Return to Don Sussman

REPORT NO. UMTA-MA-06-0048-79-2

EVACUATION AND RESCUE IN AUTOMATED GUIDEWAY TRANSIT

VOLUME I: DATA COLLECTION, SCENARIOS, AND EVALUATION

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DECEMBER 1979

FINAL REPORT

Prepared for

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

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0048-79-2	PB-80 195761	

4. Title and Subtitle	5. Report Date
EVACUATION AND RESCUE IN AUTOMATED GUIDEWAY TRANSIT Volume I. Data Collection, Scenarios, and Evaluation	December 1979
	6. Performing Organization Code
7. Author(s) Benjamin, David E.	8. Performing Organization Report No. DOT-TSC-UMTA-79-47, I
9. Performing Organization Name and Address Vought Corporation* P.O. Box 225907 Dallas TX 75265	10. Work Unit No. (TRAIS) UM 933/R0764 11. Contract or Grant No. DOT-TSC-1314-1
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration Office of Technology Development and Deployment Washington DC 20590	13. Type of Report and Period Covered Final Report July 1977 - May 1979 14. Sponsoring Agency Code UTD-42

15. Supplementary Notes

*Under contract to U.S. Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, Cambridge MA 02142

16. Abstract

Evacuation and rescue are significant problems in all transportation systems. Serious injuries and loss of life can result from situations in which inadequate means of evacuating and rescuing passengers exist. In conventional transportation systems, transportation personnel can help to evacuate and rescue passengers. AGT systems, however, present a number of special evacuation and rescue problems because they are highly automated systems. Operation of AGT systems with elevated guideways also presents significant problems.

This document is Volume I of the Final Report on Evacuation and Rescue in Automated Guideway Transit and describes the methodology used in developing evacuation and rescue guidelines. Volume II is a Guidebook to evacuation and rescue intended for use by AGT planners, designers and decision makers. The report number of Volume II is UMTA-MA-06-0048-79-3.

17. Key Words	18. Distribution Statement
Automated Guideway Transit Evacuation, Rescue, Emergencies, Safety	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	84	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

The U.S. Department of Transportation's Urban Mass Transportation Administration (UMTA), in order to examine specific Automated Guideway Transit (AGT) developments and concepts, has undertaken a new program of studies and technology investigations called the Automated Guideway Transit Technology (AGTT) program.

The objective of one segment of the AGTT program, the Systems Safety and Passenger Security Study (SS&PS), is the development of guidelines for the assurance of actual and perceived passenger safety and security in AGT systems. This work has been contracted, through the Transportation Systems Center (TSC), to a team composed of Dunlap and Associates, Inc., the University of Virginia, and the Vought Corporation.

The Systems Safety and Passenger Security (SS&PS) study has involved six related but separate tasks. Three were concerned with the development of guidebooks dealing with 1) passenger security, 2) evacuation and rescue, and 3) passenger safety and convenience services. A fourth task required the development of a passenger value structure model; a fifth involved research on the retention of seated passengers during emergency stops; and a sixth involved the conduct of a joint Government and Industry workshop to review and revise the three guidebooks.

The Evacuation and Rescue task has as its objective the production of a guidebook detailing the most effective methods and procedures for providing evacuation and rescue in AGT systems.

The author wishes to acknowledge the time and cooperation received while visiting various transit properties in the U.S. and Canada. Without the cooperation of transit officials and other experts, completion of this task would have been impossible. The author also wishes to thank the UMTA and TSC technical personnel for their assistance in the performance and documentation of this work, and in particular Duncan MacKinnon and Robert Hoyler, program manager and monitor respectively for UMTA, and Donald Sussman, project monitor for TSC, and his professional associates Janis Stoklosa and Walter Hawkins.

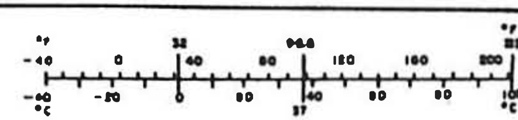
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

Approximate Conversions from Metric Measures

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



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EXECUTIVE SUMMARY

Evacuation and rescue of passengers from disabled transit vehicles is a problem common to all fixed guideway transit systems. Automated Guideway Transit (AGT), because of its unmanned nature and unique guideway configurations, presents several new problems related to evacuation and rescue. The purpose of this portion of the Systems Safety and Passenger Security Program was to identify these problems and, where possible, recommend solutions.

While evacuations are not common occurrences, a wide range of evacuation and rescue potential problems and responses exist in today's conventional rapid transit systems. The most severe of these problems include fire or smoke in the subway tunnels and extended service interruptions. Because of the seriousness of the hazards associated with evacuation, considerable effort is spent on trying to get stalled trains to operate prior to giving consideration to deboarding passengers. If passengers are to be deboarded, most transit systems prefer to deboard them directly onto another train, either on an adjacent track or at the front or rear of the stalled train. It is with reluctance that passengers are deboarded onto the track area. The important distinction in conventional transit is that operating personnel are always onboard the train to assist passengers in situations requiring evacuation and rescue.

Evacuation and rescue problems in AGT systems differ from conventional rapid transit systems in that AGT systems are unmanned and utilize more elevated guideway structure. In addition, several AGT technologies use guideway configurations which are unsafe for use as emergency walkways. Because AGT vehicles are unmanned, central control plays an important part in the detection, analysis and response to problems. There are a variety of evacuation and rescue provisions in existing AGT systems, ranging from wide adjacent walkways onto which passengers can evacuate, to knotted ropes which passengers are expected to climb down in the event of serious emergencies.

Because safety of transit passengers must be a primary objective of every AGT system, it requires attention from the earliest stages of the program through its entire operational life. During the formative period of the system when many concepts of system service and route alignment are being considered, basic design decisions are made which may ultimately affect the safety of the system with respect to evacuation and rescue. A safety organization is necessary early in the AGT program to review with respect to evacuation and rescue numerous design considerations, such as guideway elevation, the terrain over which the guideway will pass, the size of the vehicles and support which will be required from emergency response agencies. During specification and contractor selection, attention should be given to the guideway design and the type of electrification used, any vehicle egress constraints which may exist, and general design to minimize hazards. During detail design, construction and test, safety efforts should monitor the design to assure that no undesirable design features or hazards are incorporated into the system design. Prior to initial operation, the safety organization is key in negotiating mutual aid agreements with local emergency response agencies, in formulating evacuation and rescue procedures and in training operating personnel with respect to evacuation and rescue. After the system is open to the public, the safety organization should plan preparedness training drills to keep operating personnel familiar with procedures. Also, any incidents requiring evacuation and rescue should be reviewed to assure that existing procedures are working properly.

Evacuation and rescue techniques can be divided into two classifications depending upon the implicit degree of passenger self-sufficiency during evacuation. The first classification, self-evacuation or rescue, is restricted to those techniques in which passengers are able to egress from the vehicle to a place of safety at will and without assistance from any outside personnel. Self-evacuation and rescue capabilities are desirable for all systems, but their use should be restricted to only those situations in which passenger injury may result if passengers do not exit the vehicle immediately. Three satisfactory techniques exist for providing self-evacuation and rescue capabilities to AGT systems. These include using an adjacent walkway, using the vehicle's guideway as a walkway and providing an emergency egress path to ground level using a device such as an inflatable slide. In contrast, the second classification, assisted evacuation or rescue, relies upon the actions of personnel and/or the use of equipment from outside the vehicle. These techniques are recommended for use in situations in which time is not of critical importance. In order of preference, these techniques include:

1) Moving the vehicle to a station under manual control,

2) Push or pull the disabled vehicle to a station with another vehicle,

3) Transfer passengers into an operational vehicle that has either been pulled along side or up to the end of the disabled vehicle,

4) Assist passengers in walking to a station or another place of safety,

5) Lowering passengers to the ground using truck-mounted platform lifts or articulated booms.

The evaluation portion of this task is documented in Volume I of this Final Report. It will be of most interest to researchers in AGT safety. Volume II is a Guidebook for AGT Evacuation and Rescue and is intended for AGT planners, designers and decision makers.

CHAPTER 1 - INTRODUCTION

Evacuation and rescue is a problem common to all fixed guideway transit systems. Guideways or tracks are frequently elevated above the ground or submerged in subway tunnels. Even when they are built at grade they are virtually always separated from other forms of traffic. While traffic separation contributes to the safety of the system it also poses special problems with respect to evacuation and rescue of passengers during system emergencies. Elevated structures and subways significantly limit the access of normal emergency services such as fire, police and ambulance to these systems. Officials of most existing conventional systems have given thought to these problems and have developed procedures for handling them.

Automated Guideway Transit (AGT) systems, however, present an entirely new set of evacuation and rescue considerations. While the nature of AGT emergencies will likely be similar to those of conventional transit, the situations are complicated by the lack of on-board personnel and the use of guideway configurations unique to AGT. It is necessary, therefore, to develop for AGTs the necessary methods and procedures which will perform the functions that on-board personnel perform on conventional transit.

The objective of this portion of the System Safety and Passenger Security Program is to develop a comprehensive guidebook which will provide guidelines for AGT systems planners, designers, operators, and evaluators in identifying and selecting the optimum combination of equipment, methods and procedures for safe evacuation and rescue of passengers from AGT systems.

This document is Volume I of the final report of the Evacuation and Rescue task. Volume I includes:

- Literature search and review
- Determination of current transit practice from visits to several transit properties and interviews with transit experts
- Development of AGT evacuation and rescue scenarios depicting realistic situations which may be encountered in future automated systems

- Selection and classification of potential evacuation and rescue methods and procedures.
- Evaluation of method and procedure effectiveness in the evacuation and rescue of AGT passengers.
- Recommendation of evacuation and rescue methods and procedures for future AGT applications.

In addition to the above, Volume II of this report is a guidebook for the provision of evacuation and rescue services in automated guideway transit.

CHAPTER 2 - APPROACH

The technical approach utilized in the production of the set of guidelines for evacuation and rescue of AGT passengers is based upon the following subtasks:

- Literature search and review - A computerized literature search was conducted to locate books, reports, papers and manuals which contained information relevant to AGT evacuation and rescue. These documents were obtained and reviewed in detail.

- Current transit practices - Visits were made to several major U. S. and Canadian conventional and automated transit properties to determine current evacuation and rescue practices. Additionally, phone contact was made to other properties and numerous experts in the field.

- Scenario development - Scenarios were developed for AGT evacuation and rescue utilizing information acquired during visits and discussions with transit officials and industry experts. While many of the scenario variables are common between AGT and conventional transit systems, considerable care was taken to highlight situations that reflected realistic AGT evacuation problems rather than problems which were more common to conventional transit.

- Methods and procedures selection - Collected data were used to select appropriate evacuation and rescue methods and procedures for evaluation relative to AGT evacuation and rescue scenarios. New and untried methods and procedures which were potentially well suited to AGT were included.

- Methods and procedures evaluation - Evaluation criteria were developed and applied to the selected methods and procedures to assess their effectiveness in resolving the scenario emergency situations. From this process, it was possible to recommend methods and procedures for future AGT applications.

- Guidebook review and revision - In the spring of 1979, an industry workshop was conducted to review a draft version of the evacuation and rescue guidebook. As a result of these valuable comments, several revisions and additions have been incorporated into the final version of the guidebook.

The work done to date has been coordinated between SS&PS team members to reduce costs to the contract and to minimize the burden on transit properties and experts who have been queried.

Figure 2-1 provides a schematic overview of the technical approach being pursued in this task.

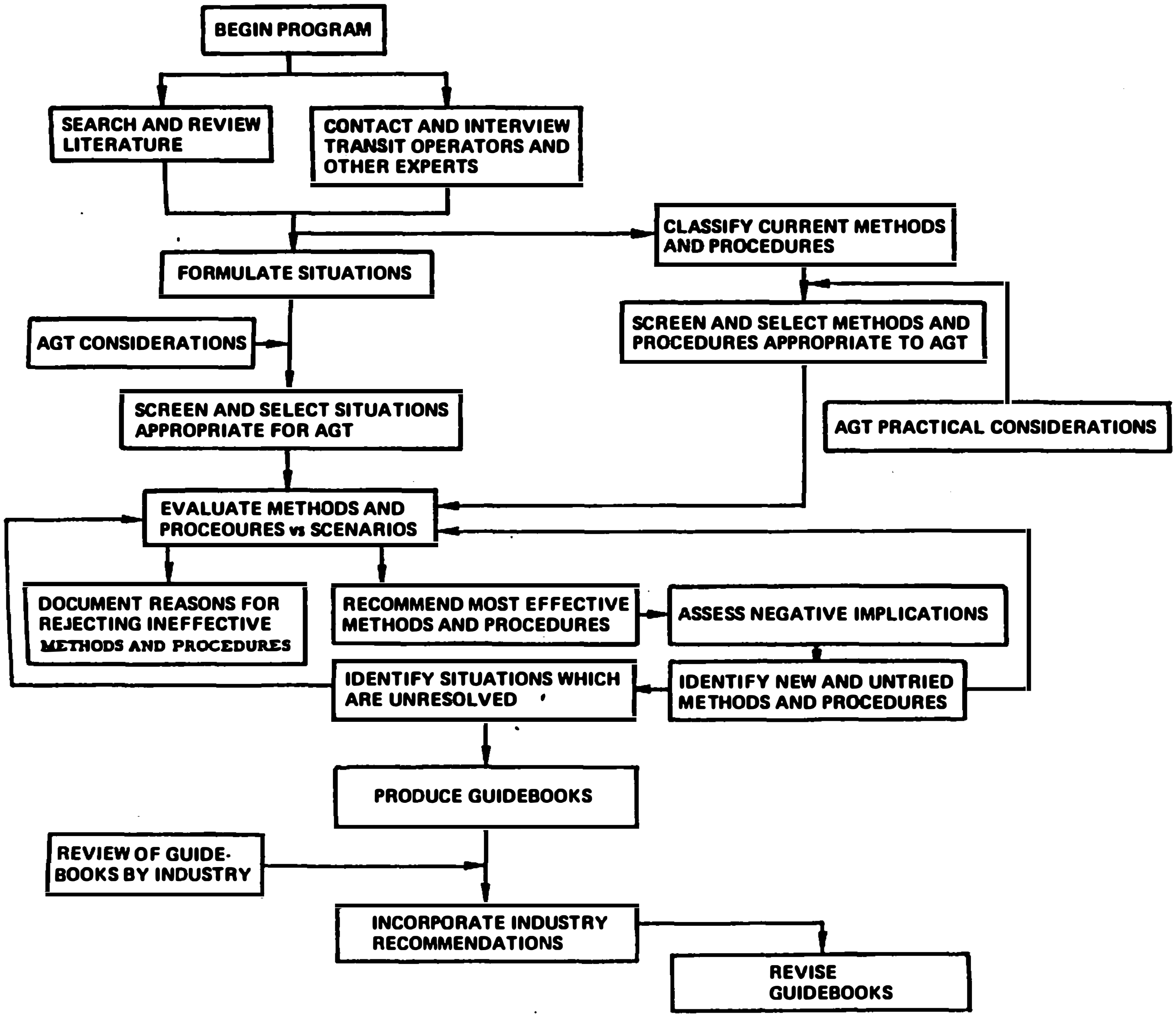


FIGURE 2-1 TECHNICAL APPROACH SCHEMATIC

CHAPTER 3 - DATA COLLECTION

The data collection subtask was divided into two parts:

- A comprehensive literature review
- Interviews with transit officials and other experts

A. Literature Review

1. Description

A comprehensive literature review was conducted to identify books, reports, technical papers, and periodical articles containing information relevant to evacuation and rescue of passengers from transit vehicles.

