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GUIDELINES FOR THE DESIGN AND EVALUATION OF HUMAN FACTORS ASPECTS OF AUTOMATED GUIDEWAY TRANSIT SYSTEMS

Anna M. Wichansky
E. Donald Sussman

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
Transportation Systems Center
Cambridge MA 02142

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FINAL REPORT

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16. Abstract

This report is a summary of human factors considerations for the planning, design, construction, and implementation of Automated Guideway Transit (AGT) Systems including Downtown People Mover (DPM) systems. Design concepts such as passenger safety, security, comfort, and convenience are discussed in relation to various AGT subsystems, including the vehicle, the guideway, the command and control center, and the terminal. Potential interactions between AGT systems and the surrounding community are considered. The guidelines also address such issues as accommodation of elderly and handicapped passengers, design to facilitate emergency evacuation, determination of acceptable levels of ride quality, and the optimal assignment of command and control tasks to humans and machines. The appendix summarizes the major guidelines presented in the text in a convenient checklist format; it is intended for use in the planning and evaluation of existing and proposed AGT systems.

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Preface

This document has been compiled to provide guidance in the planning, design, fabrication, and evaluation of human factors aspects of automated guideway urban transit systems. It is based on the present state of knowledge in the areas covered and as such it draws on: 1) past and ongoing research, 2) applicable national and international codes and standards, and 3) current practice in transportation construction, law enforcement, fire safety, and military operations.

The document has been organized to provide human factors information on automated guideway transit systems in several different formats, which may vary in usefulness depending upon the purpose of the reader. The bulk of this report provides guidelines for "good practice" where available and reviews controversial areas where there is currently a lack of agreement. The bibliography provides references for the reader who needs more detailed information than that provided in the guide. The appendix is a checklist which is intended to allow individuals evaluating existing or proposed systems to identify potential problem areas.

The present set of guidelines is based upon and supersedes two previous internal documents which were intended to provide human factors guidelines for the design and evaluation of Personal Rapid Transit (PRT) Systems. While these prior efforts were restricted to applications in PRT Systems, the present document is intended to cover systems ranging from PRT's through GRT (Group Rapid Transit) Systems. The intended first application of the present document will be in the implementation of the "Downtown People Mover" Systems program which has recently been initiated by UMTA.

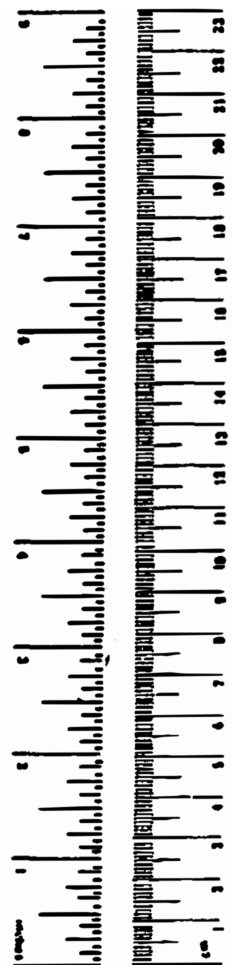
The authors gratefully acknowledge the contribution of John P. Jankovich (DTS-322) as the senior author of two earlier versions of this document. The contribution of John Marino (UTD-60) in initiating this series of documents and providing suggestions and review of its content is greatly appreciated. We also wish to thank Frank Tung, Chief of the Urban Systems Division (DTS-72), for programmatic support during the early phases of this work; George Anaganostopoulous (DTS-16) for his technical suggestions and encouragement during the early phases of this work; and Ronald Kangas (DTS-70) and H.P. Bishop, Chief of the Human Factors Branch (DTS-532), for their guidance and review of the current document.

Finally, we would like to acknowledge the technical, financial, and programmatic support provided by UMTA's New System and Automation Division. In particular, we wish to thank Charles Broxmeyer, Division Chief, and Duncan MacKinnon for their efforts during the early phases of this work. Special thanks are also extended to Steven Barsony, Director of UMTA's Office of AGT Applications, wich provided programmatic and financial support during the final phase of this effort.

METRIC CONVERSION FACTORS

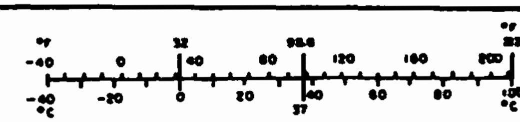
Approximate Conversions to Metric Measures

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



Approximate Conversions from Metric Measures

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



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1. INTRODUCTION

Several advanced technology, Automated Guideway Transit (AGT) system concepts are currently being studied under the sponsorship of the Urban Mass Transportation Administration. The objective of an AGT system is to provide convenient, fast, safe, and comfortable transportation for a large number of people in an urban environment. The size of AGT vehicles may range from small, "personal" size vehicles used to carry passengers between selected points without transfers as automobiles or taxis do, to larger, bus-size vehicles which may be used in shuttle- or loop-type operations. The vehicle is controlled, routed, and driven automatically to the selected destination via an automated guideway.

At the time of this report, a large scale program to implement automated guideway transit in urban environments has been initiated. The systems to be constructed under the "Downtown People Mover" Program are intended to be the first application of this guideline.

To be successful, a public transportation system must move people between points of their choice safely, comfortably, conveniently, and economically. Success, therefore, is dependent upon the careful monitoring of human factors aspects of the system design as well as more traditional areas such as structure, power, propulsion, command, and control. The design should insure that: 1) the passenger or public areas of the system provide an acceptable level of service; 2) the operators' stations provide an efficient work environment and facilitate the required man-machine interactions; and 3) the maintenance facilities and features of the equipment provide for thorough, rapid, and efficient maintenance which does not expose the crew to hazardous conditions.

In addition to its effect on passengers and employees, the system will have an impact on the surrounding community. The sources of this impact may vary, but they are usually attributable to three general operations: system construction, revenue service, and maintenance. The form of the impact can vary, but usually among the most significant environmental problem areas are the acoustic noise produced and the temporary and permanent disruptions of pedestrian and vehicular traffic created by systems construction requirements.

The objective of this report is to summarize the most important human factors and environmental considerations which should be incorporated into the design of the AGT system. Operational values such as passenger and crew safety, security, comfort, and convenience must be considered with respect to the planning, design, construction, operation, and maintenance of the system as a whole. However, in terms of initial conceptualization, planning, and design, it may be more meaningful to consider these values as aspects of specific subsystems, such as the vehicle, the guideway, the command and control center, the terminal, and the community. Each subsystem in turn consists of various components, which must be designed to interact such that total system functioning is enhanced.

The design characteristics of these subsystems and components which make important contributions to total systems effectiveness will therefore be discussed in detail. The appendix contains a checklist which could be used in the evaluation of new and existing systems. The major considerations included in the report are provided here in a condensed format.

This report was prepared as part of TSC's support to UMTA's Office of Technology Development and Deployment. In application, it is intended to serve as a general guideline to planners and developers who are considering construction of an automated guideway system in an urban area.

2. THE VEHICLE

The AGT vehicle may be considered as a subsystem of the total AGT system The vehicle subsystem in turn may be considered as a composite of various components, each of which must be designed to function effectively with the others so that high levels of passenger safety, security, and accessibility may be maintained. The design of components must also permit operation and maintenance functions to be carried out safely and efficiently. The major components of the AGT vehicle subsystem which require consideration of these concepts in design will presently be discussed in detail.

2.1 General Exterior and Interior Design

The exterior and interior surfaces of the AGT vehicle must be crashworthy, vandal-proof, easily maintained, and capable of minimizing the incidence and consequences of fire. Materials used in vehicle construction and the design layout of the car must therefore be considered in terms of the relevant human factors necessary to meet the above requirements.

Exterior surfaces should be made of corrosion-resistant materials which can endure heavy-duty cleaning processes and still remain handsome in appearance. The vehicle exterior design should not include surface projections and recesses which might interfere with thorough cleaning, or injure pedestrians or other vehicles in the event of a collision. Exterior surfaces should be cleaned and serviced regularly in an automated washrack cleaning station.

Vehicle design should avoid recesses or pockets in and under the motors and transmission, where oil, oil-soaked dirt, combustible road bed materials, or other refuse may accumulate. Electric conduits and lubricating and hydraulic oil lines should be designed so that they do not collect road sediment. The areas around them should be readily cleanable. Fire hazards in the hydraulic, brake, and tire systems should be minimized. Combustible fluid lines must be routed away from hot surfaces and shielded from heat. In order to insure fire safety, careful consideration should be given to the selection of all materials used in construction of the vehicle interior and exterior, including seat cushions, frames and upholstery; thermal, acoustical, and electrical insulation; wall and ceiling panels; and carpeting or other flooring materials. Materials which emit toxic gases when heated or burned should also be avoided.*

Interior walls and other surfaces should be made of smooth, non-absorbent, washable, vandal-resistant materials consistent with fire and crashworthiness considerations, such as formica or fiberglass. These materials are also easy to clean and maintain.

Vehicle interiors should be regularly cleaned and serviced, since a well-cared-for appearance tends to increase the value of the vehicle in the eyes of the community and discourage vandalism. Cleaning stations should be designed and located so that the vehicles may be cycled through them on a periodic basis for both exterior and interior cleaning. The cleaning process should incorporate inspection procedures designed to detect problem areas in the vehicle and to determine the need for increased frequency of cleaning due to special environmental or meteorological conditions and vandalism.

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*The Urban Mass Transportation Administration of the U.S. Department of Transportation is currently sponsoring and performing research which is expected to provide detailed guidance with regard to fire safety design and material considerations for urban transit vehicles.

Interior surfaces must be securely mounted so that they cannot loosen or become displaced in ordinary service or by vandals. If partitions are installed, they should be permanently bolted, riveted, or welded in place. Partitions must be installed such that they provide for dynamically balanced loading of the vehicle.

In general, an effort should be made to minimize the effects of "the second collision," which occurs when passengers are thrown about the interior of the vehicle upon impact. All vehicle surfaces, edges, trim, etc., should be designed so that a person cannot snag his clothing or cut himself. All unnecessary protrusions should be eliminated to prevent passengers from bumping into them under normal or emergency conditions. Sharp corners and edges should be avoided. Padded interiors provide some extra protection for passengers in the event of a collision; however, they seem to encourage vandalism and therefore may not be practical. The use of vandal-resistant materials with controlled crush characteristics should be considered in applications where vandalism is anticipated. Use of materials which will shatter or break and leave sharp edges upon impact should also be avoided.

Thoughtful consideration of vehicle layout is very important, since a well designed interior floor plan will facilitate passenger movement and minimize dwell times, increase the accessibility of the system to the general public, and decrease the incidence of pocket picking and other crimes. Vehicle layout should facilitate rapid entrance and exit, and movements to and from seats. For this reason fixed supports for standing passengers should not be placed near the exits or entrances. However, grab handles should be available near the doors for the convenience of exiting passengers. Overhead clearance must be sufficient to prevent people from bumping their heads. Clearance of at least 84 in. (2.13 m) is recommended where consistent with other design considerations.

In order to maximize safety and comfort, it is recommended that special consideration be given to the personal space requirements of both standing and seated passengers. Under normal operating conditions, individuals require approximately 3.5 sq ft (0.33 sq m) per person to maintain both physical and psychological comfort for short periods of time and to optimize passenger flow rates.*

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*This space guideline does not invalidate the use of more stringent sizing requirements (e.g., 1.5 sq ft/person) in

(Continued)

These requirements conform to Fruin's (1971) description of the "no-touch zone". Under crush conditions, it is recommended that 2.5 sq ft (0.22 sq m) of space be allowed per passenger, conforming to Fruin's "touch zone" and considered suitable in elevator-type situations for extremely short periods of time. At no time should loadings or design factors encourage space reduction below 2 sq ft (0.19 sq m) per person. The above space requirements are considered the maximum practical loadings achievable in revenue service and consistent with long-term passenger acceptance.

The special space allocation needs of the handicapped may be met by advantageous positioning of fixtures and supports within the vehicle interior. Enough clear space should be provided immediately inside doors for wheelchairs to fully enter before turning is required; a 60 x 60 in. (1.54 sq m) space is desirable. Wheelchairs also require 32 x 54 in. (0.82 x 1.38 m) rest areas which are accessible through aisles at least 32 in. (82 cm) wide, and which do not block entrance and exit by other passengers. Vehicles should be longitudinally and transversely symmetric

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(Continued)
vehicle design to achieve a high level of structural integrity.

about each door to aid the blind. General vehicle design features should comply with ASA A117, 1-1961 (American Standards Association, 1961) in order to insure accessibility to the handicapped.

Floors should be designed and constructed of materials which prevent the spread of fire. One method is to coat the floors with fire retardant and surface them on both sides with sheet metal. Non-slip surfaces (e.g., rubber matting) are suggested for use inside the vehicles. Floors should be kept free of paper, water, cigarette butts, and other debris, which may be especially hazardous to passengers using crutches or other walking aids. Also, floor surfaces should not become slippery when wet. Thick carpeting should not be used as it makes the movement of wheelchair-bound patrons difficult and is difficult to clean.

2.2 Entrances and Exits

No more than two entrances are recommended for vehicles carrying up to 16 passengers. Each entrance should be provided with horizontally closing doors, and each door should be equipped with force activated door guards which release when a person or object is blocking normal operation.* For center opening doors, the reopening device should be designed so that the obstruction of either panel when closing will cause the reopening device to function. A manually operated switch may also be provided in the vehicle to cause the doors to stop or stop and reopen.

The accessibility of entrances and exits to the handicapped requires that certain design specifications be met to insure the safety and well-being of these passengers. In order to accommodate a standard wheelchair or a person using a walking aid (crutches, stick, brace, artificial limb, etc.), entrances and exits must be at least 32 in. (82 cm) wide and free of steps. Wider doors will make it easier for all passengers to enter and exit the vehicle. The resultant decrease in congestion and improved traffic flow may also reduce opportunities for pickpockets and molesters as well as altercations between passengers.

