuts to become loose which connected the bells to the suspension rods. Further development which had begun during the Mannheim operation led to significant changes. While material failures are not indications of faults in the system concept itself, they underline the importance of quality control during the production process.

Human Factors

o The Mueller Aerobus configuration for Mannheim would not fulfill the elderly and handicapped accessibility requirements for new public transit systems in the United States. Design changes to the vehicle would be required for a fully accessible Aerobus system.

o Ride comfort analysis showed that the cableway (vehicles running on blank cable) produced a "washboard" effect. This effect induced accelerations which tended to increase proportional to the vehicle speed. The developer has designed an improved track which conceptually will significantly reduce the washboard effect. Future system demonstration tests will be required to verify the design and expected ride quality improvements.

o Interior and exterior noise levels were reported to be low.

o Passenger seating should be improved for use in a modern transit system. The benches were not anatomically formed and did not provide arm rests.

o Safety aspects should be studied before locating the driver's position in the vehicle center for future Aerobus systems.

Technology

o The Mueller Aerobus system has not yet reached a complete state of maturity even though the third generation system is already under development.

- The technical subsystem assessment has shown that tests and operating experience in Mannheim prove the soundness of the basic system concept and design. However, during the course of this first application, problems were encountered with materials, primary and secondary suspension, and safety at the vehicle articulation. Responding to these problems, development of improvements are underway. The same system as operated in Mannheim will not be built again.

- The developer/manufacturer claims significantly higher maximum speed capabilities than allowed by the Mannheim operator. Since this higher performance was not demonstrated in Mannheim, a third generation demonstration system would be required to establish that performance is satisfactory at these higher speeds.

2.4.2 Potential Urban Applications

The Mannheim Aerobus experience demonstrated that cable technology offers a feasible solution to urban transportation problems. Similar Aerobus applications, connecting two population centers, bypassing existing traffic patterns and negotiating natural and artificial barriers can be envisioned. This is the conclusion which may be based on the Mueller Aerobus system's first public transportation application, which served as a demonstration and test system in Mannheim. However, the Mueller Aerobus system has undergone considerable further development since Mannheim and the same system, as it operated at the Bundesgartenschau 1975, will not be built again. These further developments are a direct result from the only application as a public transit system. Therefore, the results of the Mannheim operational experience serve well to assess the pros and cons of the system concept and the impact of system improvements now under development.