Computerized literature searches were conducted which examined the following indices:

- Computerized Engineering Index (COMPENDEX)
- National Technical Information Service (NTIS)
- Smithsonian Science Information Exchange (SSIE)
- Transportation Research Information System Network (TRISNET)
- National Aeronautic and Space Administration Scientific and Technical Information System (NASA)
- Defense Document Center (DDC)

These searches produced a lengthy collection of titles and associated abstracts. Each abstract was carefully screened to determine the title's relevance to passenger evacuation and rescue from transit systems. The titles that seemed relevant were subsequently procured and reviewed for pertinent information.

In addition to the computerized searches, personnel also examined corporate technical files, reports, and other records to locate useful sources of information.

2. Useful Sources

Problems associated with evacuation and rescue of passengers from disabled or stalled transit vehicles are not well documented in the published technical literature. While there has been considerable interest in system safety (i.e., maintenance of safe vehicle separation, use of fire resistant materials, etc.), most of this research fails to address directly the provisions associated with the passenger safety in emergencies.

Very useful information, however, was obtained from unpublished sources of technical literature. These sources included proposals, requests for proposals and engineering studies of numerous systems and applications. These were particularly useful in the development of realistic AGT evacuation and rescue scenarios.

3. Summary of Literature Review Findings

This section summarizes the findings of the literature review. The review findings have been divided into four topic areas:

- Passenger Perceptions
- Existing Conditions and Past Experiences
- Existing Guidelines and Procedures
- Related Information

a. Passenger Perceptions

The attitudes of passengers toward safety are well documented. The concern of the traveler for his own safety and well being has been repeatedly shown to be one of the most important critera used in evaluating transportation.[1,2,3,4] This concern for safety is present in virtually all population groups from young to old, rich to poor. While this concern for safety exists, it is most often a passive consideration in the traveler's modal choice selection. The traveler appears to assume his journey will be safe unless he has reason to suspect otherwise.

The introduction of Automated Guideway Transit (AGT) will provide increased levels of automation to all aspects of the transportation experience. Increased automation will also undoubtedly alter the nature of the problems associated with assuring that the passengers assumptions of safety are a reality. While past studies have shown that introduction of increased levels of automation will develop little passenger aversion to riding, it is likely that if passengers perceive these automated systems to be unsafe, a significant impact on system ridership will result.[5, 6]

Perceived safety is not always an accurate reflection of the actual safety conditions existing on a system. An isolated incident or series of incidents may totally obscure an otherwise spotless safety record. Even extended coverage of incidents by the news media can distort perceived safety.[7]

The size of headlines and the amount of air time devoted to a news story concerning a transit incident can significantly impact the public's perception of the seriousness of the incident. Thus, the perceived safety of a transit system can be affected by such unrelated factors as the amount of important news occurring on the day of a transit accident or a newspaper publisher's desire to sell newspapers.

With AGT still somewhat in its infancy, it is difficult to conclude whether the frequency of situations requiring evacuation or rescue from AGT will be significantly different than for conventional rail transit. However, it can be said with certainty that no matter how high the standards of reliability, there will eventually be incidents which require passenger evacuation or rescue. While collisions of vehicles will certainly continue to be rare occurrences, unscheduled shut-downs of the systems may be more frequent. These shut-downs may be caused by a variety of events, ranging from a vehicle breakdown to a power outage from the utility. In the case of a vehicle breakdown, passenger evacuation may be required because of the length of time that will be required to resume system operation. In the case of a power outage, passengers may be forced from vehicles by extreme temperatures that result from the loss of the vehicle environmental control system.[9]

b. Existing Conditions and Past Experiences

According to the literature, conditions that exist in the older conventional rapid transit systems do not typically meet high standards of safety design. The description of tunnel design by the Chief of the National Transportation Safety Board Railroad Safety Division, Thomas DeW. Styles, characterizes existing conditions relative to passenger evacuation and rescue provisions:

"Safety walks originally intended for use in the evacuation of passengers have been utilized to accommodate signal and electrical facilities. Walks are also used for the storage of maintenance of way material. Emergency exits having been located immediately adjacent to turnouts presenting an obstacle course of running rails, guard rails, and energized third rails. Exits are sparsely located and difficult to identify under normal circumstances, both inside and outside of the tunnels. Exits are narrow and steep, easily negotiable by a spry young man, but another matter for a not-so-spry elderly lady. In some instances, in-tunnel lighting is practically non-existent and ventilation is dependent upon natural drafts. The hazards of tunnel evacuation are recognized in existing rule books that indicate that detraining of passengers within tunnels must only be accomplished as a last resort."[10]

While subway evacuation by walking the passengers out is not a frequently used procedure, it does happen often enough to be of concern. Probably the largest evacuation of passengers by walking them from the system took place during the power blackout of New York in 1965.[11, 12] Occurring during the peak of evening rush hour, the blackout left an estimated 800,000 passengers trapped in New York's subways, some for as long as fourteen hours. Only through an extraordinary effort by transit, fire and police personnel was it possible to move most of these people through dimly lit tunnels to safety. Some passengers walked as far as 2,000 yards from trains trapped under the Hudson River. No panic was observed as passengers took out their irritation in sarcasm.

Another recent incident concerning rescue of passengers captured news headlines in the spring of 1977 when a gondola type sky-ride at an Ohio amusement park jammed as a thunderstorm approached the park.[13, 14] Twenty-seven people, one of whom was pregnant, were trapped as high as 95 feet in the air during the wind and heavy rain which accompanied the storm. Some of the riders remained stranded for as long as eight hours as rescue efforts were delayed by trucks being mired in mud, trees having to be cleared to allow access under the system, and immediately available equipment being incapable of reaching the highest gondolas.

c. Existing Guidelines and Procedures

Most of the major rapid transit and AGT systems in North America have written operational procedures and guidelines for use by transit employees.[15, 16, 17] In these documents responses to emergency conditions take up considerable space. These documents are written in a straight-forward, concise manner. The sections on emergency procedures typically cover the following topics:

- Emergency notification
- Response
- Chain of command
- Safety precautions to be taken
- Evacuation procedures
- Fire-fighting equipment available
- Emergency ventilation (subways)
- Communications

It is evident from reading these procedures that transit officials recognize that during an emergency situation there is seldom time for personnel to turn to a book to locate the proper procedure. They feel it is therefore important that all personnel involved in transit operation be trained and fully conversant with established instructions and procedures.

In addition, procedures can only identify the first steps of a response, as all emergency situations are different. The actual details of carrying out the procedures are left to the personnel involved. In all cases, the first consideration is for the safety of passengers, employees, fire and rescue personnel.

Evacuation procedures for most systems can be summarized as follows:

- Only evacuate passengers when absolutely necessary.
- Detrain passenger into other trains, if possible.
- If passengers must be detrained to track area, first make certain the power rail is de-energized and that sufficient personnel and equipment are on hand to assist.
- Guide passengers safely to street level or station platforms.

These procedures also stress that evacuation from subway tunnels presents significant problems. Evacuation by way of the nearest station is usually the simplest way out of the system and is thus the preferred means of evacuation. Tunnel portals provide good means for evacuation, except for the fact that fences along the rights-of-way may make it difficult to reach the street. Emergency exits often provided at single entry stations and between stations can also be used. However, as their use involves climbing stairways up to 100 ft. high and exiting through very narrow hatchways, they are not considered a desirable means of evacuation.

As the possibility exists that a portion of the passengers being evacuated will be handicapped, elderly or very young persons, procedures note that it is normally necessary to assign a large number of employees to assist in evacuation exercises. This is especially true when evacuations will involve long walks or use of emergency exits.

In addition to the procedures and guidelines developed by the individual properties, the Institute of Rapid Transit (now part of the American Public Transit Association) developed a set of generalized safety guidelines for rapid transit.[18] This document addresses all aspects of rapid transit safety with one chapter devoted to "Emergency". The "Emergency" chapter is divided into two sections:

- General procedure - actions which are applicable to any emergency situation.
- Specific procedures - actions which apply only to specific types of emergencies.

This will be an important reference source for subsequent AGT guideline preparation.

d. Related Information

Several sources of information were uncovered which provided interesting insight into the problems associated with AGT evacuation and rescue, but which did not fit easily into these topics. The most interesting will be discussed below. They concern the following:

- Evacuation of aerial tramways and skilifts.
- Emergency evacuation of airliners.
- Disaster planning.

1) Evacuation of aerial tramways and skilifts

Aerial passenger tramways and skilifts have evacuation problems which are quite similar to those of some AGT's. Not only are the gondolas or chairs suspended as in some AGT technologies, but passengers also ride without an attendant onboard their vehicle on systems designed to carry six or less passengers.[19] Also the evacuation methods used are very similar to those often proposed for suspended AGT:

- Mechanical Equipment - Evacuation by this method involves removal of passengers from a stranded carrier by use of mechanical equipment such as portable slides, cranes, cherrypickers, helicopters, and other aerial rescue devices.

- Ladder - Passengers are frequently removed from a carrier by use of a ladder that may be hand-carried and placed by a rescue team, or mounted on mobile mechanical equipment and placed either by hand, hydraulically, or mechanically.

- Rope - The most common method of evacuating passengers from a carrier is the use of a synthetic fiber or wire rope, that may pass over or through a ring, wheel, or other support. Typically a harness or chair device is attached to the rope to support the passengers during descent. Rate of passenger descent may be regulated by hand or by a mechanical descent control device.

- Self-Evacuation - The evacuee is required to perform duties other than merely securing himself to a device or climbing down a ladder. Self-evacuation is limited to trained personnel authorized under specific conditions set forth by management.

2) Emergency evacuation of airliners

While emergency evacuations from commercial aircraft are not very similar to AGT evacuations, there are several findings from a National Transportation Safety Board study of ten air carrier accidents that are worth noting.[20]

- Inflatable evacuation slides that have been employed in aircraft in the past have been unreliable.
- Unsafe conditions for the use of slides can be caused by such factors as strong winds and heights higher than the design height.

Adequate illumination is an important factor that can dramatically effect the number of injuries associated with evacuation.

Since some suspended and monorail AGT's have proposed inflatable slides as a means of emergency egress, it seems advisable to further investigate airline satisfaction with these devices prior to their use with AGT.

3) Disaster planning

To be adequately prepared for most disastrous situations which may occur, disaster planning is required.[21] Because of the urgency associated with getting injured passengers to safety and medical attention, collisions on transit systems often result in the need for expeditious passenger rescue and medical attention. The unlimited variety of situations which might exist after a collision make these emergencies very difficult to adequately prepare for. Judgement and improvisation are required to adapt written procedures into effective responses. To improve the efficiency of rescue operations during an actual emergency, it has been shown that frequent rehearsals of disaster plans in the form of full-transit scale disaster simulations are most desirable. These drills should be staged at least once a year, to obtain improved results with more frequent exercises.

Planning for a transit disaster involves the three C's: command, communication, and coordination.

- Command: Not only is it important for personnel responding to an emergency to know their job, it is imperative that a clearly visible organizational heirarchy exists at the disaster scene. This chain of command helps assure that decisions are made expeditiously by the best qualified persons. Designated responsibilities might include medical coordinator, fire chief, police chief, transit chief, and coroner.

- Communications: Communication is essential to assure that the needed emergency support is provided at the accident site. Not only must organizations and individuals be notified of the emergency, but channels of communication must exist so that the particular types and levels of assistance required can be effectively dispatched.

- Coordination: Interagency coordination and cooperation is required to maximize the results of post-accident rescue and evacuation efforts.

B. Current Transit Practice

1. Description of Data Collection

The problems of evacuation and rescue that will be encountered by future AGT systems will likely be similar to those encountered by today's existing AGT and conventional rail systems. For that reason, several representative transit properties were visited by a research team to establish the nature of current transit practice relative to evacuation and rescue.

a. Properties

Twelve transit properties were selected for visits and comprehensive interviews:

- Seattle-Tacoma Airport Satellite Transit System (Sea Tac)
- Seattle Monorail
- San Francisco Bay Area Rapid Transit (BART)
- San Francisco Municipal Railroad (MUNI)
- Dallas/Ft. Worth Airport AIRTRANS
- Toronto Transit Commission (TTC)
- West Virginia University at Morgantown People Mover (MPM)
- Washington Metropolitan Area Transit Authority (WMATA)
- Port Authority Trans Hudson (PATH)
- Port Authority Transit Corporation, N. J. (PATCO)
- New York City Transit Authority (NYCTA)
- Roosevelt Island Aerial Tramway.

These particular sites were selected because they were considered to represent the forefront of transit innovation with respect to system operation and design.

In addition, less intensive interviews were conducted during visits made to the following additional properties:

- Fairlane, Detroit, Mich.
- Busch Gardens, Williamsburg, Va.
- Houston Intercontinental Airport Monorail, Houston, Texas
- Transit Expressway, South Park, Pa.
- WEDway, Walt Disney World, Fla.

b. Topics Covered

Discussions at the various properties were directed to the departments and personnel who were responsible for the development and/or execution of the evacuation and rescue methods and procedures. While organization varied considerably between properties, the discussions typically involved personnel from operations, safety, and security sections.

Topics covered during the course of the site visits varied considerably with the properties. At all properties, however, the following basic topics were discussed:

- types of incidents leading to passenger egress
- descriptions of situations requiring evacuation and rescue
- procedures used in handling emergency situations
- agencies conducting evacuation or rescue
- adequacy of existing procedures
- any particular vulnerability that the system may have relative to evacuation and rescue

When possible, copies were obtained of existing written procedures. In all cases personnel were identified for future telephone contacts.

2. Summary of Present Practices

A wide range of evacuation and rescue problems, potential problems and responses exists in AGT and conventional transit today. This variety is primarily attributable to variations in the characteristics of the technologies used, the environment into which the technologies have been placed, and differences in operating philosophies among the individual system designers and operators.

In summarizing the existing state-of-the-art relative to evacuation and rescue problems and practices, it is useful to examine:

- types of problems
- detection of problems
- assessment and responses to problems
- responsible agencies

a. Types of Problems

Table 3-1 summarizes the problems most commonly associated with transit evacuation and rescue.

TABLE 3-1 TYPICAL PROBLEMS AFFECTING OR COMPOUNDING EVACUATION AND RESCUE

Equipment Problems	
• Collisions	• Door failures
• Fire	• Derailments
• Smoke	• Tunnel flooding
• Service Interruptions	
Access Problems	
• Subways	• In buildings
• Elevated guideway	• Other inaccessible locations
• Over water	
Passenger-Related Problems	
• Injured	• School-aged children
• Ill	• Panic
• Handicapped	• Emotional shock
• Elderly	
Other Problems	
• Adverse weather	• Industrial accidents
• Tornadoes	• Traffic accidents
• Earthquakes	

Discussions with transit operators indicate that the problems which have given conventional transit the greatest challenges relative to evacuation and rescue are those involving smoke and fire, particularly when the smoke and fire occurs in subway tunnels. While these incidents are not frequent occurrences, transit officials feel they represent the greatest potential for serious injury or loss of life. The enclosed subway environment traps and retains toxic and noxious fumes and their lethal and debilitating effects can rapidly turn a small fire into a disaster. The sources of the fire and smoke are many, but they most often originate from electrical sources. They may result from equipment failure, collision, and a number of other causes.

Other problems to which subway systems are particularly vulnerable include flooding, cave-ins, and the intrusion into the tunnel of flammable or toxic liquids and gases. All of these problems involve an immediate and serious threat to the safety of the passengers. As such, transit operators feel response times to these emergencies are of crucial importance.