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*ANSI A17.1-11971 (American National Standards Institute, 1971) recommends the kinetic energy of the door, computed with the average closing speed and the sum of the door mass and all rigidly connected parts, as a criterion for reopening. Automatic elevator doors are designed, for example, to open when this energy exceeds 2.5 ft-lb. Some elevator doors are calibrated according to a resistant force, and will not close when it exceeds 30 lb (13.7 kg).

Doors which always stop in the same places along the platform and are unobstructed by stanchions below a height of 53 in. (1.35 m) will increase vehicle accessibility to the handicapped. An automatic vehicle stopping system which provides reliable and accurate door positioning is also highly recommended, especially in systems serving handicapped and elderly passengers.

The vehicle floor should be level with the platform floor at doors to aid wheelchair passengers. Change in level should not exceed 2 in. (5.1 cm) in any case, and should be clearly marked by a contrast in color, texture, resiliency, and/or lighting. It is desirable to make the gap between platform and vehicle floors as small as possible to prevent passengers' belongings and parts of the body from getting caught between these two surfaces; at most, therefore, this gap should not exceed 2 in. (5.1 cm). In most instances, a gap of less than 0.5 in. (1.3 cm) should be achievable.

Doors should remain open for at least 7 sec to allow for disabled passengers' movements. The Command and Control Center should receive a signal when a vehicle door is not securely closed, and the vehicle should not be permitted to leave the station until the door is secure. An audio-visual warning signal to be activated approximately 2 sec before doors are about to close is also suggested.

To make cleaning easier, glass panels in power-operated car doors must be substantially flush with the inside surface of the door panel. The rest of the door panel should also have a practically flush surface without recessed or raised moldings. The doors must be strong enough to protect vehicle occupants, and capable of withstanding a 250 lb (113 kg) force without deformation when passengers lean against them. Doors should not open accidentally even when frames become distorted in accidents. Occupants should be able to open doors with a simple motion of the hand and a force not exceeding 8 lb (3.75 kg), to get out quickly in an emergency or other situation accompanied by power failure.

All doors should be manually operable from inside as well as out to facilitate rescue efforts. The manual door activation mechanism might be covered with a frangible seal to eliminate the possibility of casual or inappropriate use. Manual door activation should be possible when the vehicle is stopped. Conversely, vehicle movements should be automatically prohibited unless all doors are closed, and the vehicle should come to an immediate stop whenever a door is opened. Suitable instructions for manually opening doors should be provided both inside and outside the vehicle.

Emergency doors should open outward or retract into the walls, and be accessible through aisles at least 32 in. (82 cm) wide. They should be at least 84 in. (2.13 m) high (or ceiling height in the case of vehicles less than 84 in. high), 32 in. (82 cm) wide, and devoid of thresholds. Doors should be operable by a single manual effort not exceeding 8 lb (3.75 kg) of pressure. Sliding doors work well for this purpose and seem to prevent panic. It is recommended that two emergency exits be provided in transverse (i.e., front and rear) locations on each AGT vehicle, in addition to the doors designed for ordinary use. Such positioning will facilitate emergency evacuation of passengers into a rescue vehicle, which can be pulled up in front of or behind the vehicle in distress. This arrangement is especially important in systems with elevated guideways.

2.3 Passenger Supports

Vertical stanchions may be located near seats and spaces reserved for the handicapped where they do not obstruct aisles or doors or cause congestion near entrances or exits. These poles provide support through a wide range of heights, and can be used by able-bodied and wheelchair passengers alike. Vertical stanchions are not, however, recommended for use in front of doors. In these positions, the poles obstruct general traffic flow and hinder the movements of handicapped passengers, who must often put their wheelchairs through several extra motions to maneuver around them. It must be also recognized that the location of any hand supports near doors may promote congregation of standing passengers, interfering with passenger flow.

Full-width seatback bars extending nc more than 1 in. (2.54 cm) toward the aisle from the edge of the seats to which they are attached are also recommended. Front seats require vertical stanchions or horizontal bars at the same height and position as the seatback bars. Horizontal or vertical handgrips with straight grasping surfaces at least 11 in. (28 cm) long should be provided near doors for passengers who have not been seated before the vehicle starts. Horizontal handgrips 30 to 40 in. (0.76 to 1.02 m) from the floor may be located immediately inside doors to aid wheelchair passengers or others who require some support for steadying their balance rather than standing. Grip circumference on all passenger supports should range between 3 and 5 in. (8 and 13 cm). At least 2 in. (5 cm) clearance should be provided between support grip areas and other surfaces in the vehicle interior. Padding of passenger supports may be desirable to cushion the impact of sudden decelerations.

2.4 Seats

Contoured bench-type seats are recommended for use in the AGT vehicle. Plush or deeply padded seats are quickly vandalized, may give off toxic gases from padding if set on fire, and provide little or no significant vibration attenuation. Seat frames should be constructed of metal or other fire-resistant material of similar strength; seat material should be fire-retardant.

Seat arms are desirable and may be especially helpful to the blind and other handicapped in seat positioning. One arm approximately 5 in. (13 cm) high (measured above the lowest point of the uncompressed seat surface), and extending 6 to 9 in. (15 to 23 cm) forward from the seat back, should be provided next to each single person seating space. In the case of seats oriented along the direction of travel, such arms may prevent passengers from being thrown from their seats during emergency stops.

It is recommended that seats near doors be reserved for the handicapped to completely eliminate standing and walking while the vehicle is in motion. Seats should be arranged to shorten walking distances and facilitate quick seating. Efficient use of space may be achieved by hinging longitudinal seats near the doors. These could be reserved for handicapped and/or elderly passengers with casts, braces, crutches, cardiac conditions, etc. All folding seats should be equipped with mechanical locks in both the folded and unfolded positions, which are strong enough to withstand collision impact loads. When folded up, these seats could provide 32 x 54 in. (0.82 x 1.38 m) rest areas for wheelchairs. Wheelchair rest areas should accommodate wheelchairs oriented perpendicular to the direction of travel.

If the system incorporates high deceleration rates (in excess of 0.3 g), then seating should be oriented along the direction of travel. It has been found that passengers retain their seats more easily over a wide range of acceleration/deceleration levels, if forward-facing seats are tilted backward by 5°, and seat covering materials with high coefficients of friction relative to clothing are incorporated into the design (Abernethy, et al., 1977).

Seats which all face in the same direction could reduce the incidence of pickpocketing, larceny, and exhibitionism. Seats should be suspended from the wall or built on pedestals to facilitate cleaning. It is recommended that no smoking be permitted on AGT vehicles. However, if smoking is to be permitted or if it is anticipated that passengers will smoke anyway, special smoking areas or vehicles should be designated, and readily cleanable, self-contained ash trays with covers should be supplied for each seat.

2.5 Passenger Restraints

In AGT vehicles where emergency deceleration do not exceed 0.5 g or where all seats are facing backward, restraint systems (e.g., seat belts, air bags) are not considered to be necessary for the safety of able-bodied passengers. The necessity of such systems for the handicapped and elderly, however, is an area of debate.

Abt Associates (1974) recommended maximum starting and braking accelerations of 0.1 g to optimize the accessibility of the Metropolitan Washington, DC, Public Transportation System to handicapped and elderly groups. With restraints, however, seated passengers can tolerate much higher levels of motion. Even relatively low levels of acceleration/deceleration and jerk may be sufficient to throw individuals out of their wheelchairs, or cause uncontrolled movement of these chairs. The safety of other passengers is also at stake in the event of vehicle collision or derailment, as wheelchairs and other walking aids may become flying projectiles if they are not tied down.

It should be noted that many handicapped individuals resent any special restraint requirements which might be placed upon them, since these make them feel "different." With short dwell times and no on-board personnel to assist them it might be difficult for handicapped persons (who tend to move slowly) to release any restraints and still get to exits before the vehicle departs. Furthermore, many of these individuals are convinced that they could remain stable in the AGT motion environment if appropriate passenger assists (stanchions, handrails, etc.) and non-skid floor surfaces were provided.

Based on Abt's (1974) recommendation, for systems with emergency deceleration levels exceeding 0.1 g, it is desirable that each AGT vehicle be equipped with at least one sliding bolt wheelchair restraint device recessed into the wall behind the wheelchair rest area, and one set of seat belts also retractable into the wall, located approximately 24 in. (61 cm) above the floor and 27 in. (69 cm) apart. The sliding bolt device should be designed to allow at least 6 in. (15 cm) of free space in each wheel dwell area in order to accommodate wheelchairs of various widths. These types of restraints must be fabricated so that they: 1) are easy to use by individuals with a wide range of physical disabilities; 2) are inexpensive and simple to install, and 3) do not obstruct traffic or create hazards for other passengers.

2.6 Windows

Damage to windows is a primary source of maintenance expense and passenger injury in existing transit systems (FM Transportation Systems, 1974). Careful consideration should therefore be given to window design.

Windows should be made of laminated safety plate glass, safety glass-tempered glass combinations, glass-plastic combinations or polycarbonate. Plastic components should be selected so as not to create fire hazards; acrylics should be avoided for this reason. Window panels should be installed and reinforced to provide adequate protection to occupants in case the glass breaks or becomes dislodged. The glass must be able to withstand damage under all the dynamic loads imposed upon it in revenue service. Protection against vandalism, such as thrown rocks, must be designed into the system. Window defogging is desirable and may be achieved by locating the air outlets of the heating-air conditioning system around the window frames, or by embedding heating wires in the glass.

For security reasons, windows should not open fully. Climate control appropriate to the season and geographic location should be provided through ventilation, heating, and air conditioning. The use of tinted glass could contribute to passenger comfort and reduce the air conditioning load in areas where cooling is a problem.

2.7 Temperature and Ventilation

Climate control appropriate to the season should be provided in AGT vehicles. Suitable temperatures must be maintained, especially when external conditions are hot and humid, to prevent passenger discomfort. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (1971) recommends effective temperature ranges of 69-73° F (20.6-22.8° C) for summer and 65-70° F (18.3-21.1° C) for winter, in order for 85% of the population to feel comfortable. However, as individuals are often dressed for the street when using mass transit, broader temperature ranges may be permitted; furthermore, energy conservation programs may make them mandatory. Therefore, in the winter season temperatures may range from 60-68 ° F (15.6-20.0° C) in the summer, temperatures from 75-85° (23.9-29.4° C) are permissible. In climates where heating and cooling are rarely needed and those with a low incidence of crime and vandalism, windows which partially open to provide ventilation may be considered.

Similarly, appropriate levels of ventilation should be maintained to prevent passenger irritation by a smoky, smelly, stuffy environment. Air outlets may be located around window frames, if windows are provided. If smoking is permitted, special smoking cars with ashtrays should be designated. Provisions for emergency ventilation should also be designed into the system. When the ventilation system fails, the vehicle interior must be vented to the outside.

Airflow within the passenger compartment must be distributed to protect the occupants and restrict the spread of fire. Air flow directly onto passengers should be avoided. Air flow seals should be required between the passenger compartment and the propulsion and control equipment of the vehicle. If any of the electrical or mechanical components require cooling or ventilation, completely separate ventilation systems should be furnished.

2.8 Electrical and Lighting Systems

Obviously, passengers should be protected from all electrical hazards. Adequate grounding must be provided for all wiring and electrical components, to protect against the effects of short circuits caused by mechanical failure of terminals or insulation due to vibration, corrosion, or other danger. Faraday shields should be used in vehicle design to prevent electrical currents from penetrating the vehicle interior. All electrical and mechanical systems should be resistant to water, solvents, and mechanical damage likely to be encountered in an automated or semi-automated washing process.

Vehicle flooring, side boards, doors, passenger compartment handles, and passenger supports should be insulated from electrical shock. The presence of high voltages in maintenance areas should be indicated by conspicuous signs. The control circuits should be designed so that control unit failure or misuse will keep the vehicle from starting or running if any of the doors is open. The vehicle should be designed so that passengers may be evacuated without bodily injury or electrical shock.

The vehicles should be equipped with electrical lights to provide 30 to 50 ft-cd of illumination at about 36 in. (91 cm) above the cab floor. This level of illumination will aid partially sighted individuals and deter crime. Light fixtures should be positioned at a minimum height of 84 in. (2.13 m) above the floor. Recessed fluorescent tubes are recommended, since these will discourage vandalism and resist accidental breakage. Light control switches are not required in the passenger compartment; if provided, they should be of the key-operated type or enclosed in a fixture with a locked cover.

Two or more sources of illumination should be provided in each vehicle. The lightest and darkest areas of the car may vary by a maximum brightness difference of 30%. Bright light sources should not be located within 60° of the passengers' normal line of sight, in order to avoid direct glare into the eyes. Diffuse lighting sources are recommended. Surface reflectance may vary between 40 to 60% on inside walls, 80 to 90% on the ceiling, 20 to 40% on the floor, and 25 to 45% on the seating. Desaturated colors (tints and pastels) should be used on all large surface areas. In case of a service power failure, emergency lighting of at least 0.2 ft-cd intensity should be provided in the vehicle.

2.9 Displays

It is recommended that all signs within the vehicle contrast well with the surroundings. Signs should be distinctive in design, legible, well illuminated, and situated at the appropriate height to be visible from every standing and seated position in the car. Schedules should be posted inside the vehicle and accompanied by taped audio station destination announcements played at regular intervals. Recorded announcements of stops should be presented before the car travels half the distance from the previous stop or 60 seconds prior to arrival at the next station (which ever is less).

Station information should be provided inside the vehicle by means of a changing visual display coupled with an audio announcement. Visual information displays should use raised letters no higher than 55 in. (1.4 m) from the floor to aid the blind. Bilingual or multilingual visual and auditory displays should be considered in geographic areas which warrant their use. All information should be clear, concise, and comprehensible to those passengers with below average reading or verbal comprehension.

Vehicle occupants must be adequately informed about what action to take in case a vehicle must be evacuated either on the guideway or at the nearest station. Passengers must also be given information about obtaining emergency aid. A combination visual-auditory display is strongly recommended under emergency conditions to accommodate passengers with impaired hearing or sight, as well as those with normal sensory capacities. An activated visual display, presented simultaneously with either voice announcement or a sound signal of alternating high and low pitched tones, could be employed. If a verbal warning technique is used, a short attention-getting audible signal or "Attention" statement should precede the announcement by about 0.5 sec, so that the listener will be prepared for the first word. If a non-verbal warning sound is used, the signal's energy should be concentrated at a frequency where the masking due to anticipated background noises is lowest.