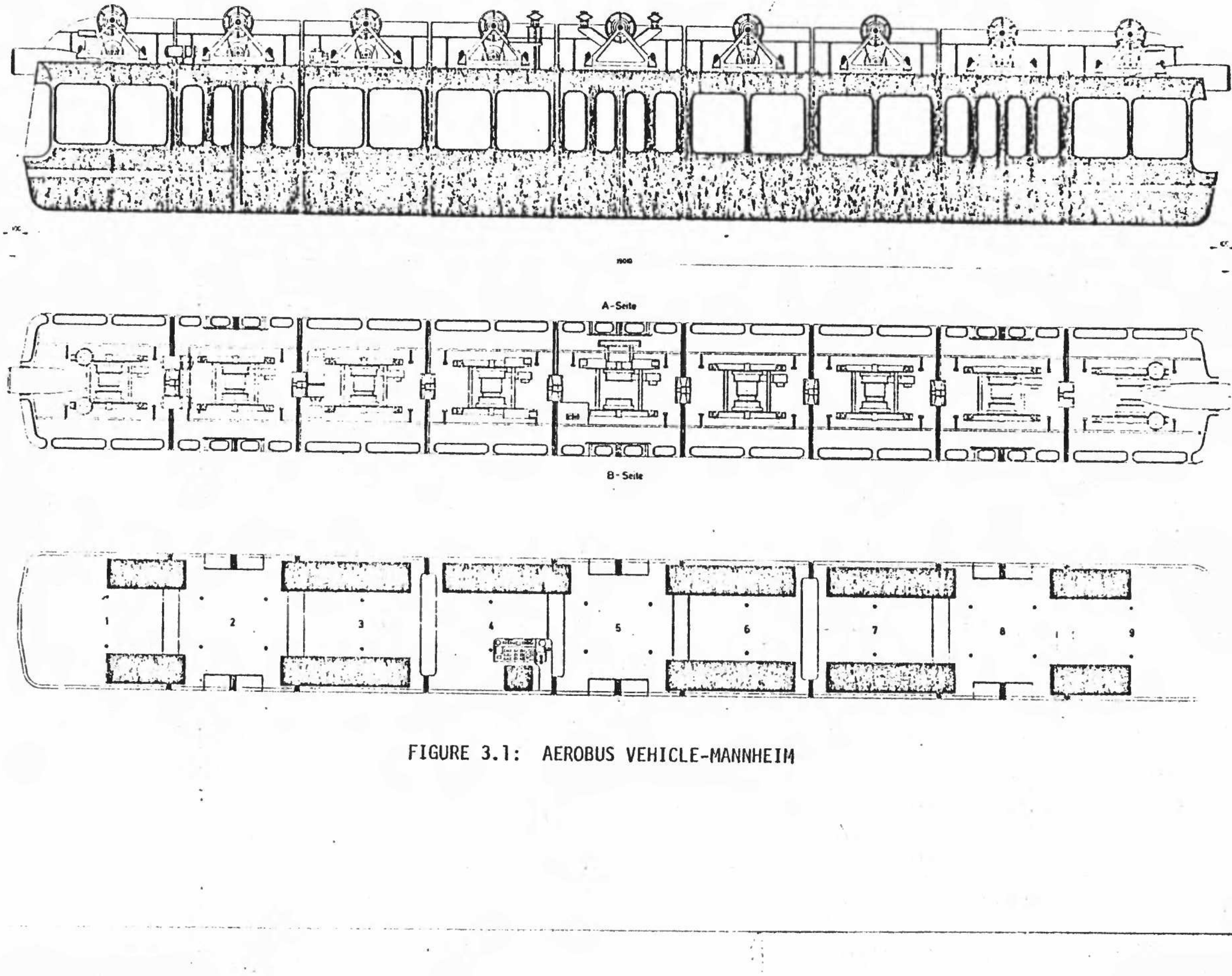


FIGURE 3.1: AEROBUS VEHICLE-MANNHEIM

Overall Length	19.01 m (62.33 ft)
Overall Width	2.10 m (6.89 ft)
Overall Height	3.20 m (10.5 ft)
Empty Weight	7,500 kg (16,500 lbs)
Gross Weight	15,000 kg (33,100 lbs)
Design Capacity	100 passengers
Seated	48 passengers
Standing	52 passengers
Maximum Speed, Mannheim	40 km/h (25 mph)
Maximum Operating Speed, Mannheim	35 km/h (22 mph)
Number of Doors	3 on each side

Functional descriptions and discussions of the vehicle body, carriage, electrical systems, and overall vehicle performance are provided in the following subsections.

3.1.1 Vehicle Body and Carriage

The articulated vehicle body consisted of nine sections. There were three types of standardized sections. The Mannheim vehicle was assembled as follows:

- End section: Each end of the vehicle - section 1 and section 9, in Figure 3.1.
- Standard section: Each vehicle had four standard sections - 3, 4, 6, and 7, in Figure 3.1.
- Standard section with two doors (one on each side): Each vehicle had three standard sections with doors - sections 2, 5, and 8, in Figure 3.1.