Service interruptions are common to the entire spectrum of transit, but may be somewhat more frequent in AGT systems because of their less mature technology. Interruption of transportation service, for extended or indeterminant periods, results in occasional situations which require removal of passengers from vehicles. These situations may result from power outages such as past blackouts of large portions of the northeastern United States, derailments or equipment failures which block the line for long periods. In the case of power outage, the situations become particularly vexing because the environmental control system normally runs off the primary power system. Thus, when power is lost, heat and air conditioning is also lost. Some of the more modern systems provide emergency ventilation with battery powered fans.

A type of problem which seems to be almost totally restricted to AGT is the unscheduled, unauthorized and unsupervised evacuation of passengers from vehicles. These passenger-initiated evacuations occur when passengers become impatient with interruptions in service and choose to abandon the vehicle and walk to the next station or point of access. The path they follow may be either along side or in the guideway. To date, these problems seem to have been confined to the more advanced AGT systems like MPM and AIRTRANS. Both systems report that the problems diminished greatly as service reliability improved, and that presently these problems occur very infrequently.

b. Detection of Problems

After a problem occurs that is likely to require evacuation or rescue of passengers from the system, the problem must be detected before its seriousness can be assessed and emergency aid dispatched. In conventional transit, the primary means of detecting the situations requiring aid are:

- onboard transit personnel
- transit personnel in stations or along rights-of-way
- transit central control personnel
- passengers
- "neighbors" to the system

In conventional transit systems, the onboard transit personnel (train operators, conductors, guards, etc.) are the principal source of detection of serious problems associated with train operation. To them, the problem is often obvious - the train will not operate, a collision has occurred or smoke is permeating through the system. Because of their training and experience with the transit system, vehicle onboard personnel can normally be relied upon to respond to emergency situations in a rational manner and to accurately relay information concerning the nature of the situation to central control.

While most problems that might require emergency responses are detected by train onboard personnel, there are situations in which onboard personnel may be unaware or unable to respond to a problem. In the past, these situations have included, among others, accidents in front of operating trains, collisions in which onboard personnel were injured, and tunnel flooding. In these situations, the initial detection of problems is often made by system personnel along the rights-of-way or in the stations. These employees are also reliable sources of rational information on which to assess the seriousness of the problem.

Transit central control personnel may also be among the first to be aware of the existence of a problem. The problem may come to their attention by a number of means:

- telephone/radio communication
- fire, smoke, or heat alarms
- malfunction or status sensors
- closed circuit television (CCTV)

While central control is an important source of problem detection information for all the systems visited, it is particularly important for the AGT systems. Since the AGT systems have no on-board personnel and few, if any, employees stationed along the system's route, central control is the primarly detector of system problems. AGT system designs compensate for the lack of humans in the system by providing much more detailed sensor and diagnostic information to central control personnel than do most conventional systems. Readily available information includes vehicle performance data, equipment status and malfunction information, and the existence and location of any abnormal operating conditions. This data is a valuable source of information on which to base a problem assessment and in many cases surpasses data available from any source in conventional transit. Because of the fail-safe nature of their design philosophy, however, AGT systems are occasionally plagued by sensor malfunctions. Since the sensors must malfunction into a condition which is known to be safe, they often indicate problems which in reality do not exist. While these malfunctions do not impair passenger safety, they do often provide central control with problems of sorting actual system anomalies from false alarms.

Figure 3-1 shows the central control area of one of the AGT systems visited. It is similar in concept to others, and is probably typical of those that will be used with future systems. The left side of the control console is the power system controls which control the network protectors and circuit breakers for the traction electrification system. Toward the center of the console is the system status panel. This panel, in combination with the CRT display informs the operators of vehicle and subsystem status and identifies any malfunctions that may have occurred. The right side of the board contains the CCTV and communications equipment. On the wall behind the console is the guideway schematic board which shows the location and malfunction status of all vehicles.

c. Assessment and Responses to Problems

Assessment of the severity of the situations and determination of proper response to problems potentially requiring evacuation and rescue is almost universally performed by personnel located at the central control room of the system. Normally, the individual responsible is the central control supervisor.

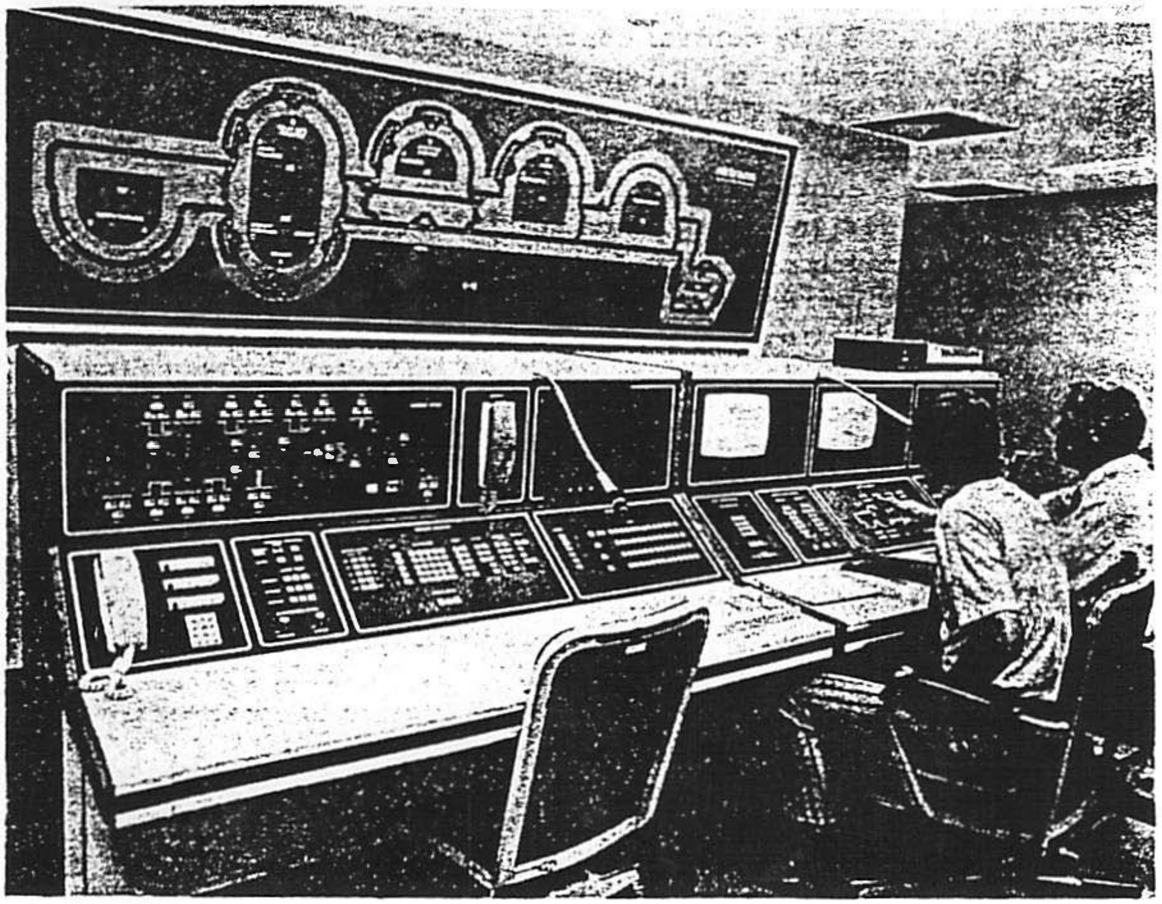


Figure 3-1
AIRTRANS Central Control Room

The central control supervisor collects information from all of the detection sources identified in the preceding section, and based upon experience, judgement, and established procedures, assesses the severity of the situation. It is then his responsibility to determine what actions should be taken and to see that they are initiated. At all properties visited, established written procedures provided considerable guidance on the actions to be taken.

Responses often include:

- call the fire department
- call transit and/or municipal police
- call for emergency medical aid
- dispatch transit personnel (maintenance and supervisory)
- remove power from sections of guideway

- stop vehicle operation in vicinity of the problem
- dispatch a train to pick up passengers
- dispatch alternate means of transportation such as buses
- communicate with vehicles involved
- communicate with stations involved

True emergencies requiring actual rescue of passengers from dangerous situations are typically performed by fire and police personnel with assistance from transit personnel. Education and training programs normally exist by which fire and police department personnel are instructed in any special procedures relating to transit system emergencies. Instructions are also given concerning safety equipment available in the transit system and the hazards along the right-of-way.

Less severe emergencies which require routine evacuations are handled differently. Officials at properties visited indicated that the safest place for a passenger is normally inside the vehicle or station. The many potential hazards that exist along the right-of-way, particularly those associated with system electrification and moving vehicles, make emergency unloading of passengers extremely dangerous without adequate safety precautions and instructions.

Because of the hazards associated with evacuation, transit officials normally expend considerable effort trying to get a stalled train to operate before they consider removal of passengers. If evacuation is necessary, transit officials normally prefer to load passengers directly onto another train rather than walking them from the system. Depending upon system design and the details of the particular situation, another train may either be pulled along side or to the front or rear of the disabled train. Passengers are then loaded from the disabled train into the functioning train. One system visited even has a special folding "plank" onboard each vehicle which can be extended from one car to another to provide passengers a path to an adjacent train.

In those situations in which transfer to another train is not possible, passengers must be evacuated to the nearest station or point of access by walking. At most properties, this involves several safety precautions including:

- trained personnel to instruct, guide and assist passengers
- removal of system electrical power
- cessation of traffic on adjacent tracks

The path along which this evacuation takes place varies considerably between transit systems and technologies employed. Some subway rail rapid transit systems have walkways in the tunnels along which passengers can walk. These walkways are often quite narrow and difficult for some people to walk along. The situation is often further complicated by equipment protruding into the walkway. Other systems require passengers to climb down a short ladder and walk along the roadbed. Depending upon the kind of roadbed used by the system, the surface on which passengers walk can range from relatively smooth and free of obstacles to very irregular.

AGT evacuation routes also vary with the technology. While the design of some open guideway, suspended, and beam-straddling monorail systems do not allow passengers to walk from the system, the major systems in the U.S. today are designed to give passengers an egress route in case of a severe emergency. Some systems provide a walkway adjacent to the guideway while others use the guideway itself for a walkway.

d. Responsible Agencies

Evacuation and rescue procedures in conventional transit systems are normally performed by a combination of transit and municipal protective services personnel. The personnel who might be called upon to participate include:

- transit security
- transit fire protective services
- vehicle onboard personnel
- maintenance workers
- municipal police department
- municipal fire department
- municipal emergency medical or ambulance

Interviews with transit officials indicate a general satisfaction with this type of arrangement. There are significant advantages to utilizing municipal personnel to supplement the transit property staff, the largest of which is economic. The cost would be prohibitive for a transit property to provide a comparable internal evacuation and rescue capability including personnel, training and equipment.

Transit properties work hard to ensure that municipal support continues. High levels of coordination and cooperation are required between transit personnel and municipal organizations which may be required to work together. For this reason formalized mutual aid aid and cooperation agreements have been found to be useful and are normally developed between the transit properties and the governmental jurisdictions through which the system passes.

Unwary municipal personnel can be exposed to serious safety hazards while performing evacuations or rescues from transit systems. For this reason, most transit properties provide instruction to municipal employees concerning not only the methods and procedures of evacuation and rescue from the transit system, but also the potential dangers in the transit environment. Power shut-down switch locations and communication requirements are only two of the subjects normally covered.

e. Unusual and Unique Methods and Procedures

Several transit properties have methods and procedures which are unique and innovative. This section will briefly discuss some of those that have been brought to our attention.

1) Roosevelt Island Tramway Passenger Safety and Comfort Provisions

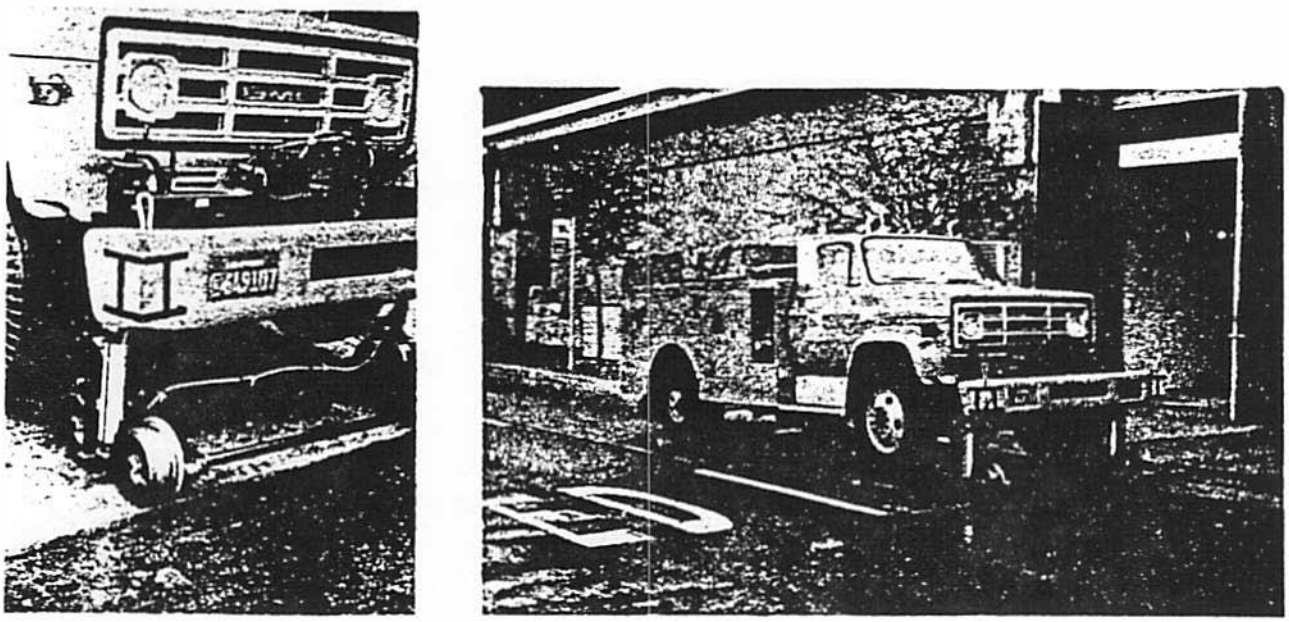
Roosevelt Island Tramway is unique in the consideration that they have given to the care of stranded passengers. The Roosevelt Island system is an aerial tramway operating between Manhattan and a residential community located on an island in New York's East River. The 3,134 ft. system has two gondolas, each capable of holding 125 passengers. At its highest point the gondolas are 225 feet above the river. The system uses electricity provided by a public utility. An auxiliary diesel/hydraulic system can be used should power be lost from the utility or an equipment problem occur. In the event that neither of these systems is capable of moving the gondolas to the stations, it is possible for a steel and mesh emergency vehicle to be placed on the cables and dispatched to the stranded gondola to rescue passengers. This process can take as long as three to four hours. To provide for the needs of the passengers while awaiting rescue, the gondolas have stored aboard blankets, food, and drink, first aid kits and a portable toilet. Because at least one of the system regular patrons uses a battery-powered life support unit, system officials are even making preparation to use the gondolas batteries in the event the passenger's battery should become discharged.

2) <u>Cabinenlift Rescue Equipment</u>

The Cabinenlift system, a 1970 ft. suspended AGT system located at Ziegenhain, Germany, uses interesting equipment and unique procedures for passenger evacuation and rescue. Because of the suspended vehicle design of the system, passengers are trapped aboard the vehicle if it stops between stations. Two unusual approaches are used to solve this problem. First, a grade is built into the aerial guideway such that if the vehicle losses power it is possible to coast into a station. Secondly a special maintenance/ rescue vehicle is available which can be dispatched under manual control to rescue passengers or perform the necessary repairs to the disabled vehicle. This special vehicle rides on the top of the guideway while the regular vehicle is supported from the bottom.