Auditory signals should be at least 10 dB above the ambient noise level and functional even when only the emergency power supply is available. The illuminated visual display could incorporate verbal instructions directly printed on the signal light in order to reduce time and ambiguity in decision making. A flashing light capable of operating on the emergency power source could be used. A flash rate with an "on" duration of at least 0.5 sec should be used. Such a warning signal attracts attention and can be seen from a distance if its brightness level is about twice that of the immediate background. Warning lights should be hooded or located away from direct sunlight, which may hamper visibility.

2.10 Controls

It is anticipated that in-vehicle operating and control devices available to passengers might be limited to (1) a manual door opening switch, (2) an emergency stop switch (where the system includes such a function),* and (3) communication equipment to the control center. Door closing should be accomplished automatically, except when it becomes necessary to hold doors open longer than the pre-programmed period. All other controls are needed in case of emergency only.

All normal and emergency controls must be placed within easy reach of the passengers entering the vehicle. Handicapped individuals in wheelchairs should also be able to operate the controls if they are located no higher than 37.5 in. (95 cm) from the floor.

All equipment used by passengers must be of enclosed electric type construction. An emergency stop switch should be located in a conspicuous position within

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*While the inclusion of such a control on an AGT vehicle is controversial, the authors have found no evidence to contraindicate this provision. In fact, such a switch might be useful when the guideway is obstructed by debris which may injure passengers or harm the vehicle on impact.

easy access to all passengers. The emergency stop switch must be manually operable even when the vehicle is not powered. It should have a red actuating handle or button and must be spring-loaded so that it will remain in either position (run or stop) once deployed. In the run mode, it should be covered by a frangible or breakable partition or glass panel. Switching to the stop mode should cause an audible alarm to sound in the Command and Control Center.

The controls must be adequately illuminated. Possible distractions from windows, such as reflections at night and masking by direct sunlight in the daytime, should be minimized. Controls must be arranged to minimize the possibility that the occupant will activate the wrong control accidentally. Instructional signs, if needed, should be clear, concise, and straightforward, and provide maximum legibility for the expected viewing distance.

2.11 Other Vehicle Equipment

2.11.1 Passenger Overload Device. AGT vehicles may be equipped with an overload device which prevents operation of the car when an established proportion of permissible passenger load is exceeded. Audio-visual signals should be provided to indicate to the passengers the reason the vehicle failed to start. The magnitude of permitted overloading should be determined by the safe maneuverability, braking characteristics, and structural strength of the vehicle. Injury to passengers and damage to an overloaded vehicle in a collision should also be studied.

2.11.2 Capacity and Data Plate. Each vehicle should be provided with a capacity and data plate stating the permissible load of the car. Additional information such as weight of the car and the manufacturer's name and address might also be included. The plate should be made of a durable material and fastened permanently in a conspicuous position inside the car. Letters and figures should be at least 0.25 in. (6.4 mm) high, with one stroke width space between characters and six stroke widths between words.

2.11.3 Fire Detection and Extinguishing Systems. The fire detection system should relay information about vehicle fires directly to the Command and Control Center. The distinction between overheat conditions and actual fires should be made obvious. Command and Control response should also differ appropriately: overheated vehicles could be diverted to the nearest station, while fire catastrophes may call for an emergency stop and evacuation of the vehicle.

Fire detection units should be able to withstand the adverse environment to which they will be exposed during system operation; this includes extremes in temperature, vibration, inertia, corrosion, humidity, and exposure to oil, water, and cleaning fluids. The detectors must reset automatically and be capable of warning signal deactivation when the overheat condition ceases to exist. The fire detection system should include a test operating mode so that its integrity may be tested periodically.

Fire extinguishing systems must be designed to complement the fire prevention and evacuation technology designed into the system. Hand-held extinguishers might be adequate for systems which could be evacuated rapidly, while more elaborate, automatic fire extinguishing systems might be necessary in other cases.

2.11.4 Vehicle Obstruction Sensor. A simple electro-mechanical vehicle obstruction sensor should be considered for installation on the AGT vehicle. The function of this sensor would be to stop the vehicle upon impact with any object which might cause damage to the vehicle or injury to the passengers.

2.12 Special Security Provisions

It is recommended that consideration be given to equipping all vehicles with some type of special security monitoring facilities. Video surveillance cameras which can be monitored by Command and Control center personnel should be considered. The cost of such visual surveillance facilities, however, may be prohibitive for system-wide use and therefore installation might be limited to critical areas.

Passengers might also be provided with emergency buttons to signal the Command and Control Center. Passenger microphones, two-way radios, and a centrally controlled public address system could be used in conjunction with or instead of video surveillance in the vehicle. K-9 squads might be employed to police high crime areas, especially at night.

2.13 Vehicle Ride Environment

2.13.1 Passenger Motion Environment. The vibration and acceleration levels normally experienced while riding the AGT vehicle are aspects of the vehicular environment which significantly affect passenger safety and comfort. While exposure to a ride of constant velocity has no effect upon either handicapped or able-bodied passengers, unexpected and irregular longitudinal accelerations and decelerations can disturb passengers, cause them to lose their balance, and cause collisions between passengers and parts of the vehicle interior which are not normally considered to be travel barriers. Extreme noise and ride motion may also interfere with passenger activities such as talking, reading, etc., which may play a role in the acceptability of the system to the public.

Passenger discomfort due to irregular sustained longitudinal acceleration and deceleration resulting in a change in vehicle velocity may be minimized through the use of jerk and acceleration control circuits built into the vehicle. Such circuits are particularly important where velocity is a function of speed zones.

For systems which are intended to accommodate standing passengers, sustained service accelerations and decelerations resulting in speed changes should be limited to 0.15 g along the direction of travel (Hirshfeld, 1932). In studies of emergency braking conditions currently in progress,* the deceleration levels at which passengers were dislodged from their seats were systematically measured for various seat configurations. The highest decelerations consistent with the passengers remaining securely in their seats were measured using forward-facing, fabric-covered contoured seats, tilted back 12° from the vertical and equipped with a simple footrest. Under these conditions, 50% of the subjects remained in their seats at decelerations of 0.46 g. For passengers in laterally oriented, fabric-covered, contoured seats equipped with armrests, the level at which 50% of the passengers remained securely in their seats was 0.37 g. Closed loop emergency braking systems should be used for maximum passenger safety.

Jerk (rate of change of acceleration) limitations are often cited; for instance, Abt Associates (1974) recommended a limit of 1.5 mi/hr/sec^2 (0.68 m/sec^3)

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*Based upon unpublished results of recent experiments conducted by Dunlap and Associates under Contract No. DOT-TSC-1314 for Task 5, "Emergency deceleration and jerk."

for the Washington Metro System. However, a recent study has shown that jerk does not play any role in affecting passenger's seat retention capabilities during emergency stops.* Jerk may nevertheless be important in influencing passenger comfort. Therefore, jerk limits should be used as guidelines rather than as boundaries or limiting values.

2.13.1.1 Prediction and Assessment of Ride Comfort

The control of ride vibration is critical to the acceptance of new transit vehicles. At the present time the International Organization for Standardization (ISO) "Guide for the Evaluation of Human Exposure to Whole Body Vibration" (1974) (ISO Document 2631) is the most widely accepted guide for the evaluation of transit system vibration.

The objective of ISO 2631 is to provide the system designer or system evaluator with provisional guidelines on acceptable levels of vibrations to which humans may be exposed. Acceptability is defined in terms of

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*Based upon unpublished results of recent experiments conducted by Dunlap and Associates under Contract No. DOT-TSC-1314 for Task 5, "Emergency deceleration and jerk."

safety, work efficiency, and comfort. Applicability of the standard is limited to vibration transmitted to the body as a whole through a supporting surface when in the standing or seated positions. There are four physical parameters which characterize human vibration exposure: (1) direction, (2) frequency, (3) intensity, and (4) duration.

<u>Direction</u>: The document uses a coordinate system which is fixed with respect to the human body rather than based on external references. Therefore, vibration along the x (front-to-back), y (side-to-side), and z (head-to-foot) axes must be evaluated relative to the passenger's position rather than the vehicle's axes. vehicle's axes.

<u>Frequency</u>: The range of application is limited to those frequencies which have primarily mechanical effects on the human body. Frequencies in the auditory range are excluded. Therefore the basic frequency range covered in the document extends from 1.0 through 80.0 Hz.*

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*Geoffrey Allen of the Royal Aircraft Establishment (Farnsborough, U.K.) has developed an addendum to ISO 2631 which extends the frequency range covered in the document below 1.0 Hz. This addendum has been favorably reviewed by the technical experts of the ISO working group concerned with exposure to whole body vibration and will probably be incorporated into Document 2631. If significant levels of vibration below 1.0 Hz are expected on AGT vehicles, this addendum may provide useful guidance.

Intensity: The document describes the conditions under which differing intensities of vibration are acceptable. Three conditions are discussed:

a. The exposure limit. This is the highest intensity of vibration to which humans may be safely exposed.

b. The fatigue decreased proficiency boundary. This indicates the range of vibration amplitude and duration combinations which can be expected to result in a decrease in work performance.

c. The reduced comfort boundary. This boundary was developed with the intention of defining minimum specifications for human comfort. Activities such as reading, writing, or eating are considered to be possible at the vibration levels encompassed by this boundary. The values of the three boundaries can be computed from one another. The reduced comfort boundary is derived by reducing the fatigue decreased boundary by 10 dB or dividing by a factor of 3.15.

Duration: Duration is defined as a time period for which the human body is exposed to vibration. Exposure duration, however, is considered in terms of a daily "dose"; therefore, for a commuter who makes two daily 30 min trips, the 1-hour criterion would be appropriate.

Guidance for evaluation of multi-axis vibration is provided if vibrations occur in more than one direction simultaneously. The current standard states that the corresponding limits apply separately to each vectorial component in the three linear axes. However, a pending amendment to ISO 2631 (Griffin, 1977) recommends the use of the ISO weighting formula as the preferred method of evaluation for broad band vibrations such as those encountered in transit vehicles. The amendment provides the following multi-axis weighting formula which sums the weighted linear accelerations to achieve an effective level of acceleration:

$$a_{effective} = \sqrt{(1.4a_x)^2 + (1.4a_y)^2 + a_z^2}$$

The amendment states that the "effective level may then be compared with the effective levels of other motions and with the recommended values for z-axis vibration given in Table 1 and Figure 2" of the document 2631.

Using this formula requires the weighting of the vibration through use of the frequency weighting network provided in the guide, or measurement of the vibration in each of the 1/3 octave bands for all three degrees of freedom and the subsequent weighting of each 1/3 frequency octave band as per the guide. In actual use the electronic weighting network is far less cumbersome.

As an example, a commuting trip consisting of two daily exposures could be evaluated by first summing the individual trip lengths of a typical user. Therefore, for a commuting trip, each leg of which lasts 10 minutes, the value for the 25 minute reduced comfort boundary should be used as the standard of evaluation of the weighted vibration values. For the z-axis, this value is 0.059g.*

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*The z-axis ISO reduced comfort limit may be derived from the fatigue-decreased proficiency criterion in Table 1 of the ISO guide for the 25 minute period in the 1-80 Hz frequency range as follows. The entry under the 25 minute column of Table 1 for a in the 4.0 - 8.0 Hz range is first divided by 3.15 to find the reduced comfort boundary in rms m/sec^2. The value may be converted to rms g by dividing by 9.697, resulting in an effective acceleration value of 0.059g.

Criteria for rotation about the x-axis (roll), about the y-axis (pitch), and about the z-axis (yaw) are not provided in the ISO guide, but an evaluation procedure has recently been developed by Dunlap and Associates and the University of Virginia under contract to DOT. These contractors have developed models for the evaluation of comfort characteristics for intercity passenger trains, commuter buses, and aircraft, and are in the process of developing models for AGT systems. Provisional guidance for the necessary restriction of rotational motion for comfort in rubber-tired, concrete guideway AGT vehicles may be obtained from the models and techniques developed for commuter buses.

In the study, Pepler, et al. (1977) investigated the ride quality of bus operations on both straight and curving roads. The results of testing on the straight road revealed that the ride quality factor most profoundly related to passenger comfort was roll rate, w_r. In the studies on a curving road, the variables most profoundly related to comfort were sustained and vibratory accelerations along the y-axis.

The Dunlap work discriminates between passenger comfort and the percentages of passengers which find the ride acceptable. In practice the design selects the percentage of passengers which must be satisfied, and from this uses the techniques provided to derive a mean comfort value. This value is then used in the appropriate vehicle equation to derive criteria for vibration, acoustic noise, and other physical factors related to passenger comfort.

In practice it might be required to satisfy 90% of the passengers. This would require an average comfort response of 3.0 or "somewhat comfortable" on a seven point scale, where 1.0 represents a "very comfortable" ride and 7.0 represents a "very uncomfortable" ride. Using the formula for bus comfort ($C' = 0.87 + 1.05\ w_r$), a maximum roll rate of approximately 2°/sec is obtained. It is anticipated that this 2°/sec roll rate will assure acceptance of the ride by 90% of potential passengers when the other physical comfort variables are close to those encountered in the original study. Therefore, the pitch rate should be limited to approximately 2.6°/sec, the yaw rate to 2.7°/sec, and acoustic noise to 78.4 db(A). Linear acceleration should be limited to 0.059 rms g along the x-axis, 0.103 rms g along the y-axis, and 0.099 rms g along the z-axis. It should be noted that this technique provides a slightly more liberal ride environment than would strictly comply with the ISO (1974) guide; however, for short commuter trips, this is probably appropriate.*

2.13.1.2 Collision Impact Protection

The possibility that AGT vehicles will be involved in collisions with stationary objects on the tracks or with another vehicle must also be anticipated. Occupants must be adequately protected in either case by a system design capable of reducing the impact decelerations to survivable levels.