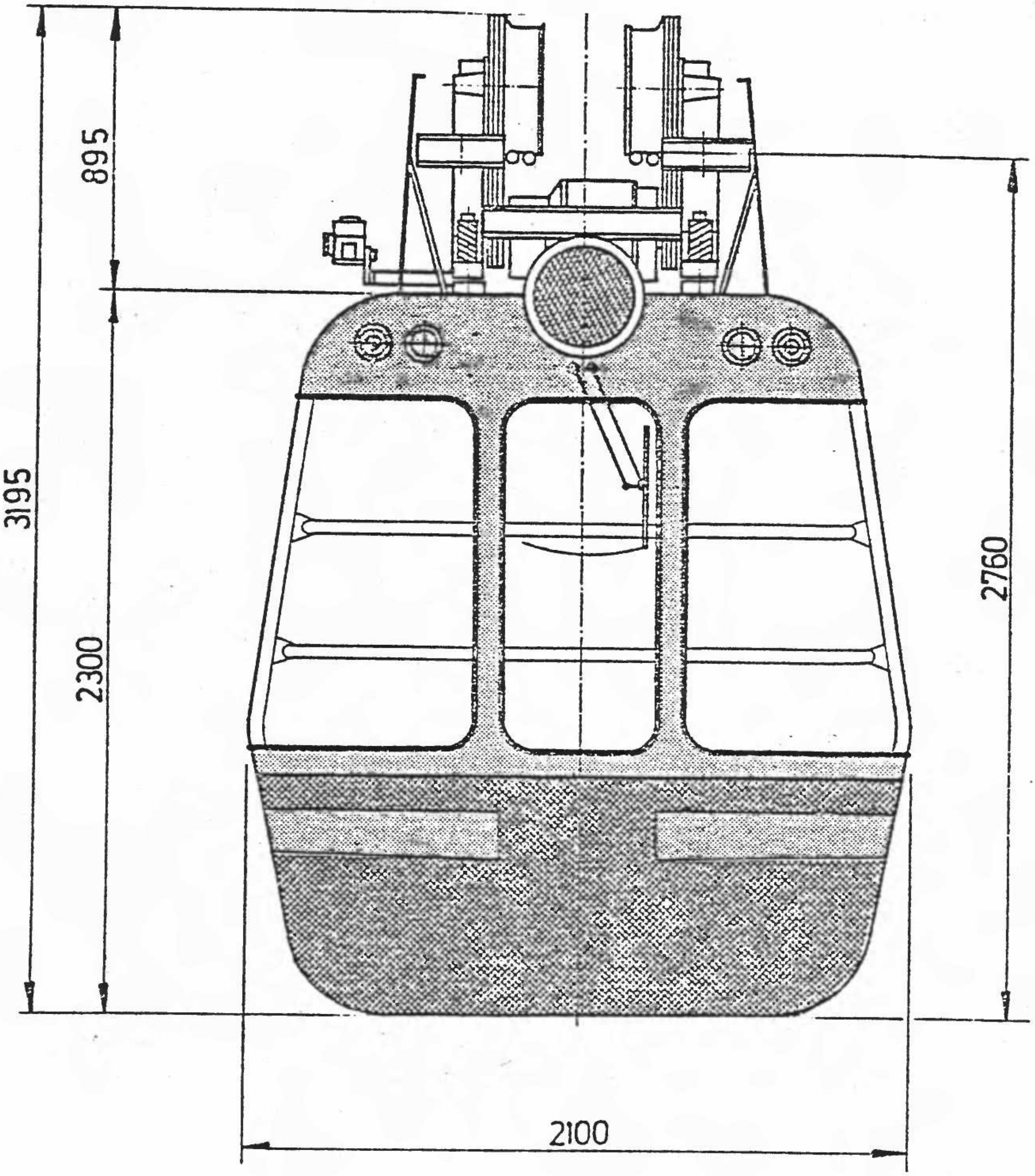


FIGURE 3.2: VEHICLE FRONT VIEW
(Dimensions in mm)

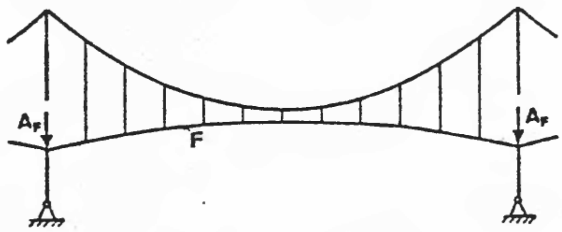
A breakdown of this total guideway length is given in Table 3.1. The cable-track portions of sections I and II consisted of cable spans of different lengths as shown in Table 3.2, where the spans are identified with respect to Figure 3.30 by the numbers of their two supporting pylons.