3) <u>BART's Steel-Wheeled Fire Truck</u>

The Bay Area Rapid Transit (BART) system has many miles of its system located in subway tunnels making it inaccessible to fire equipment. To partially solve this problem, fire trucks were designed and purchased which could operate either on highways or the BART tracks (Figure 3-2). Each vehicle is equipped with hydraulically actuated steel wheels which can be lowered or retracted depending upon the surface to be run upon. Propulsion on the rails is provided by the trucks gasoline engine driving the normal rubber-tired wheels on the rails.



Photos Courtesy of Bay Area Rapid Transit

Figure 3-2
BART's Steel Wheeled Fire Truck

Each truck is continuously manned by a single BART employee. In the event of an emergency, this employee is joined by firemen from the local municipal fire department. While the trucks are capable of 55 mph speeds, California Public Utilities Commission rules prohibit them from operating on the tracks at speeds higher than 25 mph.

4) <u>AIRTRANS Emergency Doors</u>

The AIRTRANS system, the 13 mile AGT at the Dallas/Ft. Worth Airport, Texas, provides a unique evacuation safety interlock. The system uses the flat running surface of the guideway as an emergency walkway which is accessible to passengers during emergencies from exits in both ends of the vehicle. When these doors are opened, emergency brakes are automatically applied to stop the vehicle.

In order to forestall premature opening of the doors by passengers while the vehicles are in motion, a cover is positioned over the door latch which actuates emergency brakes when removed. The vehicle is thus stopped before the passenger unlatches the door and steps down onto the guideway.

CHAPTER 4 - EVACUATION AND RESCUE SCENARIOS

A. Approach to Scenario Development

To aid in the assessment of the adequacy of candidate AGT evacuation and rescue methods and procedures, an extensive listing of realistic AGT evacuation and rescue scenarios was developed. These scenarios were based upon:

- Experiences with existing AGT systems
- Proposed AGT applications
- Existing and proposed AGT technology
- Results of the literature review
- Experiences of conventional transit operators

In order to keep the number of scenarios manageable and to assure that the scenarios selected were both realistic and representative, a selection process consisting of four steps was followed:

- Combination of similar scenarios into common variables
- Selection of a few discrete examples to represent a range of situations
- Indication of probability of occurrence so that emphasis can be placed upon problems that occur most frequently.
- Indication of the level of hazard or difficulty associated with the situation so that emphasis could be placed on situations with the greatest threat to the well-being of the passengers.

This scenario selection process identified eleven variables which are likely to influence the selection of evacuation and rescue methods and procedures. These variables range from the severity of the situation to the climatic conditions that exist. For each variable, a range of possible values exist. For example, guideway elevations can range from those of deep subways to tall aerial structures. Rather than consider all possible values, the values were categorized into from two to four ranges. This categorization was based upon characteristics of the various AGT system technologies, possible applications and likely evacuation and rescue methods.

B. Scenario Development

Table 4-1 summarizes the various scenario variables and their representative values. In addition, it contains qualitative assessments of the degree of hazard or difficulty associated with aspects of the scenario as well as an indication of likely frequency occurrence. A complete description of situations requiring passenger evacuation or rescue is obtained by selecting values from each of the scenario variables. Table 4-2 gives an example of a complete situation. The total number of scenario combinations that is obtainable from the values of Table 4-1 is 41,472.

1. Severity of Emergency

Emergency severity is probably the single most important variable in the total evacuation and rescue scenario. It will be used to differentiate between situations in which there is an immediate threat to life and property and situations in which only passenger convenience is threatened. Four levels of situation severities are identified which may precipitate evacuation or rescue of passengers from AGT vehicles:

- Critical emergencies with continuing threat to passengers
- Critical emergencies stabilized
- Less critical emergencies
- Non-emergencies

Critical emergencies are the situations which all transit properties fear. They are often the result of the failure of some critical system component or human error. In all cases, they potentially involve human injuries. For the purpose of this study, however, it is important to differentiate between critical emergencies with continuing threat to passengers from those situations which have stabilized. Fire or smoke onboard a vehicle is an example of an emergency with a continuing threat to life or property. It is categorized as such because further injury to passengers is possible as long as the fire and smoke persist. The first priority is to remove passengers from the hazardous situation to a location of safety. Time is of the essence as continued exposure to the environment can result in serious injury.

A collision without fire, a catastrophic guideway failure, or brake failure with subsequent rapid deceleration are all examples of critical emergencies which have stabilized. These situations are characterized by the fact that the majority of injuries sustained during the accident occur at the time of impact, guideway collapse or deceleration. Further injuries after the initial accident are less likely. The primary concern in these situations is the provision of medical attention to the injured and the removal of uninjured passengers to places of safety. While evacuation and rescue time is critical in these situations, it is not as critical as in situations with continuing threat to passenger safety.

TABLE 4-1 AGT EVACUATION AND RESCUE SCENARIO VARIABLES

Situation Variables	Values	Examples	Comments
Severity of Emergency	Critical, with continuing threat	Fire onboard vehicle	Infrequent occurrence with high degree of hazard to passengers.
	Critical, situation stabilized	Collision with injuries	Infrequent occurrence Medical attention required for injured.
	Less critical	Extended loss of electricity	Moderately frequent, requires evacuation of all affected vehicles.
	Non-emergency	Passenger initiated evacuation during temporary service interruption	This does not start out as an emergency, but requires inspection of guideway before service may be resumed.
Guideway Type	Safe for walking, power on	Figure IV-1(a)	Passenger can safely walk
	Safe for walking, power off	Figure IV-1(b)	Passenger can safely walk If power rails are de-energized
	Unsafe for walking	Figure IV-1(c)	Passengers cannot safely walk on guideway.
Guideway Elevation	Subway, all levels	Underground portion of proposed St. Peul DPM	Usage dependent upon system application
	At-grade	Portions of Busch Gardens SLT system	
	Elevated, 30 feet or less	Portions of MPRT	
	Elevated, above 30 feet	SLT at Pearl Ridge Shopping Center, Hawaii	
Terrain/Geography	Virtually inaccessible	Over a river	Usage dependent upon system application
	Accessible over land	Portions of proposed Denver PRT	
	Accessible by improved roads, uncongested	Dallas/Ft. Worth Airport service roads	
	Accessible by public roads, congested	Kalaniahaole Highway, Hawaii	
Passenger Group Size	Less than 10	Single PRT vehicle	Usage dependent upon system technology
	10 to 100	Single SLT vehicle	
	More than 100	Several GRT vehicles	
Passenger Condition	Non-ambulatory	Confined to wheel-chair	Dependent upon circumstances surrounding emergency.
	Ambulant with assistance	Elderly	
	Able bodied	Normal adult	

TABLE 4-1 AGT EVACUATION AND RESCUE SCENARIO VARIABLES (CONT)

Situation Variables	Values	Examples	Comments
Distance From Station or System Access	Too far to walk Within acceptable walking distance	5,000 feet 25 feet	Acceptability dependent on numerous factors including guideway type, weather, passenger number and condition
Weather Conditions	Icy or wet Temperature extremes Dry and mild	Snowstorm 105^{o}F or -40^{o}F Sunshine and 75^{o}F	Increased risk of falls. Increased risk of heat-stroke or frost-bite
Ambient Lighting	Adequate Inadequate	Sunlight Darkness	Dependent on location and time of day
Attendant on Vehicle	Yes No		Dependent on operations philosophy
Vehicle Egress Constrained	Yes No	Passengers locked in vehicles Emergency doors	Dependent on system technology

TABLE 4-2

CONSTRUCTION OF A SAMPLE SCENARIO

Actual Condition:

On a fine spring day an explosion at an electrical substation causes a loss of power to an AGT system. One of the vehicles stranded by the power outage is near the end of a bridge 27 feet over a river. Twenty people, including two elderly women, are aboard the vehicle. The technology of the AGT system is similar to that at the Dallas/Fort Worth Airport.

Scenario Construction:

Scenario Variable	Actual Condition	Corresponding Variable Value
Severity of Emergency	Power Outage	Less Critical Emergency
Guideway Type	Wide, Flat Running Surface with Exposed Power Rails	Safe for Walking Power Off
Guideway Elevation	Twenty-seven feet Above Ground	Elevated, 30 feet or Less
Terrain/Geography	Over a River	Virtually Inaccessible to Conventional Vehicles
Passenger Group Size	Twenty Passengers	Ten to One Hundred
Passenger Condition	Able Bodied Except for two Elderly People	Able Bodied and Ambulant with Assistance
Distance from Station or System Access	One Hundred Feet to At-grade Guideway at End of Bridge	Within Walking Distance
Weather Conditions	Warm Spring Day	Dry and Mild
Ambient Lighting	Mid-day Sun	Adequate
Attendant on Vehicle	No	No
Vehicle Egress Constraints	End Doors on Vehicle Allow Access to Guideway Running Surface	None

Less critical emergencies are situations involving more controlled evacuation and rescue of passengers from vehicles. They are characterized by a non-critical need for passenger removal from the system. This type of evacuation might be prompted by a power failure, guideway blockage, or vehicle failure that cannot be corrected within a reasonable length of time. These situations occur more frequently than do critical emergencies. Because of their controlled nature, they do not normally involve high levels of hazard to the evacuating passengers.

Non-emergency evacuation of passengers are normally uncontrolled evacuations. These situations are characterized by passengers abandoning vehicles without being directed to do so. This type of evacuation may occur when passengers become impatient with temporary service delays or vehicle temperatures become uncomfortable after loss of power and air conditioning. Uncontrolled evacuation can result in passengers following the guideway into an operational area, thereby being exposed to serious hazards. These situations are particularly troublesome to systems operation because restoration of service must be delayed until it is determined that the guideway is free of passengers.

It is possible for all four of these categories of evacuation and rescue to be required simultaneouly or in rapid succession.

2. Guideway Type

Guideway type is important in the determination of whether passengers can, at least to some extent, evacuate themselves from AGT systems without assistance. Evacuation routes for conventional rapid transit systems have traditionally been along the track. AGT systems, however, may incorporate suspended or monorail vehicles in specialized guideway configurations from which unplanned emergency egress is dangerous or impossible. Specialized emergency procedures and equipment will be required for these systems.

While existing and proposed AGT guideway configurations span quite a full range of designs, it is possible to categorize them into three types:

- Guideway safe for walking with power rails energized.
- Guideway safe for walking with guideway power off.
- Guideway unsafe for walking.

The horizontal elevator at the Tampa Airport shown in Figure 4-1(a) has a guideway configuration which is safe for walking with the guideway electrical system energized. A wide walkway is provided for passengers with a railing to protect them from moving vehicles. Frequently spaced openings in the railings provide access to the walkway from the vehicles.

The guideway configuration used for the AIRTRANS system at the Dallas/Fort Worth Airport, Figure 4-1(b), exemplifies a configuration which is safe for walking with power off. Its safety is derived from the guideway running surface being quite smooth and free of obstructions and holes. Additionally, the parapet wall protects passengers from walking or falling from elevated guideway structures. The exposed nature of the power rails, however, make walking the guideway with the power rails energized dangerous even though the three middle "hot" rails have been inset to protect against inadvertent contact.

There are several guideway configurations which are not safe for walking under any circumstances. The Walt Disney World Monorail system, Figure 4-1(c), illustrates only one configuration on which walking is not safe. Other configurations which are unsafe for walking include suspended vehicle systems and vehicle systems in which only a narrow running pad is used for guideway.

3. Guideway Elevation

Guideway elevation has considerable influence on the accessibility of AGT vehicles to evacuation and rescue personnel. Variations in guideway elevation, when combined with other factors, may result in extreme variations in evacuation and rescue procedures and the equipment required to execute the procedures.

The range of AGT guideway elevations that exist or have been seriously proposed range from 60 feet subterranean (subway) to about 65 feet elevated. For the purpose of this study, the following values were selected:

- Subway, all levels
- At grade
- Elevated, 30 feet or less
- Elevated, above 30 feet

Because of construction costs, subways are not commonly proposed for AGT applications. When subways are proposed they are often adaptations of existing tunnels to a new use as AGT right-of-way.

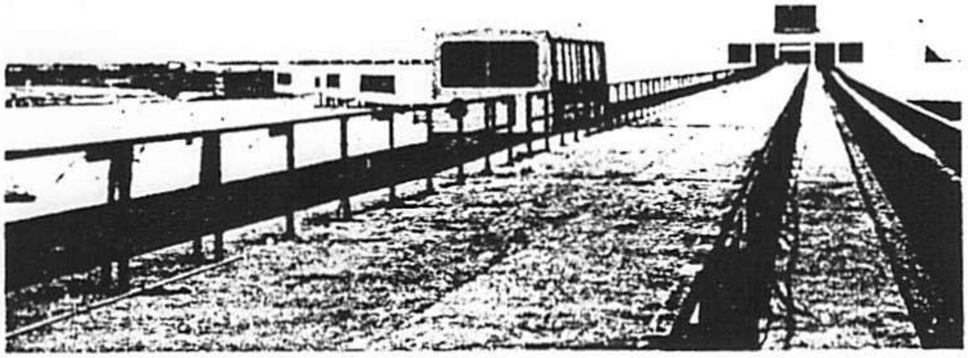
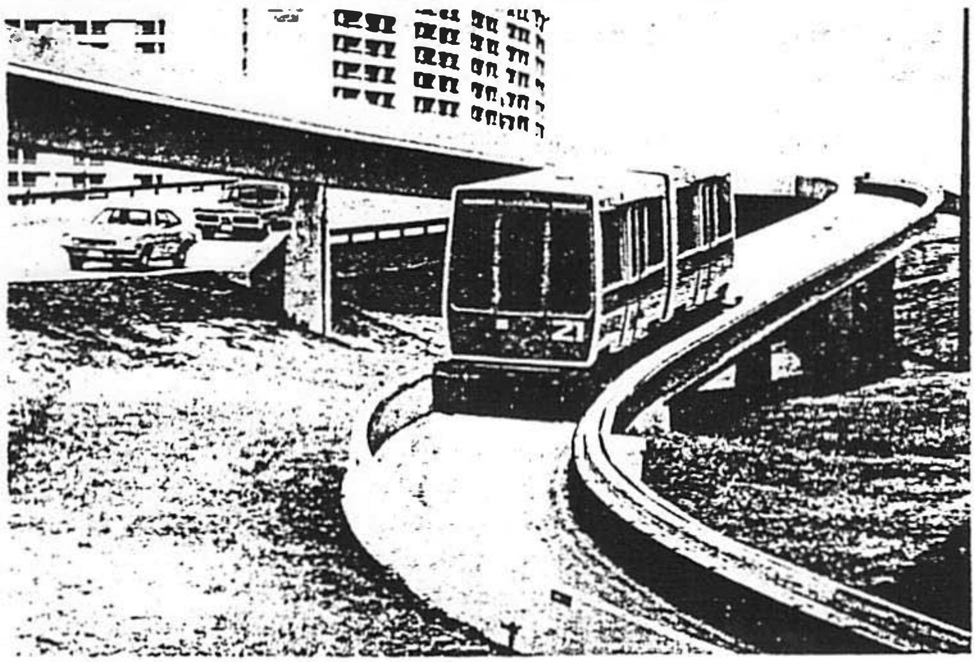
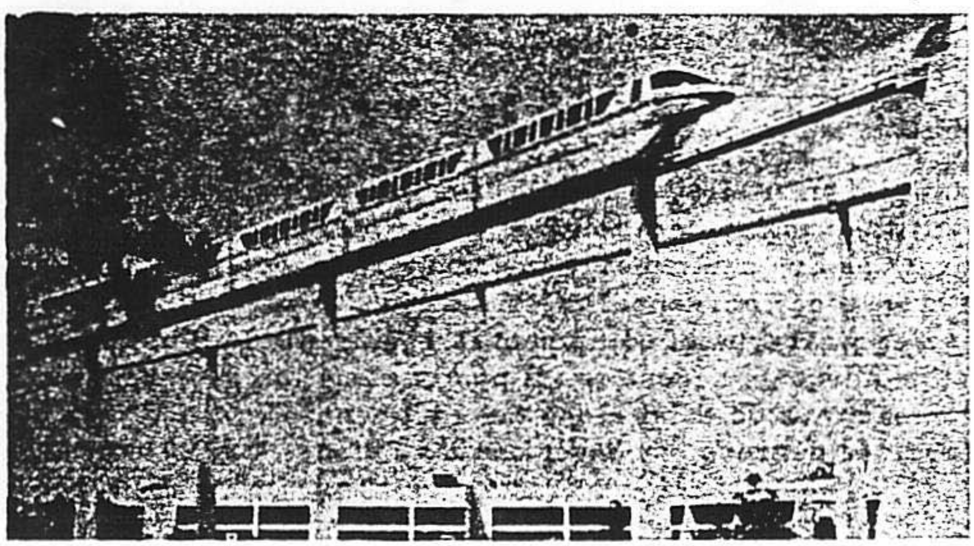


Photo Courtesy of Westinghouse Electric

a) Safe for walking with power rails energized



b) Safe for walking with power rails de-energized



c) Unsafe for walking

Figure 4-1
AGT Guideway Types

Evacuation and rescue of passengers from AGT vehicles in subways poses all the problems of similar operations from conventional subway systems. Among these are limited numbers of tunnel access points, entrapment of smoke, fumes and heat, lack of natural light, and ventilation. Because of these problems, specialized procedures and equipment are required for evacuation and rescue of passengers from subway tunnels.