For survivability, decelerations should be limited to 35 g with durations up to 0.1 sec for seated, properly restrained, and physically fit persons facing the direction of motion. Deficiencies in the restraint system, increased duration of acceleration, or variations in the physical condition of the passengers can significantly reduce the tolerance level and increase the probability of serious injury.

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*These methods of specification do not apply to systems with significant levels of narrow band (one-third to one-half octave) vibration, such as might be produced by unbalanced rotating equipment components. In such cases, ISO 2631 (1974) provides detailed guidance for ride quality specification.

It is therefore suggested that a more conservative approach be taken. Impact acceleration levels in AGT systems should be limited, where possible, to a maximum value of 20 g with a maximum duration of 0.05 sec. Such limits seem to be technically feasible by (a) utilizing the 3 sec headway between vehicles to apply full braking of 0.35 to 0.40 g prior to impact, and (b) designing the vehicle structure to absorb energy by mechanical deformation in order to provide a controlled deceleration displacement during impact. Interior seats and fixtures must be able to withstand accelerative forces in excess of 40 g. Physical parameters of various collision conditions should be studied and adequately documented in reference to known physiological and injury tolerance data.

The use of passenger restraint systems would greatly reduce the injury potential of collision situations. However, considering the anticipated short duration of the ride and the number of standees, it is difficult to recommend any specific type of individual restraint system which would be practical for AGT vehicles. Some adaptation of a passive restraint system (e.g., air bags) might be considered for vehicles traveling at very high speeds.

2.13.2 Passenger Noise Environment. High levels of noise within the vehicle can markedly decrease subjective passenger comfort and the acceptability of a system (Jacobson, 1977). Noise was found to be one of two environmental factors accounting for the greatest amount of variance in passengers' comfort ratings on Amtrak trains (Jacobson, et al., 1977). Thus, even though average ride duration on AGT systems is anticipated to be fairly short, the importance of this factor in affecting passenger comfort necessitates careful consideration of noise limits appropriate for this type of system

In general, it is desirable on transit vehicles to have noise levels which are low enough to permit normal conversation between passengers seated or standing next to each other at a distance of 1-2 ft. The SIL (Speech Interference Level) criterion for this type of interaction suggests a noise limit of 60-65 dB (Woodson and Conover, 1970), which is the average of the noise levels present in the 300-600, 600-1200, and 1200 - 2400 Hz octave bands most relevant to speech interference. Carstens and Kresge (1965) similarly recommend an average noise comfort limit of 65 dB in these three octave bands, and an over-all SPL limit of 70 dB. These values seem feasible as noise limits for AGT systems as well, and are therefore recommended.

2.14 Maintenance Functions

In order to minimize both operating costs and passenger inconvenience, the AGT vehicle must be designed for maintainability. Any AGT system will have a large number of individual vehicles, all requiring periodic inspection, cleaning and service, and occasional repair. Therefore, the equipment must be designed and constructed to facilitate future maintenance requirements.

Maintenance methods and equipment must be developed to suit the technicians who will have to perform these operations. In systems with large numbers of vehicles, maintenance requires assembly line-type operations. However, with good human factors engineering design, conventional assembly line boredom can be avoided.

The objective of this discussion is to provide appropriate guidelines for the design of an acceptable maintenance environment. In this sense, the term "environment" is employed to cover not only the physical characteristics of the work area, but also the tools, methods of work, stratification of functions, and selection of operating personnel or work groups. All of the aforementioned elements influence the nature of the maintenance operator as an individual, as well as his abilities, capacities, limitations, and performance of his duties.

2.14.1 Principles of Maintenance Hardware Design. Depending upon the level of use or mileage, AGT vehicles are expected to require two levels of maintenance:

1. Inspection for periodic checks of mechanical, electrical, and control systems, and diagnosis of system failure.

This type of routine service is performed either by the inspection personnel or by another crew (depending on the number of vehicles and requirements for special equipment). This shop serves both as a diagnostic center and as a service station.

2. Repair or replacement of rejected subcomponents, components, or whole vehicles, based on prior diagnosis.

Both types of maintenance stations must be designed around the personnel. The vehicles should enter a maintenance bay where the inspection technician will have test equipment arranged in accordance with the principles of good anthropometric work place design. The test instruments should be developed to facilitate the operator's inspection and diagnostic functions, and incorporate such convenience features as human engineered displays, proper labeling, quick release fasteners, and non-interchangeable cables, connectors, conductors. Comfortable working positions must be provided for, and human force exertion requirements must be limited to comfortable levels.

Vehicle components must be arranged so that the maintenance crew can readily locate, reach and service all units. Design of the maintenance facility should allow the use of natural body positions by the service crew in performance of their maintenance functions. Bending, stretching, kneeling, or crawling should be eliminated by designing service areas and serviceable vehicle equipment within the functional reach envelope of a standing operator. Opening devices which are easy to use and drawer or rack type modules are recommended in the design of equipment accesses. Dimensions of accesses should be determined by the sizes of tools, replaceability of modules, and critical anthropometric dimensions.

For removal of heavy components (25 to 50 lb (11.4-22.8 kg) or more), the use of powered assists, such as jacks, lifts, cranes, etc., should be incorporated into the maintenance procedures. For easy handling of vehicle components, stands or casters are more feasible for units weighing over 30 lb (13.7 kg); wheels or casters should be used for units weighing over 90 lb (41.0 kg). Recommendations for optimal maintenance work place development can be found in U.S. Army MIL-HDBK 759 (1975), MIL-STD-1472A (1970), and Woodson and Conover (1970).

Machine parts should be labeled and servicing instructions phrased in terms comprehensible to the least expert technician who will have to use the information. Units, parts, test points, and other objects must be clearly identified with respect to the proper maintenance procedures. Because grease or dirt could eventually obscure printed labels, etched or embossed lettering is generally preferred to maintain maximum legibility.

The equipment's outward appearance must be appealing, because apparatus which is unattractive and appears to be rugged actually gets rougher treatment than that which looks fragile or has eye appeal. Therefore, it is recommended that both vehicles and test equipment be designed to look no tougher than they are; however, they should be capable of withstanding the rough treatment they are likely to receive.

The control system should be modularized, since plug-in units greatly facilitate both inspection and replacement of parts. Ease of inspection and replacement should also be considered in choosing the mechanical components of the vehicle. Supporting equipment such as test stands, work platforms, and dollies should be designed to leave both hands free to work, adjust to levels which make system components easy to reach, and provide good visibility, non-skid surfaces, and quick engagement. Each unit of equipment should be identified in terms of its functional characteristics. In design and installation of connectors, conductors, mechanical fasteners, and information display devices, the recommendations of U.S. Army MIL-HDBK-759 (1975) and Woodson and Conover (1970) should be considered.

It is the vehicle manufacturer's responsibility to (1) plan for maintainability from the very first stage of systems development, (2) design maintainability into the system, (3) test and revise the maintenance technology for each version of vehicle design, and (4) document maintenance procedures. Details of all phases of maintenance design are outlined in U.S. Army MIL-HDBK-759 (1975).

2.14.2 <u>Principles of Maintenance Software Design</u>. Maintenance software design includes selection of personnel, assignment of tasks, provision of servicing instructions and procedures, logic of task allocation and sequence, job aids, etc.

Equipment inspection is one major function of the maintenance crew which cannot be fully mechanized in any automation process. It is considered good practice for a one-or two-man crew to perform routine inspection of the vehicles' mechanical, electrical, and control systems in their entirety. Service functions may be combined with inspection.

For maximum efficiency and quality of inspection, the maintenance technician should proceed at his own rate and perform a number of checks as the vehicle moves through the maintenance bay. When only one inspection function is performed by each technician on each vehicle as in a conventional assembly line, the average "catch" varies between 32% and 80% of all defects (Murrell, 1969). Overall inspection efficiency increases when a group of functions is investigated by each person.

Groups of maintenance bays could be built parallel to each other to reduce the sense of isolation which may lead to difficulty in maintaining concentration for extended periods of time. In order to eliminate monotony and the feeling of being "tied" to the work station, the maintenance men might be assigned to drive vehicles to be serviced to and from the maintenance bay. Periodic changes in the operator's task, achieved through diversification of inspection functions or frequent opportunities to leave the regular workplace, are likely to increase inspection efficiency and employee morale.

Method of payment may also influence maintenance performance. If bonuses are paid for the number of defects found, the inspector may tend to reject more units than necessary. On the other hand, if he is paid by the total number of units handled or passed, he may tend to rush through the inspection or pass all borderline cases. A payoff matrix for increased "hit" and decreased "false alarm" rates should be devised to optimize performance.

Maintenance training and brush-up courses should be designed into the system, so that inspectors and other technicians clearly understand the difference between acceptable and unacceptable system components. Quality control checks should be conducted at regular intervals to ensure that inspection standards have not drifted. A communications channel should be created to allow maintenance personnel to suggest changes to the operating and procurement organizations.

Maintenance instructions, flow diagrams, schematics, and decision trees should be provided for the maintenance crew. Explanations of maintenance procedures should be systematic and concise, with unambiguous decision points. The number of decisions maintenance personnel must make on their own should be as few as possible. Tolerance specifications for "normal" conditions, and methods for calibration and alignment should be provided.

Frequently used schematics and diagrams should be printed on durable materials. The maintenance manual must have a convenient format and avoid excessive size or weight. Instructions should be prepared in a step-by-step format which provides programmed guidance for operating equipment and test facilities and routine maintenance checks. Wiring diagrams and parts-list information should also be provided. Design recommendations to facilitate trouble-shooting can be found in Van Cott and Kinkade (1972).

2.14.3 Vehicle Cleaning. It is important to keep the interior and exterior of the vehicle as clean as possible. Cleanliness will not only support the aesthetic aspects of the system but will also enhance ridership. The automobile and airline industries have long recognized the importance of the impression cleanliness makes on the user. A dirty system, or even worse, a dirty vehicle may dissuade the borderline user. Further, cleanliness begets cleanliness. In a clean system, group pressure will reduce the likelihood of littering, and community interest and pride may reduce the incidence of vandalism

To achieve cleanliness, the vehicles must be properly designed. Interior surfaces should be non-absorbent, with no crevices, recesses, or surface projections to impede or complicate cleaning. Exterior surfaces should be cleaned and serviced regularly in an automated washrack cleaning station. Cleaning stations should be designed so that the vehicles may be cycled through them on a periodic basis for both exterior and interior cleaning. The cleaning process should incorporate inspection procedures designed to detect problem cleaning areas in the vehicle, and the need for increased frequency of cleaning due to vandalism or extreme environmental/ meteorological conditions.

3. THE GUIDEWAY

The guideway may be considered an integrated, self-contained subsystem interacting with the AGT vehicle, terminal, and community. It is difficult, however, to relate the human factors problems generated by inappropriate guideway design to particular guideway components, as in Section 2. on THE VEHICLE. Rather, implicit in the design concept of a modern AGT guideway as a lightweight structure built of slender support beams and widely spaced, gently curved piers (Ravera and Anderes, 1975), are the human factors problems of emergency passenger evacuation and provision for acceptable levels of ride quality. Security from vandalism and human obstruction is also a significant human factors problem on all guideway structures at or below grade, and on elevated guideways near platforms or other access points.*

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*At the time of the preparation of this guide, a significant effort in the evaluation of security and evacuation procedures had been initiated by DOT contractors. It is anticipated that future revisions of this material will contain much more detailed material on guideway security and safety.

3.1 Emergency Passenger Evacuation

One of the most serious human factors problems inherent to all mass transportation systems is the evacuation of passengers in the event of a fire, collision, or other emergency. Evacuation is even more difficult in AGT systems, where there are no systems personnel to direct passengers in the vehicle. Consequently, the design of the AGT guideway may be a critical factor in the passengers' ability to escape a dangerous on-board situation and make their way to safety. The feasibility of emergency evacuation techniques and accessibility to fire-fighting and other rescue equipment may also depend to a large extent upon guideway design.

3.1.1 General Evacuation Procedures and Guideway Design. In general, it is recommended for most emergencies that rescue vehicles be permitted to pull up to the disabled vehicle so that passengers may disembark through longitudinally oriented emergency doors. The gap between vehicle floors should be no more than 2 in. (5 cm) wide; otherwise, overlapping plates could be provided to bridge the gap. If side exit doors are the only ones available for evacuation, double width guideways are recommended, so that a rescue vehicle may be brought up alongside the disabled one. Passengers could then be evacuated across a short gangplank between the opposing vehicles' doors.

There are many emergencies, however, in which passengers will not be able to wait for help to arrive before exiting the vehicle. In such cases, they will probably seek refuge on the guideway itself, although this may be dangerous in AGT systems, with automatically operated vehicles. Various guideway design features are critical in such situations as fire, bomb threats, derailments or collisions; in these situations, emergency personnel cannot be dispatched quickly enough to guide passengers to safety.

Guideways should be built with a covered or recessed power rail, to minimize the possibility of passenger electrocution before the power is turned off. Such a design will prevent tripping and falling of passengers negotiating the guideway on foot, and obstruction of emergency equipment and personnel trying to reach the disabled vehicle. It will also facilitate removal of snow and other foreign objects.

Access to and adequate provisions for use of local fire department equipment should be designed into the guideway structures so that both vehicle and guideway fires can be controlled. Periodic elimination of combustibles from rights-of-way must also be provided for in AGT systems.

The presence of high voltages in maintenance or other areas along the tracks should be indicated by conspicuous signs. Emergency lighting systems should be included in the design of tunnels and activated by either loss of electrical power from the utility or loss of normal illumination in the tunnels.

3.1.2 Evacuation of Vehicles Running at Grade. Evacuation procedures for vehicles running at grade are fairly well-established. In general, the power rail is de-energized after checking that no other operating vehicles are in the vicinity. Emergency personnel are promptly dispatched to the scene of the incident, and the appropriate community authorities are notified. Emergency personnel then escort all passengers to safety, either onto other vehicles or to the next station.