The pylons number 1a and 9a carried the cable-to-rail transition sections at the entrance/exit of the Fernmeldeturm station and the Herzogenriedpark station, respectively. The pylons number 8a and 1a supported the cable-to-rail transition sections at the ends of the 90 degree curved fixed-rail track at the south bank side of the Neckar River crossing. The spans associated with these pylons were rather short with the exception of the span 1a-1 which was 188.41 m (618.06 ft) long as it crossed the Neckar River. The consistently longest seven spans were found above and along the OEG rail track in section I and ranged in length from 112.17 m (367.96 ft) to 269.67 m (884.63 ft). Section II contained four long spans ranging in length from 124.03 m (406.87 ft) to 268.86 m (881.97 ft) including the span crossing the Neckar River and the adjacent spans as well as three adjacent spans between the north end of the tree-lined Max-Joseph Street and the Herzogenriedpark station. There were four connecting spans along the Max-Joseph Street ranging in length from 57.50 m (188.62 ft) to 63.67 m (208.86) per span. This close spacing permitted the guideway to follow the slight curvature of the street (a total of 10 degrees change in direction) in keeping with the minimum radius of curvature of 5,500 m (18,000 ft), equivalent to a maximum change of track direction at a pylon of about 2-3 degrees set by the Aerobus developer for the standard cable track. Table 3.2 shows that the lengths of seven out of the nineteen spans of the Mannheim cabletrack guideway fell within the range of most economical span length from 200 m (656 ft) to 300 m (984 ft) as defined by the Aerobus developer. Table 3.1 also shows that the total cable length of 1318 m (4324 ft) and 1465 m (4806 ft) for the cable tracks in sections I and II, respectively, were well below the maximum cable length of 3,300 m (11,000 ft) specified by the developer.

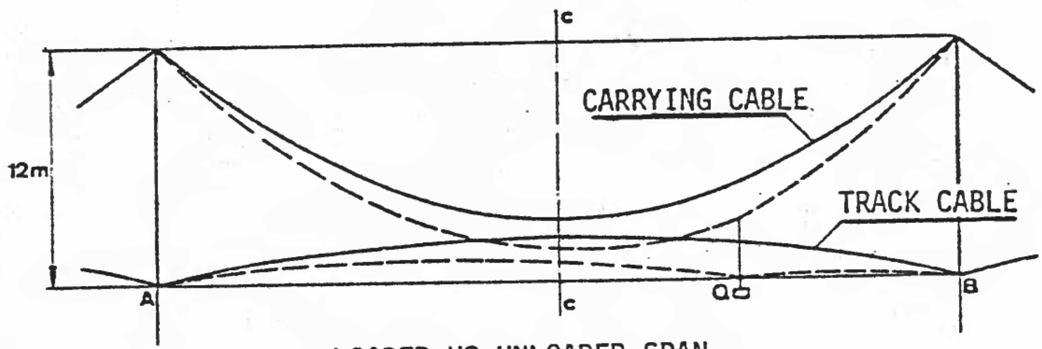
TABLE 3.1: GUIDEWAY LENGTHS

GUIDEWAY SECTION	DOUBLE TRACK CABLE m (ft)	DOUBLE TRACK RAIL m (ft)	DOUBLE TRACK RAIL SWITCH m (ft)	SINGLE TRACK CABLE m (ft)	SINGLE TRACK RAIL m (ft)
Section I	1318 (4324)	---	---	---	---
Section II	1465 (4806)	---	---	---	---
90^{o} Curve at Neckar Crossing	---	72 (236)	---	---	---
Fernmeldeturm Station, Platform	---	29 (95)	10* (33*)	---	---
Fernmeldeturm Station, Shunting and Parking	---	30* (98*)	---	---	---
Herzogenriedpark Station, Platform	---	17 (56)	10* (33*)	---	---
Herzogenriedpark Station to Maintenance, Including Shunting Section	---	---	---	---	200*(656*)
TOTAL	2783 (9130)	148 (485)	20 (66)	---	200*(656*)
	TOTAL GUIDEWAY LENGTH 3151 m (10 337 ft)				