At-grade guideway runs along the surface of the ground, on an embankment, or in a man-made channel cut into the ground. Since AGT systems are by definition grade-separated from other modes, at-grade guideway is used most commonly in newly developed areas where problems associated with existing streets are not severe.

Because it is located on the surface, at-grade guideway typically is the most accessible of the guideway elevation types to evacuation and rescue personnel. Since access is not constrained, except possibly by fences, no special equipment is normally required to reach the system. Additionally, passengers would have available numerous paths of egress once they leave the vehicle.

To differentiate it from guideway constructed on an embankment, elevated guideway in this study will be defined as guideway supported by man-made structure spanning between columns. Two height ranges of elevated guideway have been designated. The lower range, less than 30 feet, was selected because it is typical of the heights most commonly proposed and it represents the approximate upper limits of many ladder and lift truck apparatus. For heights above 30 feet, specialized equipment is likely to be required to provide access of evacuation and rescue personnel to the vehicles and guideway.

4. Terrain/Geography

In addition to guideway elevation, the physical features in the vicinity of an AGT system will have considerable effect on the accessibility of the system to evacuation and rescue personnel. Geographic considerations are particularly important when determining response time of emergency personnel to various locations within the system and in assessing what type of equipment is required. Public roadways may not provide adequate access to all points along the system's route. If public roadways do exist along the route, consideration should be given to how various degrees of congestion may hinder their effectiveness.

For this study, four types of terrain and geographical impacts on system accessibility to rescue personnel and equipment were identified:

- Virtually inaccessible to conventional vehicles
- Accessible over land
- Accessible by improved roads, uncongested
- Accessible by public roads, congested

While installations of AGT systems at locations in which portions of the system are inaccessible by conventional surface vehicles have not been proposed, often it is desirable to consider them none the less. Typically, these proposed applications call for the system to cross a body of water such as a river, saltwater ship channel, or bay. If rescuers were to access the guideway from the surface, specialized equipment would be required in all of these applications.

Occasionally, AGT systems have been proposed which have portions of the guideway running through parks, green areas, or other undeveloped areas. In many cases, the terrain in the vicinity of the system has no improved (paved) roads and, in some cases, is somewhat rugged. Conventional vehicles could have trouble gaining access to these locations, especially if the problem was compounded by mud, ice, or snow.

Most of the systems proposed have had paved roads which could be used for emergency access running along virtually their entire length. Where these roads are open to the public, however, consideration must be given to problems of private vehicle congestion. This problem could be especially taxing after major or "spectacular" accidents because of the large numbers of onlookers who would be attracted.

5. Passenger Group Size

The number of passengers requiring evacuation or rescue from an AGT system impacts both the speed with which the procedure can be executed and the facilities and equipment required for the procedure.

A wide range of vehicle and train sizes have been proposed. On the low end of the passenger spectrum are proposed Personal Rapid Transit (PRT) systems with from 2 to 9 passengers per vehicle. On the high end of the spectrum, rubber-tired automated systems have been proposed with up to 10-car trains carrying a total of more than 1,000 passengers. However, since these latter system configurations have been proposed with onboard human "monitors", they represent more of the characteristics of rail transit than AGT. For this reason, they are not fully addressed here.

Three ranges of passenger group sizes have been identified as representative of most AGT applications from the evacuation and rescue viewpoint:

- Less than 10
- 10 to 100
- more than 100

These ranges have been selected based upon Shuttle Loop Transit (SLT), Group Rapid Transit (GRT), and Personal Rapid Transit (PRT) system characteristics as well as the characteristics of existing equipment that might be utilized for evacuation and rescue.

6. Passenger Condition

The physical condition and emotional state of passengers involved in evacuation and rescue operations will greatly influence the amount of aid that they will require. This study has identified three levels of physical mobility that passengers involved in evacuations and rescues may possess. The passengers may be:

- Non-ambulatory
- Ambulant with assistance
- Able bodied

Non-ambulatory passengers may result from physical injuries received during a transit accident. These passengers may possess a wide variety of injuries and require a range of first aid medical treatment. In addition, the strain encountered after a severe accident may result in emotional shock that disables some passengers. However, accidents should not be considered the only source of non-ambulatory passengers. As transit systems become increasingly accessible to them, elderly and handicapped non-ambulatory passengers will become regular system riders. Non-ambulant passengers will require being carried from the system.

Some passengers are strong enough to walk, but may be unsteady to the point of requiring support from another person. Passengers with less severe handicaps, the elderly, children, and those persons who have only minor injury or are just "shaken-up" fit into this category. These passengers can walk from the system with assistance from rescue personnel or other passengers.

Able bodied passengers are normally capable of exiting the vehicle under their own power. These passengers can be called upon in an emergency to assist in getting other passengers out of the vehicle.

7. Distance from Station or System Access

The choice of evacuation method from an AGT system will often hinge about the distance to the closest station or point of system access. Depending upon the distance to the nearest station or point of access and its acceptability based upon other factors such as guideway type, weather, and passenger number and condition, walking may be used to remove passengers from disabled vehicles to a place of safety.

Because of the many variables that can impact the acceptability of walking from disabled vehicles, meaningful quantification is impossible. Instead, a binary situation is assumed.

- Too far to walk
- Within acceptable walking distance

8. Weather Conditions

Weather conditions can cause significant variations in evacuation and rescue problems. Three conditions have been identified:

- Wet or icy conditions
- Temperature extremes
- Dry and mild

Icy conditions, whether caused by snow, freezing rain, or water frozen after fire fighting, can make the entire evacuation and rescue task much more hazardous. Not only is access to the scene more difficult, but many evacuation methods may be unsafe under icy conditions.

Wet conditions can also pose problems, although normally not as severe as icing conditions. In particular, access via unimproved routes may be rendered impassable because of mud and water. Additionally, moisture may make metal and concrete surfaces quite slippery if proper surfaces finish do not exist.

Temperature can affect evacuation and rescues from two standpoints. First, it will affect how long passengers will tolerate loss of heat and air conditioning systems. Secondly, it will affect how long personnel conducting evacuations or rescues will be able to work efficiently without fear of such temperature related problems as frost bite and heat stroke.

9. Ambient Lighting

Lighting has been shown to be an important factor in the success of emergency evacuations. While most AGT installations will be in urban areas with relatively high ambient light levels even at night, evacuation and rescue operations during darkness will likely require additional external illumination along many portions of the system.

For this study, two levels of ambient light were considered:

- Adequate
- Inadequate

10. Attendant on Vehicle

While most AGT systems proposed have not included the provision of an attendant onboard the vehicle, the existence of such personnel could significantly alter the nature of the evacuation and rescue problem. For this reason, the impact of onboard transit personnel is addressed.

11. Vehicle Egress Constraints

The specific evacuation and rescue methodology selected for a particular system technology will depend upon any constraints in egress from the vehicle. These include the ability of passengers to pass between entrained vehicles and to open doors to the outside without assistance.

CHAPTER 5 - ANALYSIS OF METHODS AND PROCEDURES

Numerous techniques for passenger evacuation and rescue were identified in the literature review, survey of current transit practice and conversations with experts in a number of evacuation and rescue fields. This section will deal with the candidate methods and procedures which were considered to have potential application to AGT. It will include:

- Description of the candidate evacuation and rescue techniques.
- Criteria used for evaluating their applicability to AGT.
- Summary of the merits and problems of the candidate techniques.
- Recommendations of equipment and procedures to be considered for future AGT applications.

A. Candidate Evacuation and Rescue Techniques

1. Classification

Candidate evacuation and rescue techniques which were identified from previous investigations were divided into two classifications based upon their implicit degree of passenger self-sufficiency during evacuation. The first classification, self-evacuation or rescue, is restricted to those techniques in which passengers are able to egress from the vehicle to a place of safety at will and without the assistance of any outside personnel. To qualify as a self-evacuation or rescue technique, all of the equipment and procedural information required for safe egress from the vehicle must be constantly available to the passengers. In contrast, the second classification, assisted evacuation or rescue, relies upon the actions of personnel and/or equipment from outside the vehicle. As personnel and equipment may be dispatched to the scene of the emergency from another location, assisted evacuation and rescue techniques would be expected to have longer response times associated with them.

2. Baselines

For the purpose of comparison between the candidate techniques, design baselines were established for each technique. To make it as realistic as posssible, this baseline was an existing AGT system wherever such a system existed . Unfortunately, all of the methods and procedures have not yet been deployed. This necessitated the evaluation baseline for some techniques to be the composite of two or more existing technologies. Other techniques were evaluated based upon very limited design information, and the baselines were quite conceptual and hypothetical in nature. Although sensitivity of the effectiveness of the techniques to change in technique characteristics was considered during later evaluation, attempts were made to incorporate the most desirable characteristics into the technique baselines.

Table 5-1 lists the candidate evacuation and rescue techniques which were selected for further evaluation and identifies an exaple or origin of (the baseline for) each technique.

3. Description

The following are brief descriptions of the candidate evacuation and rescue techniques which were evaluated. Only the most important design considerations are identified. Desirable details of the techniques are assumed to exist and to have been provided by good engineering design.

a. Self-Evacuation and Rescue

Three basic self-evacuation and rescue techniques were evaluated with a total of nine types of equipment.

1) Egress from Vehicle onto Adjacent Walkway

The shuttle system at the Tampa Airport was used as the baseline for this technique. The most important design considerations of the baseline are:

- Service doors which can be opened from within in the event of an emergency
- Wide, adjacent walkway at same height as vehicle floor.
- Railings to protect passengers from moving vehicles on adjacent guideways.

During emergencies, passengers may open the vehicle doors and easily egress onto the walkway. Passengers may then walk along the guideway until they reach a

TABLE 5-1 CANDIDATE AGT EVACUATION AND RESCUE TECHNIQUES

Technique	Example or Origin
Self-Evacuation And Rescue	
Egress from vehicle onto adjacent walkway	Tampa Airport
Egress from vehicle onto guideway running surface (unobstructed)	Niagata
Egress from vehicle onto guideway running surface (obstructed)	Fairlane
Egress to ground level using:	
. inflatable evacuation slide	Cabinenlift w/Aviation Slide
. synthetic cloth chute	H-Bahn w/Cloth Chute
. rigid ladder or stairs	Conceptual
. rope or wire ladder	Conceptual
. knotted rope	Jet Rail
. lowering vehicle floor	Conceptual
Assisted Evacuation And Rescue	
Move vehicle to station or safe deboarding location using:	
. vehicle manual control	Sea-Tac
. another vehicle to push or tow it	AIRTRANS Prototype
. gravitational forces	Pearlridge
Transfer passenger from disabled vehicle to:	
. normal AGT vehicle	AIRTRANS
. specialized rescue vehicle	Cabinenlift
Transfer passenger to ground using:	
. truck-mounted articulated boom (cherry-picker)	Actual Equipment
. truck-mounted platform lift	Actual Equipment
. truck-mounted turret ladder	Actual Equipment
. portable ladders	Actual Equipment
. boatswain's chair	Actual Equipment
. portable stairs	Actual Equipment
. helicopter	Conceptual with Actual Equipment

safe location. This technique is applicable to all guideway elevations, and variations of it are applicable to all guideway types. Figure 5-1 (a) shows the system as it exists at the Tampa Airport, and Figure 5-1 (b) illustrates how it might be implemented for a suspended vehicle system.

2) Egress from Vehicle onto Guideway Running Surface

Two baselines were used for this basic technique to account for the extreme differences in ease of egress. The baseline systems were the Japanese licensed version of AIRTRANS being constructed in Osaka City, Japan and the Fairlane shuttle system in Detroit. The important design considerations are:

- Emergency exits giving access to guideway.
- Wide, flat vehicle running surface.

During emergencies, passengers can gain access to the guideway running surface by way of emergency exit doors in the end of the vehicle. As is shown by Figure 5-2, emergency egress from the Japanese design is quite easy because of the built-in step between the emergency exit and the guideway. In contrast, emergency egress from the vehicles in the Fairlane system requires crawling over an equipment compartment and dropping several feet to the guideway running surface. In both cases, once passengers reach the guideway running surface, they must be protected from hazards associated with moving vehicles and guideway electrification. This technique of providing evacuation and rescue is applicable to all guideway elevations but can only be used on vehicles supported from below by relatively flat, continuous guideways.

3) Egress to Ground Level

Six methods of allowing passengers to go from elevated guideway to ground level were evaluated. These techniques used a variety of equipment which included:

- Automatically inflated evacuation slides similar to those used on commercial airlines. This type of device is shown as applied to an AGT system in an artist's concept in Figure 5-3.

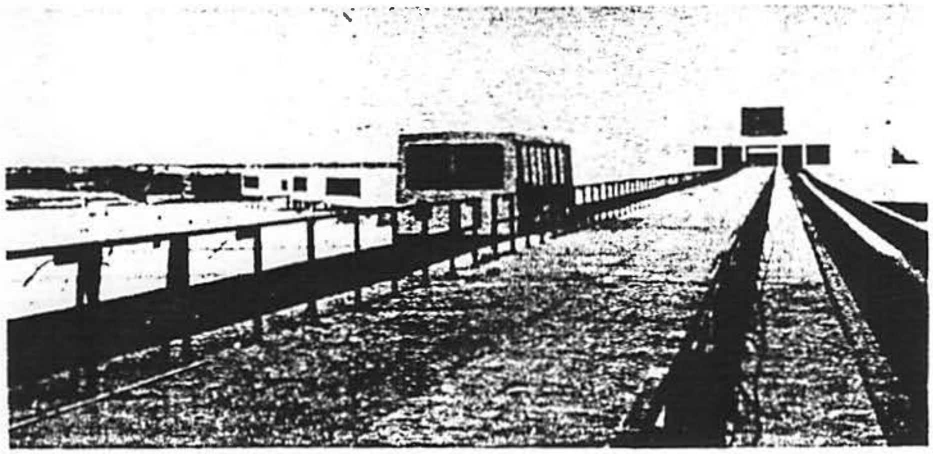


Photo Courtesy of Westinghouse Electric

A) Adjacent walkway with supported vehicle.