It is essential that systems emergency personnel be well trained and all contingency plans worked out and rehearsed in advanced. (See for example the guidelines prepared by the American Public Transit Association, 1977. The result of figuring out the appropriate rescue techniques at the scene of the emergency may be the unnecessary injury and death of AGT passengers.

Design of escape routes should be based on the entire range of possible body movements of the general population dressed in winter clothes. Escape procedures should be developed and tested by each individual system to accommodate special system features which may make routine evacuation procedures unfeasible.

3.1.3 Evacuation of Vehicles Above and Below Grade. Evacuation from guideways above or below grade is a much more difficult problem. On elevated guideways and tunnels the difficulties involved in vehicle breakdown may not be nearly as serious as those caused by power failure or obstruction of the guideway itself. In such cases, rescue vehicles must have an independent power supply. Emergency equipment from the surrounding community (fire ladders, "cherry pickers", etc.) is generally relied upon by existing transit systems to evacuate passengers in such situations.

However, it is recommended that AGT systems strive to develop independent evacuation technologies to suit their own particular needs, integrating available community facilities wherever this is practical but not relying solely upon these for the solution of all emergency problems.

3.1.3.1 Evacuation Problems on Elevated Guideways

The lightweight, elevated concrete guideway is destined for use in many AGT systems because of its practicality, relatively low cost, and anticipated public acceptability in urban environments. There can be serious difficulties in effecting emergency evacuation from such systems. Unless rescue vehicles are rapidly dispatched to the emergency scene and are able to reach the disabled vehicle unobstructed by other cars still in service, passengers cannot be evacuated efficiently and safely. Passengers escaping a disabled vehicle onto the guideway are relatively trapped and risk falling, electrocution by the power rail, and impact from other vehicles. If the progress of rescue vehicles is obstructed, passengers are trapped in the vehicle or on the guideway unless rescue devices from the community emergency authorities are able to reach them. In some cases these devices are unable to ascend high enough (i.e. more than 30 ft (9.2 m)) to contact the guideway, necessitating the use of helicopters or other extreme measures. These problems underscore the necessity of developing contingency plans for emergencies well in advance.

Of all elevated guideway systems designs, the suspended monorail presents the most difficult problems in terms of emergency evacuation. In the case of a vehicle fire or collision, passengers who may be able to escape are virtually trapped in the vehicle if no rescue system is provided. Use of a suspended monorail guideway design for AGT systems requires extremely careful consideration in light of these serious evacuation problems.

3.1.3.2 Evacuation Problems on Underground Guideways

Underground guideways in tunnels present difficult problems in terms of emergency evacuation. The presence of other vehicles in tunnels may block rescue efforts by emergency personnel attempting to reach the disabled vehicle. The underground location is often inaccessible to the most effective fire-fighting equipment, ambulances, and so on. The close quarters and limited number of access points necessitated by most tunnel designs make rescue efforts especially difficult. In addition, smoke, fumes, and heat tend to become trapped in tunnels, reducing the amount of time available to implement rescue procedures.

Underground guideways using tube construction resulting in narrow cross-section tunnels are much more difficult to evacuate in emergencies than those using cut-and-cover construction. Lateral exit from the vehicle is impossible unless the emergency occurs at a station or setback, or unless an emergency/maintenance walkway is provided, since the vehicle doors normally in use are completely obstructed by the tunnel walls. If passengers are forced onto the guideway, they are still trapped in the tube, which is not likely to provide an accessible foot path to safety for any but the most able-bodied passengers.

3.1.3.3 Recommendations for Design of Above- and Below-Grade Guideways

At present, technological solutions to the evacuation problems inherent in above-and below-grade guideway designs have not been fully demonstrated. One possibility might be guideways laid out with parallel sets of tracks which are close enough to extend a ramp for passenger evacuation. In this way, passengers could at least escape the immediate dangers of fire or explosion. Similarly, the power rail on the alternate tracks could be deactivated without jeopardizing the attempts of rescue vehicles to reach the disabled car.

Another alternative might be special ramps or passageways running parallel to the guideway. These would also facilitate intervention by transit police and emergency personnel on electric scooters or other such devices. Such ramps should be dedicated solely to the emergency function and kept clear of maintenance equipment and other debris which tend to accumulate with only intermittent use. Emergency exits on the sides of vehicles could open directly onto the ramps, so that even wheelchair passengers could propel themselves to safety. Such ramps should be at least 36 in. (92 cm) wide with 1.5 in. (4 cm) high lateral flanges to facilitate wheelchair use. Again, the gap between the vehicle floor and the evacuation ramp should not exceed 2 in.

Certain general aspects of guideway design should also be considered for their impact on ease of passenger evacuation. Guideways should be laid out to provide numerous points of access for rescue equipment and a wide range of escape routes for passengers whenever possible. Availability of natural light and requirements for artificial illumination should be assessed depending upon the location and design of the guideway. Similarly, adequate ventilation for passengers, rescue workers, and systems personnel must be considered in the design of underground guideway structures.

3.2 The Guideway's Contribution to System Ride Quality

Guideway design may significantly influence the passenger acceptability of AGT systems through its effect on ride quality. The fact that the vehicle interacts with the guideway to produce a characteristic set of ride motions for any system allows the AGT designer an extra degree of freedom in creating an acceptable motion environment which will foster system patronage. Furthermore, recent studies (Ravera and Anderes, 1975,; Wormley, et al., 1977) support the notion that significant and cost-effective improvements can be made in the level of ride quality achieved on concrete guideways by the careful consideration of guideway feature design trade-offs prior to system construction.

It is clear that the motion environment experienced by the passenger in the vehicle is a direct function of the interaction between vehicle design features, such as the suspension and seating, and certain aspects of guideway design, including the track, roadbed, and pier spacing. Regardless of guideway type, the tracks, rail, roadbed, or other surface components must be well-maintained and kept free of debris and obstructions in order to achieve a fair level of ride quality. The random and irregular motions produced by sudden stops and speed changes resulting from uneven, run-down guideways are often a major source of passenger dissatisfaction, as they negatively influence comfort. This is especially important in automated systems where there is no operator to change vehicle speeds depending upon the varying quality of the guideway.

It is a common assumption that a guideway design which will produce an extremely high level of ride quality is quite expensive, and therefore in the long run may not be cost-effective. Thus, the requirements for generating an acceptable motion environment must often be met through the manipulation of various vehicle features (e.g., suspension system, seating) which may have less of an effect on ride quality than certain guideway features. Recent studies of elevated concrete guideways, however, have suggested that manipulation of certain guideway features can significantly increase ride quality and still remain cost-effective.

Based on the results of simulation studies, Ravera and Anderes (1975) suggest that lightweight concrete guideways can be built with ride quality characteristics comparable to guideways almost twice as heavy, if deeper and narrower I-or box-beams are used. Use of shorter pier spans ((75-125 ft) (22.7-37.9 m)) may produce a rougher ride despite the resulting increased stiffness of the guideway, which might be expected to improve ride quality. The authors also caution that span fundamental frequencies of new guideway designs must not equal vehicle primary or secondary frequencies, since the resonance effects would quickly weaken the guideway structure in addition to creating an uncomfortable ride. Procedures for estimating guideway costs for particular vehicles are also discussed.

Wormley, et al. (1977) discuss ways of getting a better cost/benefit ride quality ratio in their ride quality/guideway cost sensitivity trade-off study. In terms of the guideway superstructure, they suggest use of precast box-beams rather than I-beams and continuous spans of three to six beam lengths as cost-effective design features to improve ride quality. Lateral and vertical motion can be minimized most effectively by reducing surface roughness and joint offset from 0.25 to 0.19 in. (0.64 to 0.48 cm).

Wormley, et al. also suggest that certain guideway features have little or no influence on ride quality and therefore do not deserve excessive monetary outlay in terms of guideway construction costs. For instance, the authors state that support pier design does not affect ride quality; cast-in-place round piers, which cost less than 60 percent of the pre-cast, trapezoidal variety, are therefore recommended. Also, it appears that such factors as angular panel deviation and pier height variations do not (within certain limits) significantly influence ride quality. Thus, the authors provide guidelines for guideway costing which maximize ride quality while minimizing unnecessary or fruitless expenditures on design features which do not affect or only slightly influence ride quality.

Both Wormley, et al. (1977) and Ravera and Anderes (1975) stress that the ride quality expected of a certain guideway design can change drastically with changes in vehicle speed. In general, as speed increases, ride quality gets worse. Also, span lengths can create problems of resonant frequencies at certain speeds; however, Ravera and Anderes state that no major effects will be felt if pier spacing ranges between 75 and 125 ft (22.7 and 37.9 m). In light of these recommendations, it is suggested that vehicle speed be considered as a significant factor in planning a guideway design for AGT systems. A narrow speed range should be established early in the system design effort, since the determination of guideway characteristics to achieve a certain level of ride quality will vary depending upon vehicle velocity.

Vehicle size will also affect the over-all level of ride quality and guideway costing. The cost of a guideway for a small, 10,000 lb (4.6 metric ton) vehicle is about 75% of the cost of a guideway for a larger, 20,000 lb (9.2 metric ton) vehicle, which requires a heavier and wider structure. In general, the small vehicle system will have better vertical and poorer lateral ride quality at levels complying with the ISO (1974) 2631 Reduced Comfort Boundary for a ride duration of 90 min at a speed of 60 mph (96 km/hr). The larger vehicle system might be expected to have better lateral and poorer vertical ride quality, at levels which would be acceptable within the ISO Reduced Comfort

Boundary for a ride duration of 55 min at a speed of 60 mph (96 km/hr) (Wormley, et al., 1977).

Other design features of the guideway beside its general superstructure may also influence ride quality and public acceptance of the system. The guideway should be provided with control and communications channels and a means of power pick-up by the vehicle. Systems with automatically steered vehicles require positive retention of the vehicle along the guideway sidewall or center guide rail for maximum safety.

3.3 Vandalism and the Guideway

A serious security problem exists in the high level of guideway crime and vandalism experienced by a number of existing transit systems. Guideway obstruction, switch and signal damage, and stoning of moving or stranded vehicles with passengers in them are among the major problems reported which are likely to interfere with AGT systems operation if appropriate measures are not taken to maintain proper guideway security. These crimes are particularly serious in fully automated systems, where there is no operator to detect incidents of vandalism or guideway obstruction before they affect systems operation.

In general, elevated guideways have the advantage of relative inaccessibility to vandals. At-grade guideways are the most difficult to protect, as they present no obstruction whatsoever to vandals who wish to enter systems property.

Efforts can be made to prevent guideway vandalism or at least ameliorate its effects on systems operation by including appropriate features in the guideway design. First, it may be assumed that the guideway will be most subject to abuse in those areas of the surrounding community which have the highest crime rates. Second, most vandals seem to be young boys who perform the largest number of criminal acts during the after-school, daylight hours (Harris, 1971; Southeastern Pennsylvania Transit Authority, 1974). Thus, it is recommended that anti-vandalism measures be concentrated during the late afternoon hours in areas already known to foster crime.

Certain sections of the guideway may require high fences and barbed wire to keep vandals from entering the system. Systems property adjacent to all guideways should be cleared periodically of debris and junk such as tires, appliances, automobiles, etc., which members of the community may deposit there. These types of materials not only give the guideway area a run-down appearance, but provide ammunition for vandals to obstruct tracks or throw at vehicles. It is imperative that all switches, signals, and other means of automatic communication between the guideway and the vehicle be protected from damage and obstruction.

Although an important goal of AGT systems is the complete automation of all functions, it may be necessary to employ some human help in the area of security. One system which appears to be useful is the intermittent helicopter patrol of the system's property. In one year alone, helicopter patrol of 13 commuter railroads under the jurisdiction of the Southeastern Pennsylvania Transportation Authority (SEPTA) resulted in a 46% decrease in passenger injuries due to vandalism (rock-throwing) and reductions in track obstruction and switch and signal damage by 19% and 35%, respectively (SEPTA, 1974). The New York Metropolitan Transit Authority (NYMTA) and Atlanta Transit System have had similar success with helicopter patrol of commuter trains and buses, respectively (Schnell, et al., 1973). This type of security measure seems to be quite effective not only because large areas of the system can be surveyed simultaneously, but also because it creates the important psychological impression that vandals might be under surveillance at any time.

Unfortunately, helicopter patrol is relatively expensive as a security measure even on an intermittent basis (e.g., SEPTA paid $74/hr in 1974). Thus, if AGT systems are experiencing excessive damage due to vandalism or other guideway crimes, it might be more feasible for the system to initiate a cooperative effort with other transit systems in the same region (e.g., buses, commuter railroads, trucks) to divide the costs of helicopter surveillance for the entire region. The cooperation of local and/or systems authorities in apprehending transit criminals sighted by the helicoptor must also be obtained.

Another guideway security design alternative is video surveillance of critical areas, particularly those where sabotage or vandalism may affect moving vehicles. Such areas include switch points, guideway underpasses, and guideways running parallel to roads or railroad tracks.

4. THE TERMINAL

AGT terminals may be considered as a subsystem of the total AGT system, functioning as a vital interface between the community and the vehicle/guideway complex. Careful design of terminal units and selection of station features and locations are imperative for optimal system utilization. Pedestrian traffic patterns and security requirements inside and outside terminal structures must be considered as a primary factor in the selection of station features which will optimize passenger acceptance of the AGT system, as well as safety and security.

4.1 General Interior Design

AGT terminals must be designed to facilitate pedestrian traffic flow in a safe and comfortable environment. Certain aspects of the general interior design of these structures are particularly important in terms of passenger security, crowd control, and overall safety, comfort, and efficiency of AGT system use.

Depending upon the number of passengers to be accommodated in the terminal and average frequency of service, requirements for climate control may vary.