*Length Estimated



UNLOADED SPAN



LOADED VS UNLOADED SPAN

FIGURE 3.32: AEROBUS CABLEWAY SYSTEM CONCEPT

symmetrical with respect to the span center C-C and has no inflection points. The shape of the load-path curve depends on the magnitude of the vehicle load Q relative to the resultant vertical pretension force. If the vehicle load predominates the pretension force, the load-path curves downward (concave path); if the pretension force predominates, then the load-path curves upward (convex path). Under an intermediate condition the load-path becomes a straight line, a desirable condition which can be approximated by proper choice of system parameters. Under this condition the vehicle can travel past the pylons without any sudden vertical deflection of the track cable, thus permitting considerable increase of vehicle speed over that of conventional cableway systems. The concept permits this ideal condition only for a fixed vehicle weight. However, deviations from the ideal load-path curve remain sufficiently small for a single vehicle in a span whose weight ranges between empty and full load, provided that the track cables are under sufficient pretension. In a practical system design the ideal load-path should occur for an average vehicle loading. Also, an operational restriction should be imposed that only a single vehicle load of comparable weight should be permitted within one span at any one time.

A hard upper speed limit for the Aerobus cableway is given by a kind of "sound barrier"; namely, the propagation velocity of transversal oscillations of the cables. With the customary 60 Mp* pretension of 45 mm steel cables this upper speed limit lies at about 700 Km/h (345 mph), far above the projected maximum Aerobus speeds of 60 to 80 Km/h (37 to 50 mph).

The Aerobus cableway system has to be considered a complex dynamical system with many low frequency natural modes, the excitation of which could lead to undesirable resonance phenomena. The most obvious excitation could result from driving over those points of the cable track where the many vertical suspension rods are attached. This effect could be controlled, for example, by random spacing of the vertical suspension rods. Although no evidence could be found of such adverse excitations, neither on the experimental track in Schmerikon nor during the Mannheim operations, dynamic modal analysis for future third-generation Aerobus systems is considered necessary by the assessment team.

A comprehensive analysis of the Aerobus cableway system was performed and published by H. Wettstein. A summary of the main topics of this report describing single-span calculation, cableway route selection, loaded span calculation procedure, and mounting conditions is given in Appendix B at the end of this report.

*1 Mp = 1 metric ton force.