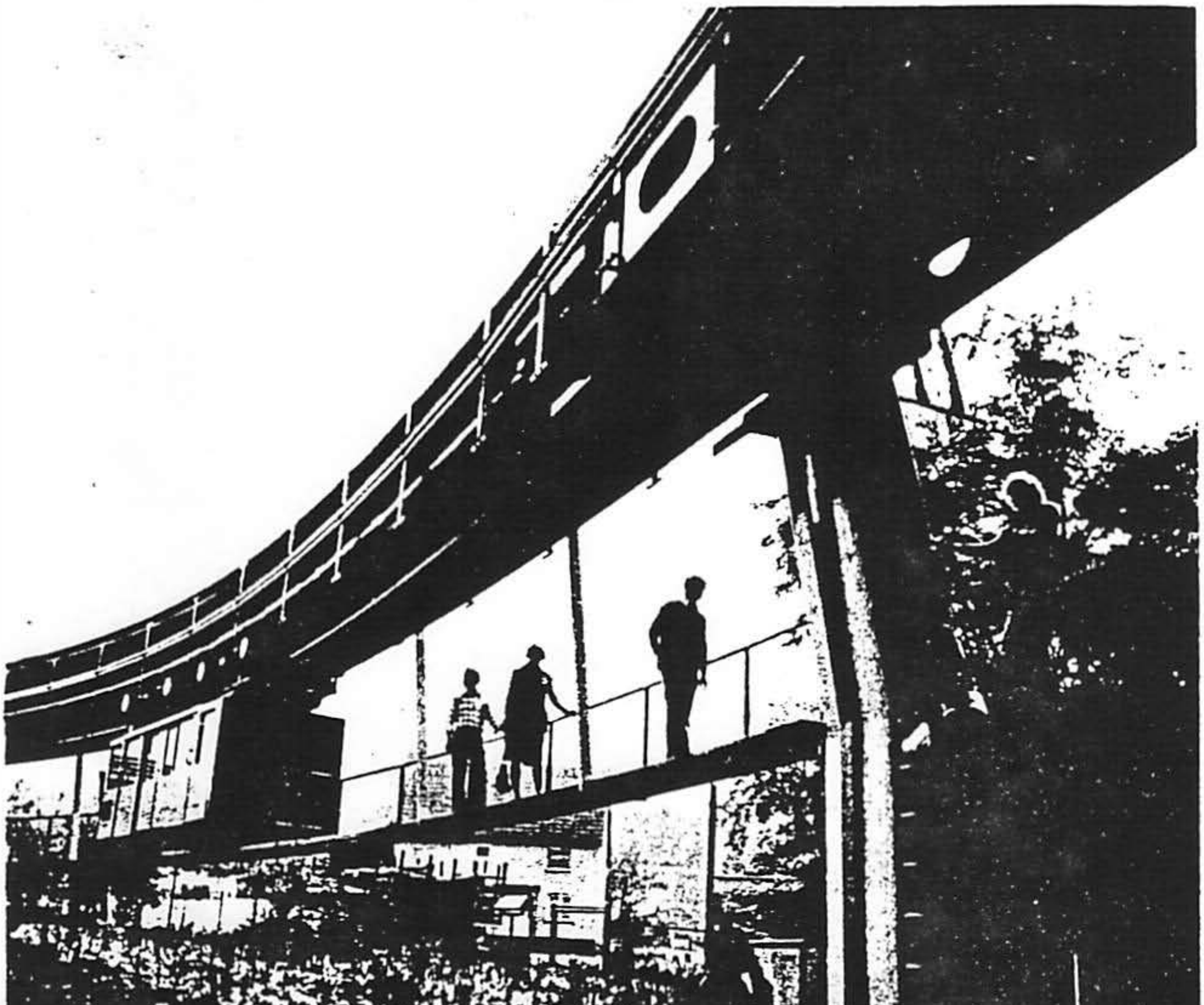


Photo Courtesy of DEMAG Fordertechnik

B) Adjacent walkway with suspended vehicle.

Figure 5-1

Implementation of Adjacent Walkways

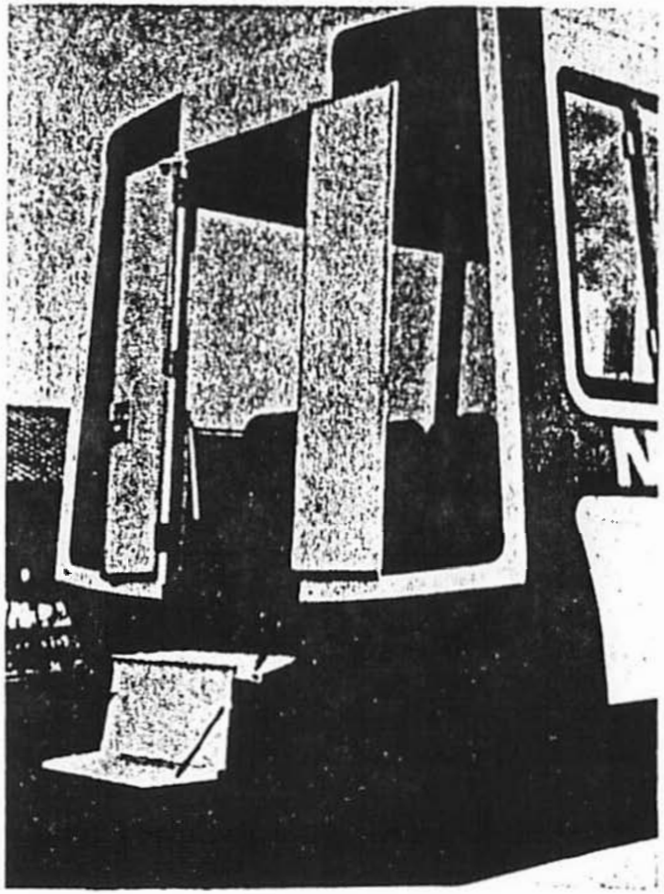


Photo Courtesy of Niagata Engineering, Ltd

Figure 5-2

Emergency Exit to Guideway with Built-in Step

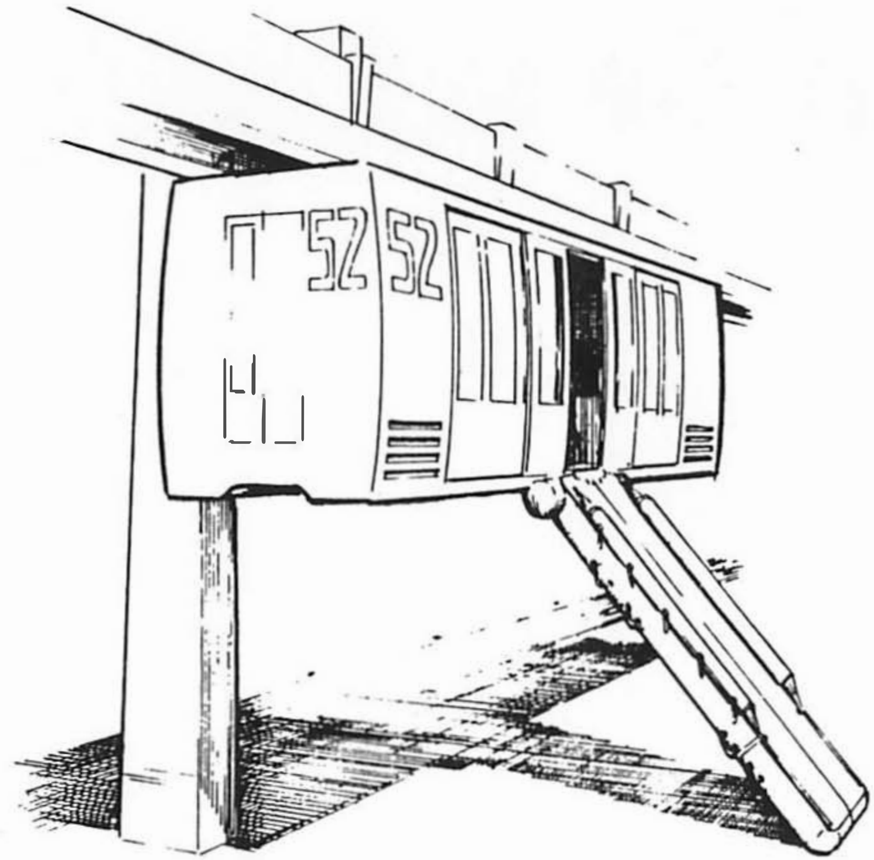


Figure 5-3

Evacuation Slide as Applied to AGT

- Synthetic cloth chutes through which passengers can lower themselves to the ground. Decent velocities are controlled by friction of arms and legs against the sides of the chute. Figure 5-4 illustrates the use of such a chute being developed in Europe.

- Emergency folding stairs or ladders similar to the type often found in homes to access attics, which can be deployed by passengers during emergencies.

- Rope or wire ladders attached to pivoting support arms on the side or end of the vehicle which can be deployed by passengers during emergencies.

- Knotted rope which passengers can attach to recepticle over door and climb down to ground. This technique was actually employed on the Jet Rail system at Dallas Love Field.

- Floor lowering mechanism which, upon commands from either onboard the vehicle or central control, can lower all or part of the vehicle to the ground.

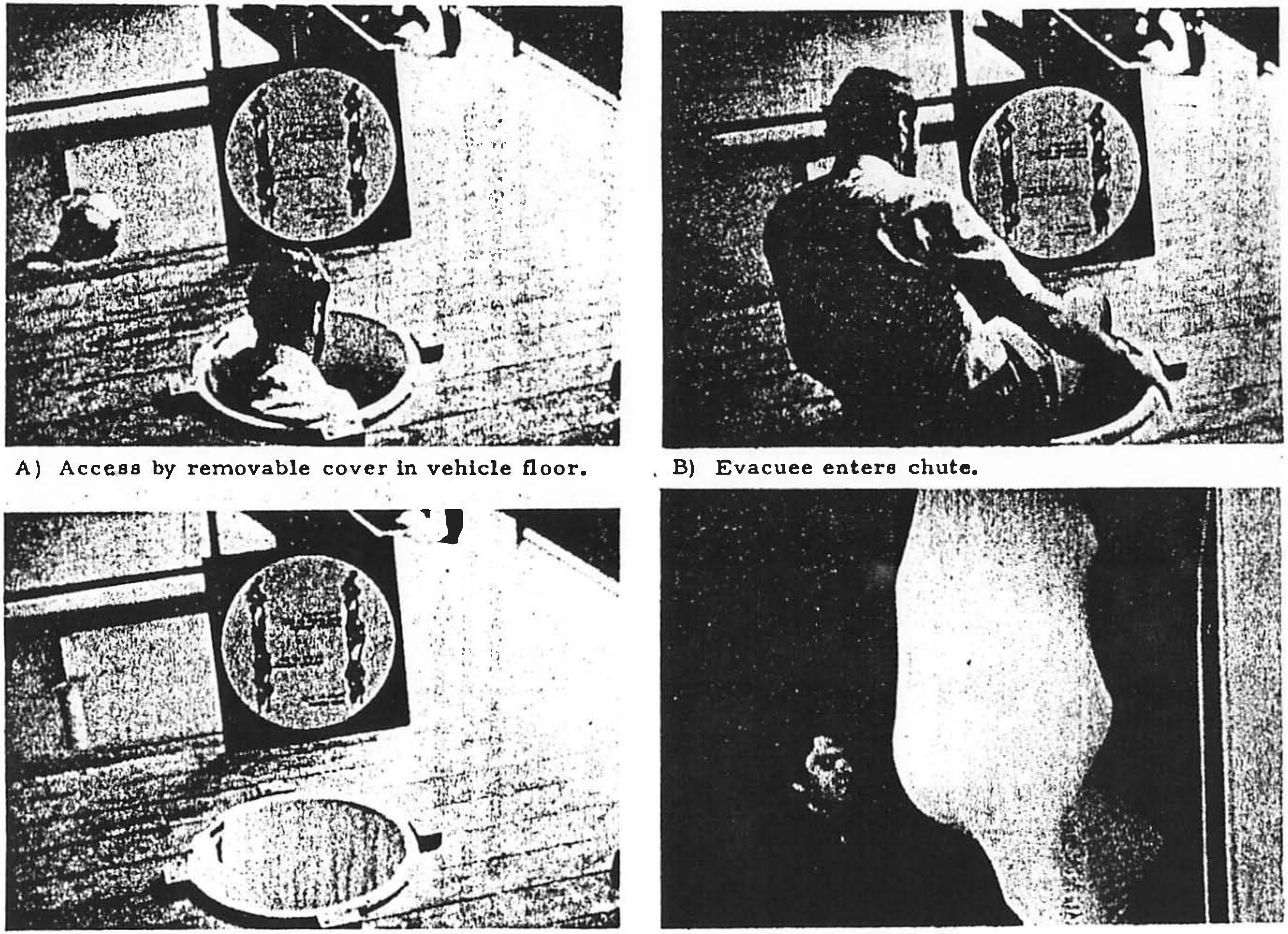
All of these candidate techniques could be applied to either supported or suspended vehicle technologies with the exception of synthetic cloth chutes and lowering vehicles, which are only suitable for application to suspended vehicles.

b. <u>Assisted Evacuation and Rescue</u>

Assisted evacuation and rescue techniques also were found to be of three types with a total of twelve different varieties being evaluated.

1) <u>Move Vehicle to Station or Other Safe Deboarding Location</u>

Three methods of moving disabled vehicles to safe deboarding locations were identified:



A) Access by removable cover in vehicle floor.

B) Evacuee enters chute.

C) Lowers himself slowly.

D) View from underneath.

Photos Courtesy of J. Edward Anderson, U. of Minn.

Figure 5-4

European Synthetic Cloth Evacuation Chute

- Move the vehicle under its own power but under the manual control of an onboard operator.

- Use another vehicle to push or tow the disabled vehicle. This vehicle may be either another passenger vehicle or a specialized tow vehicle.

- Coast the vehicle to a station or other safe deboarding location under manual control.

When employing all of these techniques, the fundamental policy being followed is that the safest place for passengers is in the vehicle. These techniques are suitable for all guideway types and elevations. The technique which relies upon gravity for coasting vehicles into stations, of course, has significant vertical alignment requirements.

2) <u>Transfer Passengers from the Disabled Vehicle onto Another Vehicle</u>

Two basic types of transfer of passengers from disabled vehicles to operating vehicles were identified for evaluation:

- Transfer of passengers from a disabled vehicle to a normal vehicle which has been moved to an adjacent location. Passengers may use vehicle end doors if the normal vehicle approaches on the same guideway or side (service) doors if the normal vehicle is on an adjacent guideway.

- Transfer of passengers from a disabled vehicle to a specially-equipped rescue vehicle. Figure 5-5 illustrates such a vehicle used in conjunction with a West German hospital AGT installation.