Centrally oriented terminal buildings serving large numbers of passengers over substantial time intervals should be equipped with properly controlled heating, cooling, and ventilation systems. Inside temperatures should be maintained at levels which are comfortable to people entering these buildings in street clothing, (i.e., 75-85 °F (23.9-29.4 °C) in summer, 60-68 °F (15.6-20.0 °C) in winter). Excessive heating and cooling should be avoided. Smaller terminals which receive AGT vehicles every few minutes and which do not serve as central changeover points for large numbers of people require much less in terms of climate control. Simple shelter from the elements and free circulation of fresh air inside the terminal to eliminate smoke and unpleasant odors should suffice in these smaller structures.

Non-skid materials should be used on floors and stairs, which tend to become wet and slippery due to cleaning and maintenance or exposure to adverse weather conditions. Floor surfaces should not catch toes and heels. They should be relatively free of water, grease, cigarette butts, paper, excessive wax, and garbage. Strategic placement of water fountains, vending machines, garbage cans, and floor mats or carpeting to absorb rain and snow will help to keep floors clean.

Strips of textured floor material could be used to warn visually disabled pedestrians that they are entering a heavy traffic or highly constricted area in the terminal. This will help prevent collisions between passengers. Such "caution strips" should be at least 3 in. (8 cm) wide and placed 9 in. (23 cm) apart in series of three or more. A roughly textured surface should precede danger areas (e.g., boiler rooms, loading docks, stairways, high voltage) by 36 in. (92 cm) and extend 12 in. (30 cm) to each side of the entrance to be avoided.

It is suggested that stations be designed to expand and contract in area, so that an optimum security passenger density level might be maintained. Passengers traveling in off-peak hours should not be forced to wait on huge but deserted platforms and mezzanines. These few people could easily be concentrated into a small group by physical partitions which make the waiting area smaller, thus warding off attacks on isolated travelers.

Space should be allocated within stations to facilitate long sight lines and eliminate positions of concealment. Visibility should not be restricted by columns, walls, signs, or people in groups. High ceilings will facilitate efficient use of video surveillance cameras.

Adherence to local and state fire safety codes in material selection and station design is recommended.

4.2 Entrances and Exits

Entrance and exit doors should be clearly labeled, and the areas leading to each should be separated by a railing. Sufficient clearance should be provided between doors and adjacent passageways so that people cannot be caught between the opened doors and the wall.

Doors should be at least 84 in. (2.13 m) high and 32 in. (82 cm) wide. Sliding or swinging doors are recommended for use in AGT terminals. Sliding doors should be automatically activated. The opening device must actuate the door far enough in advance of a rapidly moving pedestrian to prevent collision with the door. The opening mechanism, if used on exterior doors, should be able to function in adverse weather conditions, such as frost, snow, etc. Swinging doors should open in one direction only and be used in pairs (i.e., adjacent "In" and "Out" doors). For the safety of pedestrians, swinging doors should be separated by a post and have windows for visibility of oncoming traffic. Visible push or pull decals are also recommended. Swinging doors should be operable by a single effort not exceeding 8 lb (3.6 kg). Pressure sensitive automatic opening devices may be used to speed operation and overcome wind pressure.

Floors must be level for at least 60 in. (1.5 m) on either side of doors. Thresholds should be eliminated. Raised or etched letters may be placed on or next to all doors at a height of 55 in. (1.4 m) as an aid to the blind. Door handles leading to danger areas (e.g., boiler rooms, high voltage) should be knurled or otherwise readily identifiable by touch.

It is suggested that most, if not all, entrances be made available to elderly and handicapped passengers, since these entrances will also serve as exits in case of an emergency. Signs directing passengers to accessible entrances should be visible to a person in a seated position before he arrives at an inaccessible entrance. Accessible entrances should be designated by the handicapped emblem. At least one entrance should be accessible to wheelchair passengers on a level which would make elevators available. As a warning to the blind, pavement of a different texture should be laid perpendicular to entrances for a distance of at least 72 in. (1.83 m) and at least 36 in. (91 cm) to either side of entrances that are less than 100 ft (31 m) wide.

Consideration should be given to limiting the number of service entrances and exits in a station, since these become escape routes for criminals. One central entrance and exit point could easily be locked or blocked by police in the event of a crime. The AGT system might also be "closed" in the sense that a person perpetrating a crime in a vehicle would not be able to escape through the nearest station. By means of efficient communication links between the vehicles, Command and Control center, and terminals, a criminal could be trapped inside the system as soon as system personnel were alerted to his crime. With this type of closure, however, innocent passengers would be trapped inside the system along with the offender. An alternative to immediate apprehension within the system would be the simple identification of the criminal by taking his picture as he leaves the station. This would facilitate later apprehension.

4.3 Aisles and Corridors

Aisles and corridors should be straight with as few corners as possible; winding or curved passageways and blind corners should be eliminated from the design entirely. Paths should be laid out to provide minimum distances between points by using flow charts, diagrams, and movement analysis. Passengers should be provided with traffic guides such as arrows or lights on floors, walls, and ceilings. Aisles should be clear of obstructions; structural support columns should not protrude into any aisles. Use of one-way traffic patterns should be avoided because it is likely that they will not be observed. Aisles and corridors with right angles and those that form "T's" rather than crossing completely should not be used because they impede the traffic flow.

Passageways should be at least 48 in. (1.22 m) wide; 54 in. (1.37 m) wide corridors would permit wheelchair turning and are therefore desirable. Corridors in which two wheelchairs might frequently pass each other should be at least 60 in. (1.5 m) wide. Minimum passageway lengths should be provided wherever possible; in any case, special passageways for the handicapped should not be more than 50% longer than passageways used by other travelers. Special travel lanes for slower pedestrians would be a great help to the handicapped and elderly.

Handrails should be 32 in. (82 cm) above the floor along all passageways and mezzanines. Strips of a differently textured material should precede the top and bottom of handrails by 18 in. (46 cm). Benches should be located at convenient intervals along the corridors. All hanging signs, ceiling lights, door closers, and suspended fixtures should be placed at a minimum height of 84 in. (2.14 m) above the floor. Lights may be arranged to form a single line over the center of walks, ramps, and corridors to provide a visual path for passengers with only light perception. Clear floor-length windows or walls should have railings, or decals or frosting at a height of 60 to 72 in. (1.5-1.83 m) from the floor to warn visually disabled and elderly passengers and prevent pedestrians from walking through them.

The pedestrians' probable line of sight to important signs and visual information displays should be considered in plans for terminal design, since visual clearance is an important factor in determining the size and shape of rooms and corridors. The passengers should be able to get a direct view of the information when the angle between passenger line of sight and plane of display surface is between 60 and 90 degrees.

All terminals should be equipped with public address auditory communication systems. Systems should be designed so that all passengers are within normal voice range of the speakers located in the Command and Control Center. Acceptable voice range depends upon the prevailing noise level and the room size. Particular attention should be paid to the unique acoustical design problems engendered by terminal areas of different sizes and shapes in the determination of loudspeaker location and type.

4.4 Platforms

Passengers should be protected from platform edges and other sharp drop-offs by guard rails or fences. Areas along the platform edge where vehicle doors will stop should be closely contolled by use of the Automatic Train Operation system; these areas should be clearly marked and left free of protective barriers. If guard rails or fences are impractical, a material of different color and texture, at least 18 in. (46 cm) wide and preferably imbedded with flashing or pulsating lights, should be used along the open platform edge to warn passengers of the dangerous drop-off.

Audio and visual announcement of vehicle arrival is also desirable near the platform.

It is extremely important that accurate estimates be made of the approximate number of people using various stations, and appropriate amounts of space be provided on platforms corresponding to these estimates. When personal space is severely limited (i.e., less than 2 sq ft or 0.19 sq m per person), crowd control becomes very difficult and people may be forced onto the guideway (Fruin, 1971). An area of 10-13 sq ft (1.1-1.3 sq m) per person is recommended by Fruin (1971) for railroad platforms and elevator waiting areas and would seem applicable for AGT systems as well. Where this amount of space is deemed to be excessive and smaller areas per passenger are used, careful monitoring of passenger flow rates through the station and restriction of the number of passengers entering platform areas during periods of heavy traffic may be necessary to prevent platform accidents. Local or state fire codes may also prevail to restrict the permissable number of passengers on platforms.

4.5 Level Change

It is recommended that single level stations be used in the AGT system wherever possible, to: 1) facilitate system use by both the general public and handicapped individuals; and 2) avoid the expense incurred by installation of various level change systems, which tend to be quite costly. In any event, no more than two stories should be included in the design of any station, since security in a multi-leveled structure is very difficult to maintain

4.5.1 Stairs. Stairs within the terminal should be at least 66 in. (1.68 m) wide, and rise at an angle of between 20° and 35° from the horizontal. Riser height may range from 5-7 in. (13-18 cm); tread depth should be between 9.5 and 10.5 in. (24-27 cm). Every 10 to 12 treads should be separated by landings in order to avoid long continuous flights.

Plain facings and round nosings should be used on steps wherever possible. Non-slip surfaces should be used to cover treads. Strips of a differently textured material should precede the top and bottom of a flight of stairs by

36 to 60 in. (0.91 to 1.52 m) and extend 12 in. (30 cm) to either side.

Stairs should have a handrail on at least one side, set 32 in. (82 cm) above the tread at the face of the riser, and extending 18 in. (46 cm) beyond the stair ends. Handrails should not protrude more than 3.5 in. (9 cm) into the required stair width and should return to the wall at their ends. Handrails are recommended for both sides of all stairs, to continue through landings for the full length of the stairway. Center rails should be provided on stairs more than 88 in. (2.2 m) wide. Handrails with textured indicators directly over the center of each tread would aid the blind. Railings not constrained by walls should have a full-length grille or covering to prevent passengers from falling or slipping underneath the rails.

Stairs constitute an impassable barrier to the handicapped and elderly. Thus, they must be augmented by some other means of level change if terminals are to be completely accessible to these groups.

4.5.2 <u>Ramps</u>. Suitable ramps with a grade of 8.33% (1:12) or less should be provided for the use of handicapped passengers or others with baby carriages, luggage on wheels, etc., when steps are to be used by the majority of passengers. The use of ramps will increase visibility within the station and make level changes easier for handicapped passengers.

Ramps exceeding a 5% gradient should have 4 in. (10 cm) high curbs along both sides to aid in wheelchair braking. Minimum width for ramps handling one-way traffic is 32 in. (82 cm); ramps handling two-way wheelchair traffic should be at least 64 in. (1.64 m) wide. Handrails should be provided 32 in. (82 cm) above the ramp surface, extending 12 in. (30 cm) beyond its top and bottom. A change in pavement texture should precede the top and bottom of ramps by 36 to 60 in. (0.91 to 1.52 m) and extend 12 in. (30 cm) to either side.

Ramps are considered by many to be a universal means of level change, and it is often argued that they should be used to replace stairways completely. However, it should be kept in mind that: 1) ramps or inclines are inefficient in terms of building space, pedestrian safety, and speed; and 2) while ramps may solve the dilemma of the wheelchair user, they are more difficult than stairs for persons using canes, braces, crutches, and artificial limbs. Ramps are therefore not recommended for general pedestrian traffic over level changes of more than 13 in. (33 cm), or for the accommodation of passengers other than the handicapped, elderly, or those using wheeled devices.

4.5.3 Escalators. Escalators may be used to transport large numbers of people between multiple levels. The safety aspects of escalator design are sufficiently discussed in the relevant safety codes (i.e., ANSI A17.1-1971), which should therefore be observed in AGT terminal buildings.

The optimum rate of travel for an escalator is usually considered to be between 120 and 138 ft/min (36.4 to 41.8 m/min). Escalators should be equipped with a handrail which moves at the same speed as the steps. The customary solid black handrail should have conspicuous white, high-contrast markings (e.g., bars, diamonds) at least every 18 in. (46 cm) to make its movement apparent (Van Cott, 1972). At the exit point, the escalator guard walls should also extend from 5 to 6 ft (1.5 to 1.8 m) to allow time to become accustomed to walking on a level and stationary surface before encountering pedestrian traffic. Escalator entrance and exit areas should be illuminated at a level at least 20% greater than that of the surroundings. Illumination at the same level should be provided on entrance and exit floors by concealed lighting fixtures located at waist level or below.

Escalators are probably the most difficult device for the handicapped and elderly to use in changing levels. They are impossible for wheelchair passengers because they separate into steps. They are more difficult than stairs for the elderly and people using walking aids, such as canes, crutches, braces, and artificial limbs, because escalators do not stop for boarding and alighting. Wherever escalators are used for ordinary pedestrian traffic, it is recommended that some alternative means of level change be provided for the handicapped and elderly.

4.5.4 Elevators. Installation of at least one vertical elevator in each multi-level terminal should be considered in AGT systems. The elevator is really the only level change device accessible to all passengers. It should be equipped with force-activated door guards, electric eyes, and an audio-visual door closing warning signal. Doors should open a minimum width of 32 in. (82 cm) and be at least 78 in. (1.98 m) high. The floor of the elevator cab must be completely level with the floor of a given story, with no more than a 2 in. (5 cm) horizontal gap between them if wheelchair passengers are to be accommodated. Elevator dimensions of 63 in. (1.6 m) long x 56 in. (1.4 m) wide are desirable; 60 in. x 60 in. (1.5 m^2) elevators are also acceptable. A maximum speed of 250 ft/min (75.75 m/min) is recommended in structures exceeding 75 ft (22.7 m) in height (U.S. Department of Transportation, 1973). All elevators should comply with relevant safety codes (i.e., ANSI A17.1-1971).

Controls in elevators accessible to the handicapped should be located at the back of the car approximately 37 to 55 in. (0.94 to 1.4 m) from the floor (unless the elevator is 54 in. x 54 in. (1.37 m^2) or larger, in which case front controls may be provided). Controls should also be shape-coded to aid the blind. Raised and illuminated letters and numbers may be used inside and outside the elevator to indicate the number of the floor. Buttons outside the elevator should be placed no higher than 48 in. (1.22 m) from the floor. An audio indicator may be used which rings when the elevator stops at a floor (twice for "up" and once for "down"), and buzzes as it goes past a floor. These sounds can be used by the blind to detect the presence of the elevator and to count floors as they pass; sounds should therefore be audible both inside and outside the elevator. Strips of a differently textured surface might also be used on the floor at a distance of 36 in. (91 cm) to either side of the elevator and 72 in. (1.83 m) perpendicular to its doors.