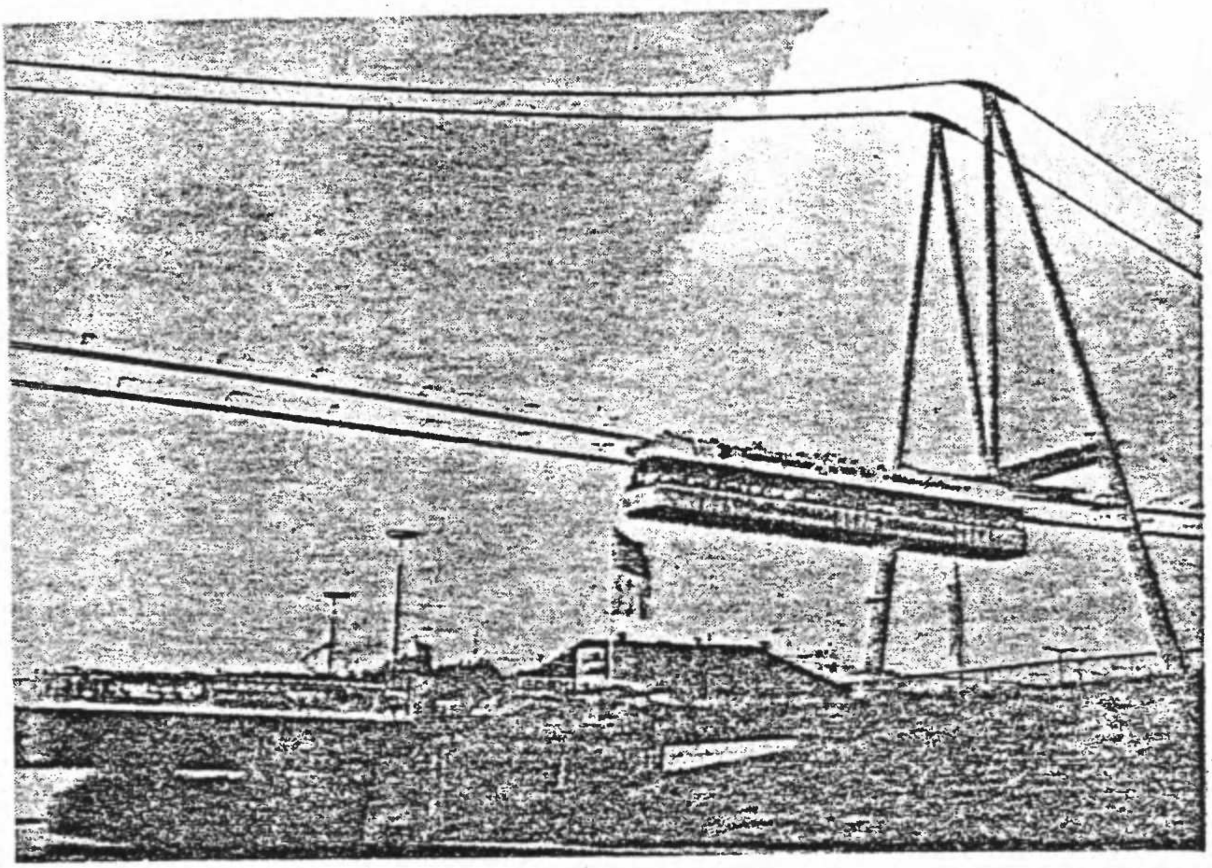


FIGURE 3.36: PORTAL PYLON AT CROSSING OF NECKAR RIVER

Anchoring - Two types of anchoring of the pretensioned carrying and track cables were used at the ends of both cableways (Section I and II) of the Mannheim system; namely, anchoring of cable ends to a rigid rail structure and anchoring to concrete foundations in the ground. Ground anchoring was used in Mannheim at both ends of the cableway section II, at the rear of the Herzogenriedpark station (Figure 3.37) and at the 90 degree fixed-rail curve at the south bank of the Neckar River (Figure 3.38).