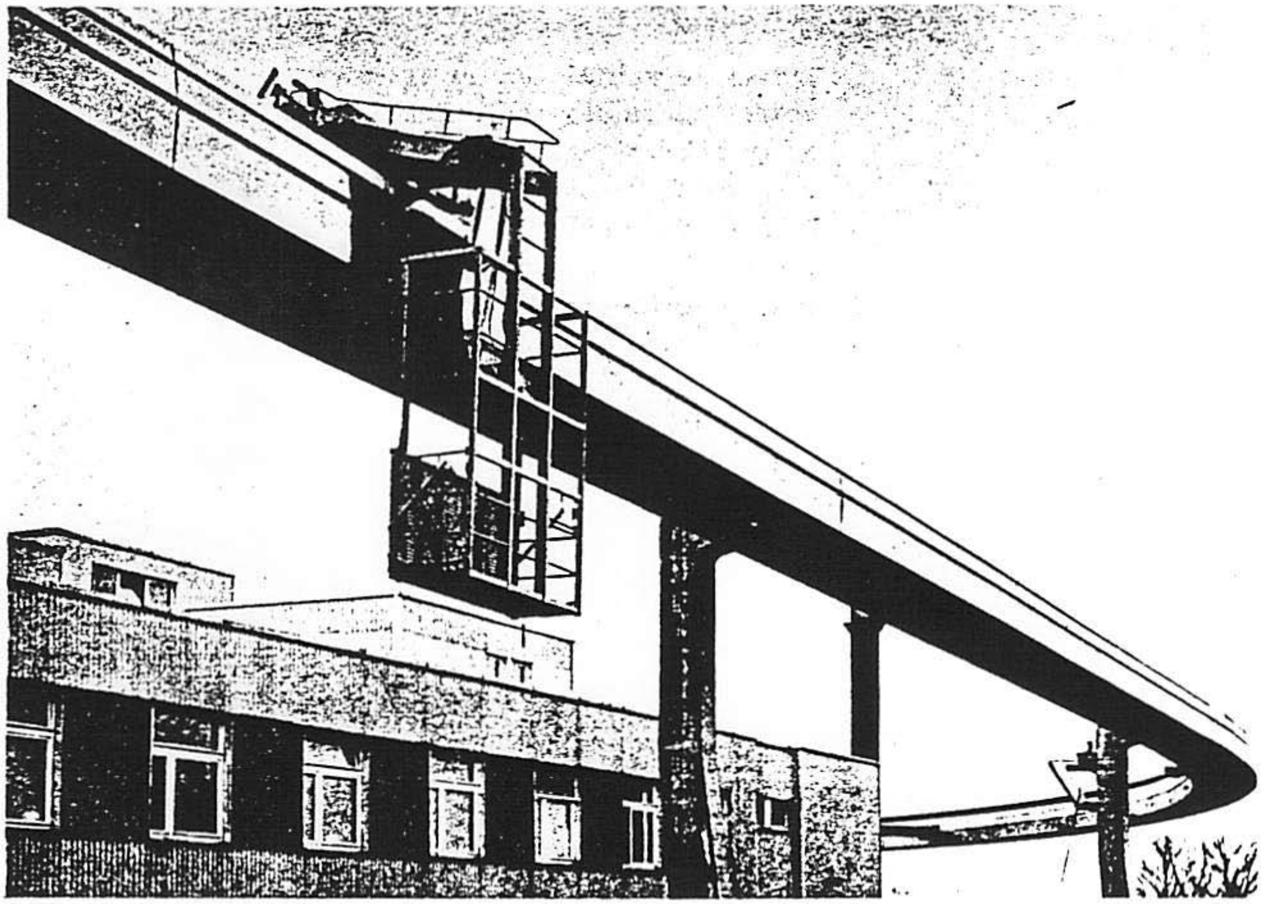


Photo Courtesy of DEMAG Fordertechnik

Figure 5-5.
Combination Emergency Rescue and Maintenance Vehicle

These techniques are also suitable for use with all types of guideways and all guideway elevations.

3) Transfer Passengers to the Ground Level

Seven different methods were identified for transferring passengers to the ground from elevated guideway structures:

- Use a truck mounted articulated boom (often referred to as a cherry-picker) similar to the ones used by utility companies.

- Use a truck mounted platform lift similar to the ones used at many airports to lift catered meals to airliners.

- Use a truck mounted turret ladder similar to the ones used by utility companies, billboard advertising firms and fire departments.

- Use an ordinary portable ladder.

- Use a boatswain's chair and pulley arrangement similar to the ones used to evacuate some ski lifts.

- Use portable stairs similar to the ones used at some airports to unload passengers from airliners.

- Use a helicopter and emergency rescue basket in a fashion similar to sea rescues.

All of these candidate techniques could be used with either supported or suspended vehicle technologies. They do have a variety of access requirements ranging from a need for roadway access to requiring clear airspace overhead.

B. Evaluation of Candidate Methods and Procedures

1. Measures of Effectiveness

Each of the candidate evacuation and rescue techniques was evaluated relative to an array of performance criteria. These criteria were selected to assess the ability of the candidate techniques to safely and surely move passengers from an AGT vehicle to places of safety under emergency conditions, to assess their impact on other aspects of urban life and to determine their relative costs.

Twelve performance measures of effectiveness were identified for use in this evaluation:

- Response time - The time required from occurrence of a situation requiring evacuation and rescue until first passengers reach location of relative safety, measured in minutes.
- Capacity - Rate at which passengers can be moved to location of safety, measured in passengers per minute.
- E&H Compatibility - Capability of the method or procedure to accommodate evacuation of elderly and handicapped passengers.
- Required Technology - A measure of the availability of the components or technologies required to implement the evacuation or rescue technique.
- Relative Safety - Comparative magnitude of the hazards to which passengers are exposed as they egress from vehicle to location of safety.
- Cost - The incremental expense of adding provisions for the evacuation technique to the basic AGT system design. Cost was quantified in dollars using readily available data or estimates.
- Dependability - The likelihood that the technique will be capable of performing the required function when called upon.

- Versatility - The capability of the evacuation system to adequately perform under a range of emergency conditions, including a variety of locations within the system.
- Inconvenience - The amount of awkwardness or discomfort (either physical or emotional) that passengers are likely to experience in using the technique.
- Aesthetics - The impact of any required equipment or provisions on the architectural or natural beauty of the surrounding environment.
- Resistance to Vandalism - The susceptibility of the techniques to destructive acts of vandalism which could impare the function of the technique in an emergency.
- Resistance to Unauthorized Use - The capability of restricting the use of a technique to those situations in which its use is required or warranted.

In addition to the primary effectiveness measures, the candidate techniques were also assessed to determine their applicability relative to the scenario variables developed earlier during this study. For the purpose of the evaluation, these variables were divided into two groups:

- Design variables, which are detemined by the characteristics of the system design technology and system application, including:
  - Guideway type
  - Vehicle egress constraints
  - Guideway elevations
  - Terrain and geography
  - Vehicle passenger capacity
  - Vehicle towability
  - Vehicle onboard personnel.
- Situation variables, which are determined by the characteristics of the particular incident which precipitates the need to evacuate or rescue passengers, including:
  - Severity of emergency
  - Physical condition of passengers
  - Distance from stations or system access
  - Weather conditions
  - Ambient lighting

2. Evaluation Procedure

As can be seen from the evaluation measures of effectiveness, many of the criteria used for the performance evaluation were subjective. To improve the reliability and confidence level associated with the evaluation, a modification of the delphi forecasting method was employed. As part of this procedure, a detailed evaluation form was prepared for each of the candidate methods and procedures. The study leader completed each form and summarized the results onto a master evaluation form. Copies of this completed master form were then submitted to each of three panel members for their comments concerning the accuracy of the information on the master form. The panel members were all experienced Vought Corporation specialists in human factors and safety. Upon the return of forms with comments from the panel members, a conference of the panel members plus study leader was convened and differences of opinion discussed. These discussions yielded a consensus of the panel members.

C. Summary of Findings

Table 5-2 provides the consensus of the human factors and safety panel review of the evacuation and rescue techniques relative to the primary measures of effectiveness. After the panel review, several specific measures were selected for comparative analysis between techniques. This process identified the critical impact areas of each technique and pointed out the aspects of each technique that were either relative strengths or weaknesses. The most significant findings are reviewed below:

- Figure 5-6 illustrates the characteristics of the various techniques with respect to response time and rate of egress. As many of the techniques have response times and rates which are dependent upon location of the disabled vehicle in the system and guideway elevation, these factors were normalized in the analysis so that responses would be comparable. The figure shows clearly that only the more rapid self-evacuation or rescue techniques are satisfactory for response to emergencies with on-going threats to passenger safety, while the assisted techniques are adequate for non-critical evacuations caused by problems such as stalled vehicles.

TABLE 5-2

EVALUATION SUMMARY OF EVACUATION AND RESCUE TECHNIQUES

Method/Procedure	Response Time	Capacity
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	10 sec	100 pax/min
Egress from vehicle onto running surface (unobstructed/obstructed)	10/20 sec	30/15 pax/min
Egress to ground level using		
. inflatable slide	15 sec	20 pax/min
. cloth chute	20 sec	5 pax/min
. rigid ladder/stairs	30 sec	10 pax/min
. rope or wire ladder	30 sec	4 pax/min
. knotted rope	30 sec	4 pax/min
. lowering floor	60 sec	100 pax/min
Assisted Evacuation or Rescue		
Move vehicle to station		
. manual control	6 min	100 pax/min
. tow	8 min	100 pax/min
Transfer passengers		
. to normal vehicle	8 min	30 pax/min
. specialized rescue vehicle	10-15 min	15 pax/min
Transfer passengers to the ground using		
. truck-mounted articulated boom	6 min	5 pax/min
. truck-mounted platform lift	6 min	10 pax/min
. truck-mounted turret ladder	6 min	10 pax/min
. portable ladders	6 min	10 pax/min
. portable stairs	6 min	15 pax/min
. boatswain's chair	7 min	1-2 pax/min
. helicopter	10-15 min	<1 pax/min

TABLE 5-2 (Continued)
EVALUATION SUMMARY OF EVACUATION AND RESCUE TECHNIQUES

Method/Procedure	E&H Compatibility	Required Technology
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	Excellent	Exists
Egress from vehicle onto running surface (unobstructed/obstructed)	Fair/Poor	Exists
Egress to ground level using		
. inflatable slide	Fair	Exists
. cloth chute	Poor	Partially Developed
. rigid ladder/stairs	Fair	Partially Developed
. rope or wire ladder	Poor	Exists
. knotted rope	Poor	Exists
. lowering floor	Excellent	New
Assisted Evacuation or Rescue		
Move vehicle to station		
. manual control	Excellent	Exists
. tow	Excellent	Partially Developed
Transfer passengers		
. to normal vehicle	Good	Exists
. specialized rescue vehicle	Good	Partially Developed
Transfer passengers to the ground using		
. truck-mounted articulated boom	Good	Exists
. truck-mounted platform lift	Excellent	Exists
. truck-mounted turret ladder	Poor	Exists
. portable ladders	Poor	Exists
. portable stairs	Fair	Exists
. boatswain's chair	Good	Exists
. helicopter	Fair	Exists

TABLE 5-2 (Continued)

EVALUATION SUMMARY OF EVACUATION AND RESCUE TECHNIQUES

Method/Procedure	Relative Safety	Approximate Cost (1977 $)
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	Good	$50-100/ft. (Elevated)
Egress from vehicle onto running surface (unobstructed/obstructed)	Good	None
Egress to ground level using		
. inflatable slide	Good	$3,000 ea
. cloth chute	Good	$2,000 ea
. rigid ladder/stairs	Good	$5,000 ea
. rope or wire ladder	Poor	$200 ea
. knotted rope	Poor	$100 ea
. lowering floor	Excellent	unknown
Assisted Evacuation or Rescue		
Move vehicle to station		
. manual control	Excellent	None
. tow	Excellent	None
Transfer passengers		
. to normal vehicle	Good	None
. specialized rescue vehicle	Good	$50-300,000 ea
Transfer passengers to the ground using		
. truck-mounted articulated boom	Excellent	$30,000 ea
. truck-mounted platform lift	Excellent	$25,000 ea
. truck-mounted turret ladder	Good	$20,000 ea
. portable ladders	Good	$100 ea
. portable stairs	Excellent	$200-1,000 ea
. boatswain's chair	Good	$200 ea
. helicopter	Fair	$250,000 ea (could be time shared)

TABLE 5-2 (Continued)

EVALUATION SUMMARY OF EVACUATION AND RESCUE TECHNIQUES

Method/Procedure	Dependability	Versatility
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	Excellent	Excellent
Egress from vehicle onto running surface (unobstructed/obstructed)	Excellent	Excellent
Egress to ground level using		
. inflatable slide	Good	Fair
. cloth chute	Excellent	Fair
. rigid ladder/stairs	Excellent	Good
. rope or wire ladder	Good	Excellent
. knotted rope	Good	Excellent
. lowering floor	Good	Good
Assisted Evacuation or Rescue		
Move vehicle to station		
. manual control	Good	Good
. tow	Good	Good
Transfer passengers		
. to normal vehicle	Excellent	Excellent
. specialized rescue vehicle	Excellent	Excellent
Transfer passengers to the ground using		
. truck-mounted articulated boom	Excellent	Excellent
. truck-mounted platform lift	Excellent	Good
. truck-mounted turret ladder	Excellent	Excellent
. portable ladders	Excellent	Excellent
. portable stairs	Excellent	Fair
. boatswain's chair	Excellent	Excellent
. helicopter	Good	Poor

TABLE 5-2 (Continued)

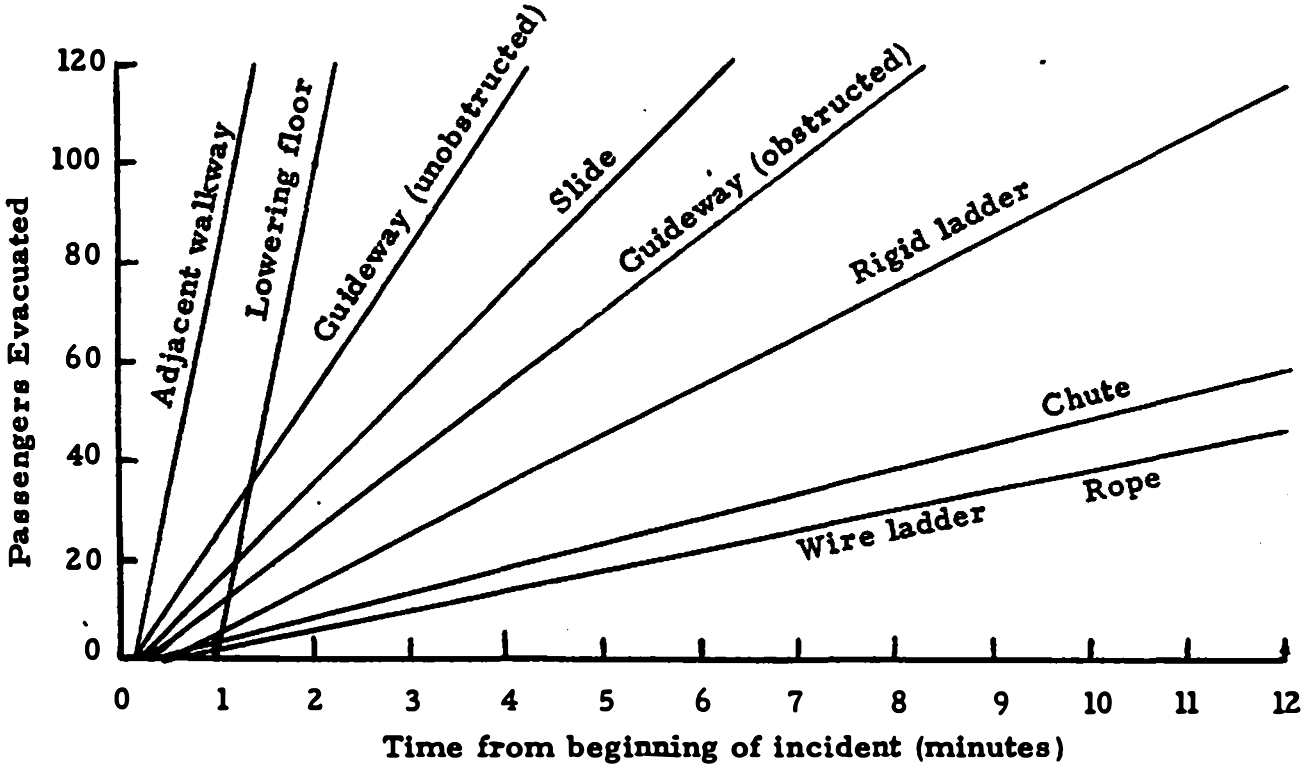
EVALUATION SUMMARY OF EVACUATION AND RESCUE TECHNIQUES

Method/Procedure	Convenience	Aesthetics
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	Excellent	Poor
Egress from vehicle onto running surface (unobstructed/obstructed)	Good/Poor	Excellent
Egress to ground level using		
. inflatable slide	Fair	Excellent
. cloth chute	Fair	Excellent
. rigid ladder/stairs	Good	Good
. rope or wire ladder	Poor	Excellent
. knotted rope	Poor	Excellent
. lowering floor	Good	Excellent
Assisted Evacuation or Rescue		
Move vehicle to station		
. manual control	Excellent	Excellent
. tow	Excellent	Excellent
Transfer passengers		
. to normal vehicle	Good	Good
. specialized rescue vehicle	Fair	Good
Transfer passengers to the ground using		
. truck-mounted articulated boom	Excellent	Excellent
. truck-mounted platform lift	Excellent	Excellent
. truck-mounted turret ladder	Good	Excellent
. portable ladders	Good	Excellent
. portable stairs	Excellent	Excellent
. boatswain's chair	Poor	Excellent
. helicopter	Poor	Excellent