Elevator cabs might be built with two clear laminated glass walls, enabling a person to see into the elevator before entering. Other passengers and station personnel would then also have a full view of elevator activity from all levels. A station agent or other system representative should be able to override the elevator controls in case of an emergency.

Elevators to move large numbers of people should be used only in terminal buildings of three or more levels, or where the terrain requires a large natural displacement between the station entrance and the guideway platform. Such high capacity elevators should incorporate a flow-through design, with individuals entering from one side and exiting from the other. Entrance and exit door opening should be staggered for optimal pedestrian traffic flow.

For one to two story terminals, a stairway is faster in high density traffic areas because of the limited capacity and availability of elevators. In such cases, elevators should be reserved for the handicapped and elderly, who might have special cards or keys to call the elevators at will.

4.6 Illumination

A high level of illumination makes all passengers feel more secure and is helpful to those whose vision is restricted or who must lipread. Light fixtures should be located at least 84 in. (2.14 m) above the floor. Recessed fluorescent tube lighting is recommended for stations to provide at least 20-40 ft-cd of illumination at all times.

Illumination is considered satisfactorily uniform if the minimum level of light at any point within an area is at least two-thirds as bright as the point of maximum illumination in this same area. Glare or "hot spots" (i.e., relatively bright light shining into the eyes within the normal visual field) should be avoided. The quality and color of illuminants and walls should be selected to create a cool and soothing atmosphere in the terminal structure, which people generally find most comfortable.

4.7 Displays

Visual displays may be used at the entrances to a system to show the time and location of the next vehicle's departure. Regular audio announcement of this information could also reduce the needless hurrying and pushing which intimidate and harass handicapped and elderly passengers. Audio and visual directional information may be supplemented by floor texture coding of pathways.

Emergency or warning signals should be audio-visual in nature; combinations of alternating high and low pitched sounds and lights flashing with a minimum "on" duration of 0.5 sec are recommended. Exit signs should be visible in all corridors and incorporate directional arrows. Doors which are inaccessible to the handicapped should be preceded by exit signs with a slashed-through handicapped emblem and directional arrows pointing to an accessible exit.

Signs in terminals and stops should be located at least 72 in. (1.83 m) above the floor, with lettering at least 3 in. (8 cm) capital height. Signs should identify stops by the name of intersecting streets and/or by the name of a familiar nearby landmark. Lettering must be visible from seated and standing positions, within the vehicle and should not be located more than 12 ft (3.6 m) from the passenger discharge point.

4.8 Ancillary Facilities

4.8.1 Restrooms. Restrooms in public transit stations are frequently focuses of criminal activity. They are often used as meeting and soliciting centers for illicit drug and sexual activities. They also isolate passengers from the general stream of traffic, providing thieves, muggers, rapists, purse snatchers, and others with victims and opportunities to commit crimes. It is therefore recommended that no restrooms be provided in stations without station attendants or in high crime areas (Harris, 1971). In stations where restrooms must be installed, only one patron should be let in at a time by the Command and Control Center or a station agent. The restroom should be easy to find without isolating oneself from the full view of other passengers and station personnel.

If restrooms are provided in larger stations, they should be located on the ground floor, with doors at least 32 in. (82 cm) wide which open outward. The one stall in each restroom should be at least 36 in. (0.91 m) wide and 60 in. (1.5 m) deep to accommodate handicapped passengers in wheelchairs. The toilet seat should be 20 in. (51 cm) high. Grab bars next to the toilet should be 1.5 in. (4 cm) in outside diameter and extend 1.5 in. (4 cm) from the walls. They should be located 30 to 33 in. (76 to 84 cm) from the floor of the stall, and extend 1 in. (2.5 cm) past the front and rear edges of the toilet seat. A toilet paper rack should be located on the wall even with the front edge of the toilet seat, approximately 24 in. (61 cm) from the floor. Flushing devices should include both a hand operated lever requiring a downward thrust and a floor pedal.

The bottom front edge of the sink should be 26 in. (66 cm) from the floor and extend at least 18 in. (46 cm) from the wall. Faucets should be side-mounted with lever-type handles. Clothing hooks should be located approximately 44 in. (1.12 m) from the floor. Towel racks, soap dispensers, and garbage cans should be easy to operate and located no higher than 40 in. (1.02 m) from the floor to be accessible to the handicapped. Drain and hot water pipes should recede sharply into the walls and be covered or insulated to prevent wheelchair passengers from burning their legs.

4.8.2 Water Fountains. It is recommended that all terminals be equipped with at least one water fountain for the comfort and convenience of all passengers. Fountains which are 30 to 34 in. (76 to 86 cm) high with spouts and hand-operated, lever-type controls are accessible to all passengers, including children and the handicapped (American Standards Association, 1961). Facilities should extend at least 12 in. (30 cm) from the wall with at least 25 in. (64 cm) clearance underneath. If the fountains are recessed into the walls, there should be ample floor space in the surrounding area for wheelchair maneuvering.

4.8.3 Public Telephones. Public phones should be located in conspicuous places and housed in alcoves or separated by partitions; booths with doors should be avoided, as these are inaccessible to individuals in wheelchairs. Phones may be accompanied by folding seats. Coin slots, receiver cradles, and dials should be no higher than 48 in. (1.22 m) from the floor to accommodate children and wheelchair passengers. Push-buttons with raised numbers and letters should be used instead of dials to aid the blind. At least one public telephone in each terminal should have a selection switch to increase the volume of transmission for those with hearing disabilities. An appropriate sign should be used to designate this phone.

4.8.4 Concessions. If concessions are permitted, they should be located where they do not impede traffic flow, but where they can enhance surveillance over various parts of the station. Concessions should be equipped with silent emergency buttons or foot pedals to alert security personnel or the Command and Control Center in the event of a crime.

4.9 Fare Collection

Fare evasion is a crime of major importance in existing transit systems which may be ameliorated by appropriate fare collection system design. Inclusion of various crime preventive design features may also simplify fare collection procedures, allowing for more efficient access to the system for the general public as well as handicapped and elderly groups.

In fully automated systems, it is recommended that no human fare collectors or changemakers be employed either in stations or on board vehicles. Rather, an effort should be made to prevent the accumulation of large amounts of money within the AGT system itself. Tokens should be available at local banks, drugstores, or other local facilities outside the system. A limited number, sufficient for one round trip, could be dispensed from a machine at the station site. Small businesses in the community might be encouraged to participate in token dispensing as a means of attracting customers to their stores.

Turnstiles are not recommended for use in systems accommodating the elderly and handicapped since they are difficult for anyone without full use of arms and legs; they are impossible for wheelchair passengers to use. Fare collection gates at least 32 in. (82 cm) wide might be better for all passengers. Some type of surveillance and audio visual message from the Command and Control Center would be required in the event of fare gate-crashing and multiple gate use. Anti-vaulting devices might also be installed around turnstiles or fare gates to prohibit free entry into the system.

The procedures used by existing transit systems for money collection from change booths and turnstiles are inadequate, since the money must pass through many channels before it gets to the bank. The more frequently money changes hands, the more opportunities there are for theft and personal injury to the money collectors. Private collection agencies (which normally work for banks) or pneumatic tubes should be considered as possible alternatives in the process of money collection.

Automatic fare receivers should also be improved to accept coins and tokens over a larger area and in a wider range of positions. Coin receivers in existing mass transit systems require the passenger to come to a full stop and orient the coin or token in a critical position. This is a difficult maneuver for handicapped and elderly passengers with arthritis or other disabilities which decrease manual dexterity. Able-bodied passengers wearing gloves also have trouble inserting coins at the correct angle.

Alternatives to coins or tokens might make fare collection simpler for the handicapped and elderly as well as facilitating traffic flow and saving time for able-bodied passengers. Any system which reduces the number of ticket-selling or change-making transactions will automatically improve fare collection efficiency. Special credit cards which record the passenger's name and account number for monthly billing might be used to activate fare gates. Prepayment cards might also be considered. Fare collection could also be dispersed throughout the trip; passengers would receive some ticket or token when they paid which would have to be deposited before they were allowed to leave the system.

Other systems currently in use in Europe require the passenger to purchase and carry a valid ticket but do not require the use of turnstiles or other barriers. Instead, the patrons cancel the ticket through a time clock device and security guards make random on-board checks, ticketing and/or arresting delinquent individuals.

If handicapped passengers are provided with a separate elevator entrance, an accessible fare collection gate may be located near that entrance; this would also separate handicapped passengers from crowds of able-bodied travelers running and pushing through turnstiles. Fare activation devices should be no higher than 40 in. (1.02 m) from the floor to be accessible to handicapped passengers.

4.10 Special Security Provisions

Video surveillance cameras, to be monitored at all times by station security personnel and/or the Command and Control Center, should be considered for AGT system security. These could be suspended from ceilings above platforms and mezzanines. The video surveillance system may also be used to monitor crowd sizes, safety of the boarding platform, door and equipment operations, and passenger movements on level change systems. Passenger microphones might also be provided in passenger waiting areas. A public address system under the control of security personnel and/or the Command and Control Center might also be considered for use. Sealed phones or other devices which permit passengers to actively call for help are unreliable due to false alarms and vandalism. They also require strong motivation on the part of passengers and may not be used in emergency situations due to fear or apathy. The installation of such devices is therefore not recommended.

Stations identified as problem areas might be patrolled by K-9 squads or police teams equipped with two-way radios. Consideration should be given to the extension of a radiating coaxial cable for subsurface radio communication in AGT systems with below-grade stations and guideways. The frequency used in the AGT radio communication network should be compatible with the frequency used by the local police, who could then cooperate with AGT security personnel in handling problems within the system.

4.11 Cleaning and Maintenance

Stations should be designed for ease of cleaning and maintenance. Materials used in stations should be able to withstand the worst abuse without sustaining permanent damage. Plastics and vinyl coatings consistent with fire-worthiness considerations are recommended for this purpose. Walls should be washable and smooth, coated with finishes which either do not readily take pencil, ink, or other markings and resist etching, or which can be quickly and economically repainted and/or resurfaced.

It is very important that stations be regularly cleaned and serviced, since a run-down appearance fosters public apathy toward the transit system and seems to attract crime and vandalism. Station fixtures should be washable and designed without surface projections and recesses which hinder the cleaning process. Lighting fixtures should not collect dust. Corridors and doors must be able to accommodate the largest automated cleaning equipment in use. Modern cleaning methods should be thoroughly considered in plans for station maintenance during the initial design process.

5. AGT COMMAND/CONTROL TASK ASSIGNMENTS

The specific human factors design requirements of the AGT Command and Control Center will vary from system to system, and have been described in sufficient detail elsewhere (see for instance, Van Cott and Kinkade, 1972) in terms of workplace design. The assignment of Command and Control tasks, however, is a problem with particularly salient human factors implications which have not been thoroughly explored in many practical applications analogous to AGT systems. While AGT systems are thought of as "automated," in reality the determination of whether to assign any particular function to an automated system, a human operator, or some combination thereof deserves more careful consideration.

In theory at least, four basic control assignment options are available for any task. When automated control is used, the system is primarily monitored and/or controlled by an automated system, and human responsibilities are restricted to maintenance. Human or manual control involves the monitoring and control of systems functions by a human operator, with automated support limited to sensors, displays, and servo. Situations involving a shared responsibility between manual control and automation may include those in which the human interacts with an automated system, monitors or supports the functions of this system, or is monitored or supported by the system. Finally, optional manual or automated control may be used in situations where either human or automated functions will be satisfactory, and task assignments are made on the basis of factors such as costs or convenience.

In making AGT task assignments using the four preceding options, two basic rules may be delineated:

1) When task requirements or conditions exceed human resources (e.g., tasks involving extremely rapid decision making, rapid and accurate computations, extremely precise control, high levels of force application, long periods of inactivity, or exposure to adverse environmental conditions), automation is dictated.

2) When human resources are available to meet task requirements, and when task characteristics are known to be very difficult to automate, human assignment is dictated. Such tasks include those in which complex descisions must be based on incomplete data, data inputs are qualitative rather than quantitative, workload is unpredictable, and successful completion of the task requires complex pattern recognition.

5.1 Critical Tasks and Operational Conditions

The critical tasks in AGT system control can be broken down into three major groups or categories: vehicle protection, vehicle supervision, and vehicle operation. It is clear that other functions such as cleaning, maintenance, emergency evacuation of passengers, prevention of crime and apprehension of criminals, and solutions to passenger problems require human participation. These tasks are discussed in detail in other sections of this guideline.

It is possible to categorize the conditions under which AGT control tasks must be performed. In fact, task assignments cannot be properly made without understanding the differences between various operational situations. Three types of conditions may be specified:

1) Normal Operating Conditions. This entails routine operations where the system is functioning on a normal schedule at normal performance levels within the predicted design parameters of the system.

2) Abnormal Operating Conditions. This entails operation under unusual conditions resulting in significantly degraded system function, due to factors such

as extreme weather, mechanical breakdown, excessive passenger loads, or power reductions. Operations under these conditions can be expected to inconvenience passengers, but do not pose a direct or indirect physical threat to passengers, system personnel, abutters, or property.

3) Emergency Operating Conditions. Under these conditions unanticipated and/or uncontrollable events, including cataclysmic system failures, extreme weather conditions, vandalism, sabotage or other criminal acts, seriously disrupt system operation and pose a significant and immediate threat to the safety, health, and physical well-being of passengers, staff, the surrounding community and property.

5.2 Guidelines for Task Assignment

AGT system subtasks must ultimately be carried out under normal, abnormal, and emergency operating conditions. In the following discussion, major system control function subtasks are described and defined, and optimal assignments to human, machine, or some combination thereof are suggested.

5.2.1 Vehicle Protection Assignments

5.2.1.1 Vehicle Detection

This requires the monitoring of track sections to determine if a vehicle or vehicles are occupying a particular track, track section, or designated block.

Under normal conditions, this operation should be fully automated.