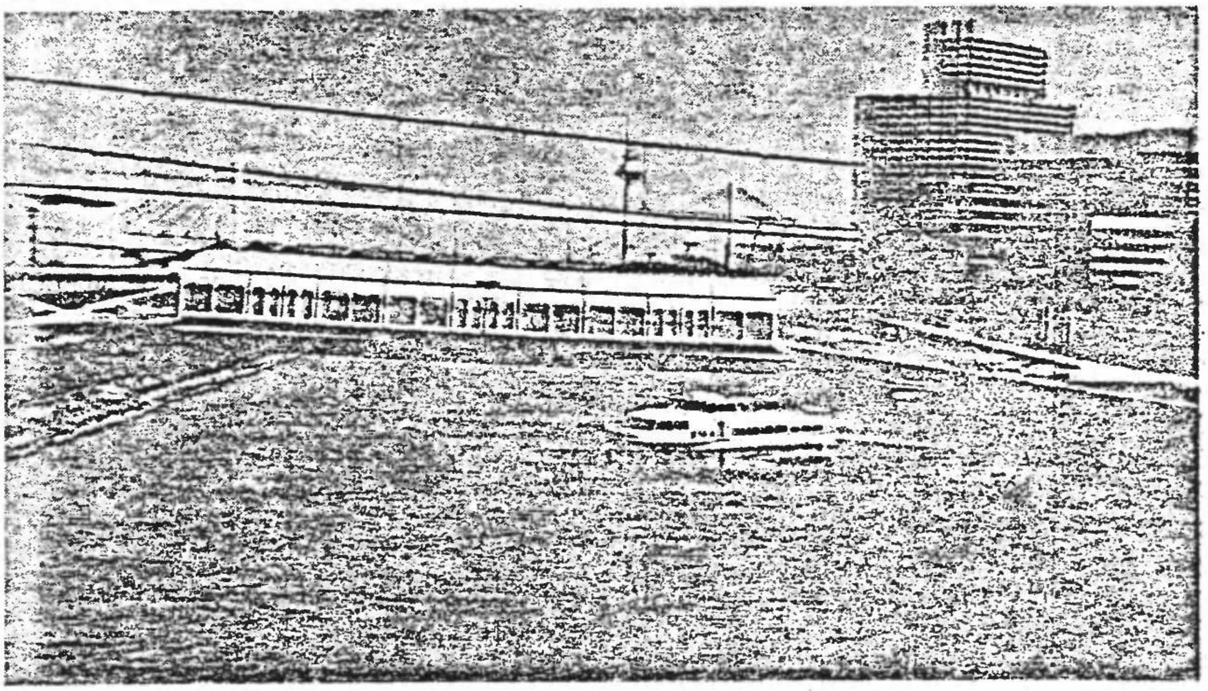


FIGURE 3.40: AEROBUS CROSSING THE NECKAR RIVER

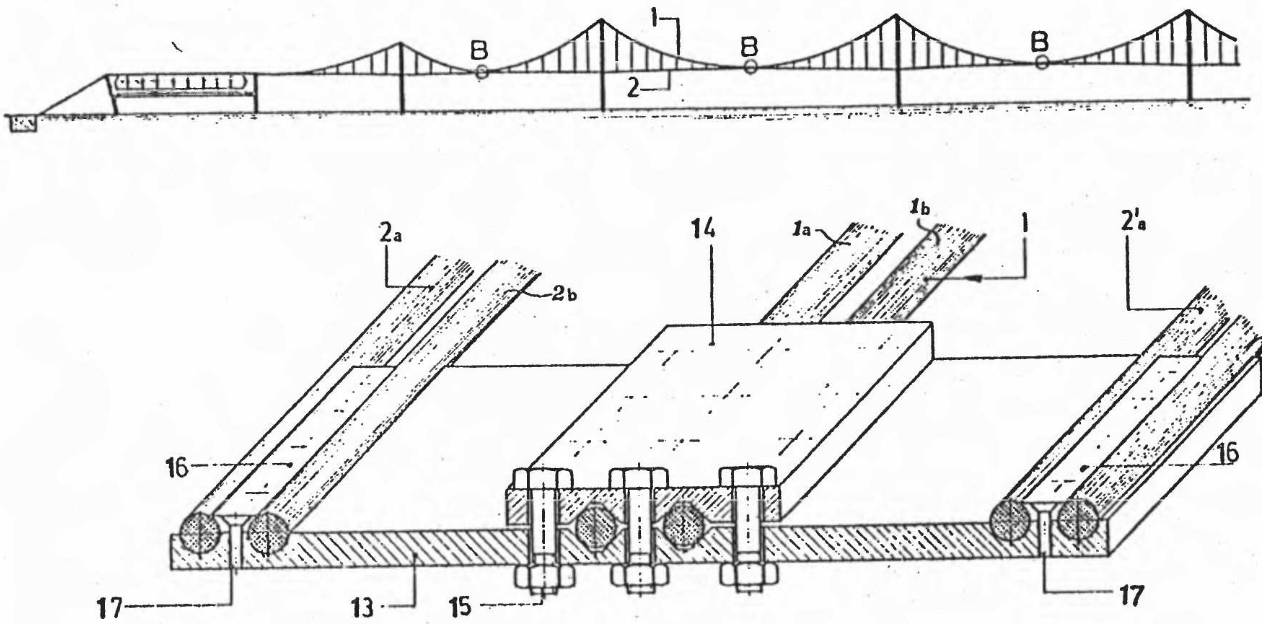


FIGURE 3.45: EQUILIZING LOCK