TABLE 5-2 (Continued)
EVALUATION SUMMARY OF EVACUATION AND RESCUE TECHNIQUES

Method/Procedure	Vandalism Resistance	Resistance to Unauthorized Use
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	Excellent	Fair
Egress from vehicle onto running surface (unobstructed/obstructed)	Excellent	Fair
Egress to ground level using		
. inflatable slide	Fair	Fair
. cloth chute	Fair	Fair
. rigid ladder/stairs	Good	Fair
. rope or wire ladder	Good	Fair
. knotted rope	Poor	Fair
. lowering floor	--	Fair
Assisted Evacuation or Rescue		
Move vehicle to station		
. manual control	Good	Excellent
. tow	Good	Excellent
Transfer passengers		
. to normal vehicle	Good	Excellent
. specialized rescue vehicle	Excellent	Excellent
Transfer passengers to the ground using		
. truck-mounted articulated boom	Excellent	Excellent
. truck-mounted platform lift	Excellent	Excellent
. truck-mounted turret ladder	Excellent	Excellent
. portable ladders	Excellent	Excellent
. portable stairs	Excellent	Excellent
. boatswain's chair	Excellent	Excellent
. helicopter	Excellent	Excellent

a) Self-Evacuation or Rescue



b) Assisted Evacuation or Rescue

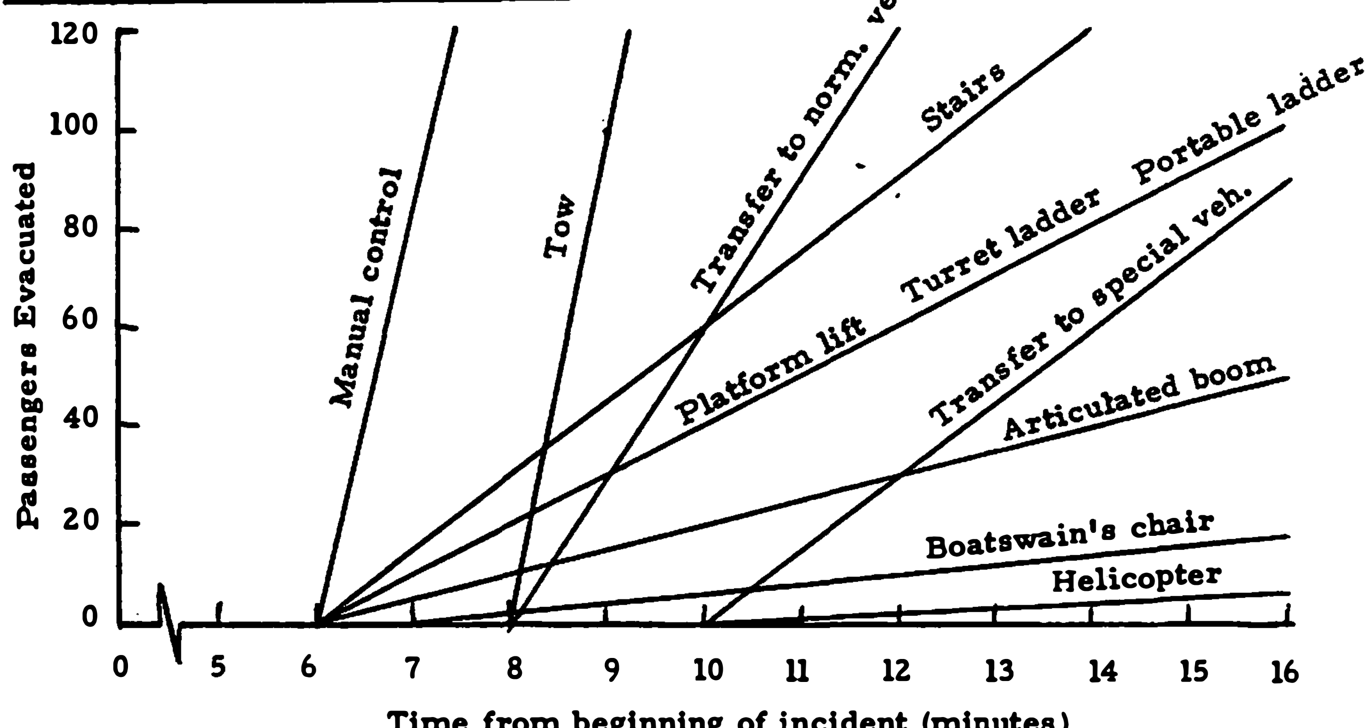


Figure 5-6.
Typical Evacuation Responses

- Comparison of safety of techniques and the associated user convenience shows a close correlation between the two. The reason seems to be that actions which passengers would find to be relatively inconvenient, such as sliding down an inflatable incline, are actions which are less safe because of the limited experience of the passengers using such a device. The exceptions to this general trend occur when the passenger is unfamiliar with a technique but is assisted by someone who is experienced with it. The implication of this is that evacuation and rescue procedures should not involve actions which are unfamiliar to passengers without assistance or close supervision.

- Costs associated with all techniques except adjacent walkways and lowering vehicle floor seemed to be quite reasonable and not of sufficient magnitude to be a major consideration in selecting techniques for deployment.

- Helicopter capital and operations costs are also quite high but could be greatly reduced by time sharing equipment with other agencies.

- With respect to accommodating elderly and handicapped passengers during emergencies requiring evacuation and rescue, only adjacent walkways, lowering floors, moving vehicles to a station, and utilization of truck-mounted platform lift equipment were considered to be adequate.

D. Recommendations

Based upon the proceeding evaluation, methods and procedures were categorized as being either recommended for application to future AGT systems or as not recommended. Techniques which were placed in the "not recommended" category were placed there primarily for two reasons:

- the performance of the technique was unsatisfactory
- there were other similar techniques which offered better performance with fewer negative implications.

Table 5-3 and 5-4 presents the principal strengths and weaknesses of the evacuation techniques identified.

TABLE 5-3

RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Self-Evacuation or Rescue		
Egress from vehicle onto adjacent walkway	Large capacity vehicle may be evacuated very quickly. Egressing passengers exposed to few hazards. Applicable to all guideway elevations. Compatible with elderly and handicapped passengers. May be used by assisting personnel in routine evacuations.	High cost of construction. Aesthetic impact caused by additional width of guideway.
Egress from vehicle onto running surface (unobstructed exit)	Medium to large capacity vehicles may be evacuated quickly. With safety precautions, egressing passengers are exposed to minimal hazards. Applicable to all quideway elevations. Compatible with many elderly and handicapped passengers. May be used by assisting personnel in routine evacuations.	Does not accommodate wheel-chair confined passengers. Requires more elaborate safety precautions than walkways.

TABLE 5-3 (Continued)

RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Egress to ground using inflatable slide	Medium capacity vehicles may be evacuated quickly. Applicable to suspended and beam-straddling monorail technologies.	Passengers using slide may suffer injuries when reaching the ground. Marginal accommodation of elderly and handicapped passen-gers. May not be suitable for guideway elevations above 30 feet. Slide may be susceptible to vandalism (cuts) Instructions on use techniques are desirable Probably would not be used during routine evacuations.
Egress to ground using rigid ladders or stairs	Medium capacity vehicles may be evacuated quickly. Applicable to suspended and beam-straddling monorail technologies. May be used by assisting personnel in routine evacuations.	Technology exists but has not been applied to the AGT evacuation problem Does not accommodate passengers in wheelchairs. Only suitable for relatively low elevations (under about 12 feet) Instructions on safe use are desirable.

TABLE 5-3 (Continued)

RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Assisted Evacuation or Rescue		
Move vehicle to station under manual control	Keeps passengers in the safety of the vehicle Compatible with elderly and handicapped passengers. Passengers disembark at a station.	Some vehicle malfunctions may not allow use of manual control
Move vehicle to station by towing or pushing with another vehicle	Keeps passengers in the safety of the vehicle Compatible with elderly and handicapped passengers. Passengers disembark at a station	Some vehicle malfunctions may not allow vehicle to be towed.
Transfer passengers to a normal vehicle	Keeps passengers off the guideway. Passengers disembark at a station.	Some situations may not permit approach by another vehicle. May not be fully compatible with all elderly and handicapped passengers.

TABLE 5-3 (Continued)

RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Transfer passengers to the ground using a truck-mounted articulated boom	Great flexibility in reaching elevated vehicles Safe and dependable Adequate accommodation of elderly and handicapped passengers	Evacuation of large vehicles may take considerable time. Requires road access or firm ground.
Transfer passengers to the ground using a truck-mounted platform lift	Safe and dependable Good accommodation of elderly and handicapped passengers.	Not as flexible as articulated boom Requires road access or firm ground.

TABLE 5-4

NOT RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Self-Evacuation or Rescue		
Egress from vehicle to ground level using synthetic cloth chutes	Simple concept which offers good dependability.	Would provide relatively low evacuation rates. Concept has difficulty handling variations in elevation

TABLE 5-4 (Continued)

NOT RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Egress from vehicle to ground level using synthetic cloth chutes (Continued)		May elicit claustrophibic reactions in some passengers. Requires considerable instruction on proper technique for use. Marginally compatible with young, elderly and handicapped or obese passengers.
Egress from vehicle to ground level using a rope or wire ladder	Simple concept which offers good dependability Not sensitive to elevation above ground.	Instability of ladder makes use difficult and compromises safety Would provide relatively low evacuation rates Not compatible with elderly or handicapped passengers.
Egress from vehicle to ground using a knotted rope.	Inexpensive	Usable by only the most athletic passengers. Incompatible with elderly passengers. Unsafe, particularly from higher elevations. Would provide low evacuation rates

TABLE 5-4 (Continued)

NOT RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Egress from vehicle to ground level using a lowering floor	Rapid evacuation of entire vehicle. Compatible with elderly and handicapped passengers. Applicable to suspended vehicles.	May not be capable of safe operation over uneven ground levels Many unresolved technical details No cost information, but likely to be expensive.
Assisted Evacuation or Rescue		
Transfer passengers to specialized rescue vehicle	Unaffected by terrain under guideway. Limited compatibility with elderly and handicapped passengers.	Relatively slow response and evacuation rate. Unknown costs; expected to be high.
Transfer passengers to the ground using truck-mouted turret ladder	Good versatility to guideway elevations	Incompatible with many elderly or handicapped passengers. More difficult for passengers to use than platform lift or articulated boom.
Transfer passengers to the ground using portable ladders	Can be used in relatively inaccessible locations.	Length of ladder limited Requires solid support for ladder. Incompatible with many elderly and handicapped passengers.

TABLE 5-4 (Continued)

NOT RECOMMENDED EVACUATION AND RESCUE METHODS AND PROCEDURES

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Transfer passengers to the ground using truck-mounted portable stairs	Good safety and convenience. Relatively rapid evacuation rates.	Very inflexible with respect to height and lateral alignment. Not compatible with some elderly and handicapped passengers.
Transfer passengers to the ground using boatswain's chair	Good flexibility to terrain and elevation variations.	Very slow evacuation rates Labor intensive Not likely to be popular with passengers Ideal topic for news media sensationalism.
Remove passengers from vehicle using helicopter	Capable of use in areas totally inaccessible from the ground	Slow response time and low evacuation rates. High cost of helicopter Likely to frighten passengers Ideal topic for press sensationalism.

APPENDIX A

GLOSSARY

Automated Guideway Transit (AGT)

The current dominant means of public transportation are the transit bus and rapid rail systems. The development of computer and automation technology, particularly in the last decade, has led to the formulation of new public transportation concepts which use vehicles capable of automatic operation on separate roadways or guideways. Such systems are generally called Automated Guideway Transit (AGT).

Group Rapid Transit (GRT)

Group Rapid Transit Systems (GRT) utilize automated vehicles on more extensive networks than SLT systems. They tend to have shorter headways than SLT systems, use switching and may or may not employ off-line stations. Vehicles with a capacity of 10 to 70 passengers, operating singly or in trains with headways of 3 to 90 seconds, characterize such systems. State-of-the-Art GRT Systems (e.g., Airtrans, Morgantown) operate at headways 15 seconds or greater.

Personal Rapid Transit (PRT)

Personal Rapid Transit Systems (PRT) are usually system concepts characterized by small vehicles (2-9 passengers) carrying parties travelling together by choice. Such systems generally feature off-line stations and an extensive guideway network. Most proposed systems call for vehicles to be operated at headways of three seconds or less.

Shuttle-Loop Transit (SLT)

Shuttle-Loop Transit Systems (SLT) are the simplest type of Automated Guideway Transit Systems and are characterized by vehicles moving along short linear segments or loops with few or no switches. The vehicles may operate singly or trained. Bypasses may be permitted in the shuttle to permit intermediate stations.

APPENDIX B

ABBREVIATIONS/ACRONYMS

AGT	Automated Guideway Transit
APTA	American Public Transit Association
BART	San Francisco Bay Area Rapid Transit
CCS	Central Control Supervisor
CCTV	Closed Circuit Television
CRT	Cathode Ray Tube
DPM	Downtown People Mover
E&H	Elderly and Handicapped
GRT	Group Rapid Transit
MPM	Morgantown People Mover
MUNI	San Francisco Municipal Railroad
NYCTA	New York City Transit Authority
PATCO	Port Authority Transit Corporation, New Jersey
PATH	Port Authority of New York and New Jersey Trans Hudson
PRT	Personal Rapid Transit
Sea Tac	Seattle-Tacoma Airport Satellite Transit System
SLT	Shuttle-Loop Transit
TTC	Toronto Transit Commission
WMATA	Washington Metropolitan Area Transit Authority

APPENDIX C

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