Under abnormal conditions, the operation should be automated but should have some degree of manual supervision.

Under emergency conditions, where the automated monitoring system itself is suspect, manual supervision is required. Otherwise a shared responsibility for this function is acceptable.

5.2.1.2 Vehicle Separation

This entails the maintenance of required between-vehicle headways to insure a proper level of service and lower the probability of collision due to emergency deceleration.

Under normal conditions, this operation should be automated.

Under abnormal conditions, the operation should be automated with a manual override where restoration of system operation is required after failure, or to rescue stranded passengers.

Under emergency conditions, where the movement of a limited number of vehicles or rescue is required, or where failure to activate will cause damage to vehicles, separation can be maintained manually. In any other situation, movement should be postponed until the situation reverts to a less dangerous or abnormal level, where automated separation control can be maintained with manual override.

5.2.1.3 Movement Commands

This entails the starting and stopping of vehicles and maintainence of speed.

Under normal conditions, this should be a totally automated operation.

Under abnormal conditions, this operation should be automated with a limited manual override as required to put the system back into service.

Under emergency conditions, manual control should be used where actual emergencies preclude waiting for the resumption of automated control. Such situations include the rescue of injured passengers or vehicles which are in immediate danger. Otherwise, issuance of movement commands should be delayed until the situation returns to normal.

5.2.1.4 Overspeed Protection

This involves the monitoring of the deviation between actual and required vehicle speed. In general, overspeed protection should be designed to fail-safe standards.

Under normal conditions, monitoring should be accomplished by the automated system. However, periodic field checks with velocity measuring devices such as the radar sensors used in the railroad industry are advisable.

Under abnormal and emergency conditions, the overspeed protection may remain in the automated function mode as long as the collision avoidance and train protection systems are operating normally.

5.2.1.5 Interlocking

This entails the prevention of conflicting vehicle movements.

Under normal conditions, this function should be under total automated control.

Under abnormal conditions, automated control with manual supervision is recommended.

Under emergency conditions, automated control may be overriden in the case of actual emergencies, where immediate dangers threaten the passengers, crew, or the system itself. It should of course be recognized that interfering with or disabling any part of the interlocking system can be extremely hazardous; therefore, only in instances where there is direct danger should the interlock controls and safeguards be overridden. In freight railroad incidents where interlocks are overridden and trains are passed into blocks which are registered as already occupied, a written statement is required from the operator, confirming conditions necessitating the movement and the concurrence of other responsible parties.

5.2.2 Vehicle Supervision

5.2.2.1 Schedule Design

This involves the planning of vehicle movements to accommodate vehicle demand within equipment, guideway, and other system constraints.

Under normal conditions, schedule design for an AGT system should be basically automated, with manual data inputs used to cover changes in work schedules due to holidays, or changes in traffic due to parades, sporting events, concerts, or other community events.

Under abnormal conditions, the system should incorporate automated schedule design with periods of manual support. When the system is capable of falling back to lower performance levels, it should be permitted to set schedules within specified parameters with minimal human support. Where unanticipated problems affect the system in ways beyond the design range of reduced performance levels, human inputs with automated support will be required.

Under emergency conditions, the schedule design to be used after service is resumed should be directly supervised and overridden where necessary by human operators.

5.2.2.2 Schedule Implementation

This entails the execution of the schedule design.

Under normal conditions, this function should be completely automated.

Under abnormal conditions, this function should also be automated.

Advanced scheduling is difficult to implement under emergency conditions, because the regular schedule is based on the successful accomplishment of goals within the original systems constraints. Therefore, schedule implementation should be under direct manual control in emergency situations.

5.2.2.3 Vehicle Identification

This involves the monitoring of vehicles within the system to determine whether the proper vehicle is at the appropriate place designated by the operating schedule.

Under normal conditions, this function should be automated.

In abnormal conditions, this function should also be automated.

Under emergency conditions, the function should be automated, except in situations where failure of the vehicle identification sensors is suspected, requiring manual support.

5.2.2.4 Vehicle Dispatching

This involves the control of the vehicle's departure from terminals or yards.

Under normal conditions, this function should be automated.

Under abnormal conditions, this function should be automated with human override available when necessary.

Under emergency conditions, this function should be manual.

5.2.2.5 Route Assignment and Control

This involves the selection and assignment of routes and the maintenance of vehicle position on the route schedule.

Under normal conditions, the function should be automated.

Under abnormal conditions, this function should be automated with manual support.

Under emergency conditions, this function should be manually controlled, with automated support for those sections of the route which are not directly affected by the emergency.

5.2.2.6 Performance Monitoring and Control

This involves the monitoring of vehicle speed, acceleration and deceleration, and/or point-to-point elapsed time, and the maintainence of vehicle performance within the systems design boundaries.

Under normal conditions, this function should be automated.

Under abnormal conditions, for instance, where increased passenger loads or reduced traction due to slippery surfaces reduces vehicle performance capacity, manual adjustment of the schedule requirements should be possible.

Under emergency conditions, performance monitoring control should remain in the automated mode for those sections of the system unaffected by the emergency. For those sections directly or indirectly affected by the emergency, particularly where the possibility of failure of the performance monitoring system is suspect, performance monitoring should be performed with direct human supervision.

5.2.2.7 Detection of Malfunctions

This entails the detection of abnormal or potentially disruptive and/or hazardous conditions in vehicles operating on the guideway.

Under normal conditions, malfunction detection should be automated.

Under abnormal conditions, detection of malfunctions should also be automated, but there should be manual observation and supervision of critical areas.

Under emergency situations, malfunction detection should be a shared responsibility, with human operators monitoring the performance of the automated system responsible for detecting malfunctions. Direct observation of the malfunction should be required before restoring sections of the system affected by the emergency to service following solution of the problem.

5.2.2.8 Control of Vehicles in Yard

This involves the assembly of trains or groups of vehicles, movement of vehicles within the yard, and dispatching of the vehicles to maintenance or service bays.

Under normal conditions, this function should be automated with manual supervision. For systems with a small number of cars, where it would be uneconomical to automate, this function should be manually controlled.

Under abnormal conditions, this function should be also automated with manual supervision, or solely manual, depending upon system size.

Under emergency conditions, this function should be automated with manual supervision and manual override, if the emergency is not in the yard. If the emergency is in the yard, then this function should be manually controlled.

5.2.3 Vehicle Operation

5.2.3.1 Acceleration and Jerk Control

This involves control of acceleration, deceleration, and rates of acceleration and deceleration, or "jerk," of individual vehicles, to ensure a comfortable and safe ride for the passengers.

Under normal conditions, this should be an automated function.

Under abnormal conditions, this should also be an automated function.

Under emergency conditions, particularly when emergency stops are anticipated, manual support is required. It should be possible for operators to remotely stop individual vehicles by overriding their speed controls or braking. These remotely controlled stops should include full automated control of deceleration and jerk if possible. When emergency stops are necessary, some level of servo support is still required to avoid the hazards of "open-loop" braking, which can cause severe forces (i.e., damaging to both the vehicles and the passengers) under low speed braking conditions.

5.2.3.2 Station Stopping (and Bypass Capabilities)

This entails control of the vehicle deceleration so that it actually stops at the designated point of the platform in the station, and so that vehicles may bypass stations when abnormal and emergency conditions prevail to relieve overcrowding at particular points along the route.

Under _normal_ conditions, station stopping should be automated. Bypass capability is not required in this type of situation.

Under _abnormal_ conditions, station stopping control should also be automated, with manual override provided to bypass empty stations and redirect vehicles to overcrowded stations. Fully loaded vehicles should also be able to bypass stations except when the unloading of passengers is required.

Under _emergency_ conditions, station stopping should be automated, with manual override and manual supervision available for station bypass, particularly where passenger evacuation is required. In this way, empty vehicles may be routed to overcrowded stations directly, without stopping at empty passenger terminals.

5.2.3.3 Door Control

This entails control of the opening and closing of the vehicle doors.

Under _normal_ conditions, vehicle doors should be opened and closed at the station automatically. Door dwell times and related forces are discussed in Section 2.2 of this guide.

Under abnormal conditions, door opening and closing should also be controlled automatically, with manual override provided where necessary to prevent passengers from entering disabled or partially functioning vehicles.

Under emergency conditions, the opening and closing of doors at the station should be under manual control with automated support. In areas of the system or sections of the station where it is imperative that no passengers enter or leave the vehicles, there should be manual override to keep the doors shut. Manual door override should also be provided for situations in which the doors must be opened to evacuate passengers in an emergency when the train is not at the station area. Manual control of the doors by the Command and Control Center is also desirable.

5.2.3.4 Vehicle Start

This entails starting vehicles in motion from the station.

Under normal conditions, this function may be automated, or it may be partially under passenger control. This depends on the exact features of the particular AGT system under consideration.

Under abnormal conditions, this function should still be automatically controlled, but manual override should be possible to allow early or late departure of the vehicle depending upon crowding conditions.

Under emergency conditions, suppression of the vehicle start command may be important, and therefore manual control of this function should be used.

6. THE COMMUNITY

The interactions between various AGT subsystems and the community are critical for the efficient functioning and success of the system as a whole. A system which is poorly integrated into the surrounding community in terms of location and design, or one which develops a negative image due to its detrimental effects on the environment, may not be able to maintain the public support necessary to insure its optimum function. Since the community and AGT system are assumed here to interact jointly, the effects of each on the other will be discussed in turn.

6.1 The Effects of AGT Systems on the Community

The implementation of any new transportation system in a community is bound to command a certain amount of attention from the public. The coming of a new system may instill hopes of increased mobility in certain segments of the population such as the poor, handicapped, and elderly. For others who harbor certain assumptions and stereotypes regarding public transportation and its effects on the community, the AGT system will be perceived as an intrusion upon an established pattern of daily life and an imposition which is difficult to tolerate. Thus, in order to maximize the positive and minimize the negative effects of systems implementation, the human factors aspects of the actual construction and introduction of the system into the community must be considered.

6.1.1 Impact of Vibration and Noise on the Community. From the time systems construction begins through the course of normal operations, certain areas in the community may experience unusual levels of noise and vibration. It may not be assumed that the public will get used to these environmental intrusions; rather, sensitivity and number of complaints may actually increase with duration of exposure. Thus, any systems implementation effort must include provisions to minimize such environmental intrusions, lest they create a negative image of the system in the community.

Vibration in the course of building and operating the system can be a particularly annoying problem to people occupying buildings directly involved in guideway and station construction. For this reason, every effort must be made to minimize public inconvenience and disturbance resulting from the construction and operation process. Where guideway or stations must physically penetrate or contact high rise buildings, stringent efforts must be made to eliminate the transmission of vibration. Residences should not become involved in systems construction if significant levels of building vibration are produced, since no perceivable level of vibration is acceptable in the home (ISO, 1977a). Special care should also be taken when installing AGT systems in hospitals and places where precision work is carried out, in order to avoid unacceptable levels of vibration. Buildings housing banks, offices, factories, and shopping areas may be best suited to accommodating the construction and operation of AGT terminals.

Blasting, if required for AGT systems construction, should never occur at night. Even in the daytime, exposure to this type of vibration should be very limited to prevent public complaint.

Buildings should be measured for the effects of vibration close to a point at which motion would be expected to enter the human body. Two proposed recommendations for building vibration limits from members of the ISO Technical Committee 108 on Mechanical Vibration and Shock are as follows:

1) Between 0.063 - 1.000 Hz, the maximum allowable horizontal vibration drops logarithmically from approximately 0.080 to 0.028 rms m/sec^2, remaining at 0.028 rms m/sec^2 between 1 and 2 Hz (ISO, 1977b suggested by Dr. A. Irwin of the United Kingdom); and

2) For vertical vibration between 4 and 8 Hz, maximum allowable acceleration in residential areas is 0.01 rms m/sec^2. Below 4 Hz, the limit changes by 3 dB/octave; above 8 Hz, the limit changes by 6 dB/octave.

For transverse vibration of 1 and 2 Hz, maximum allowable acceleration in residential areas is 0.0072 m/sec^2. Above 2 Hz, the limit increases by 6 dB/octave (ISO, 1977a submitted by the Deutsches Institute fuer Normung E.V.).*

It is suggested that vibration reaching twice the above values will result in minor complaints, while major complaints from the community will be heard at four times these values (ISO, 1977a).

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*Both of these proposals are being considered by ISO Technical Committee 108 Sub-committee 2 on Human Exposure to Shock and Vibration. It is expected that both will be adopted after editoral and format changes are completed.

Noise may create annoyance similar to that caused by vibration during the construction and operation of AGT systems. In general, noises with strong pure tone components and irregular rates of repetition should be avoided whenever possible. Noise should be minimized particularly at night around residential areas; construction and systems operating schedules should reflect this consideration. It might also be expected that the quieter the community before the introduction of the system, the less noise will be tolerable during construction and operation (Peterson and Gross, 1974).

High frequency noise is somewhat more easily masked (i.e., drowned out) by general background noise than are low frequency sounds of the same amplitude. However, low frequency noises may actually be less annoying subjectively. "Wheel squeal" is a particular problem for steel-wheeled AGT vehicles on steel-railed guideways. This squeal generally is worst in short radius turns. Therefore, in the routing of AGT vehicles of this design, every effort should be made to eliminate such turns from residential areas. Where this is not possible, sound absorbing structures should be provided for above-grade areas, and/or sound-absorbing foliage for at-grade structures.

Location of maintenance, cleaning, and parking facilities must be carefully chosen, as these functions are likely to produce noise, chemical run-offs, and disruption of street patterns. They are also a prime target of vandalism and crime. Such facilities should therefore be located in industrial or commercial rather than residential areas whenever possible.

During general operation of the system in urban residential and office areas, a maximum noise level of 45 dB or less (measured at 50 ft (15.2 m) from the guideway) has been found to be satisfactory to the public, generating no significant complaint reaction (Peterson and Gross, 1974; Woodson and Conover, 1970). Noise levels of less than 50 dB are suitable for areas near banks, restaurants, and stores (Woodson and Conover, 1970).

6.1.2 Changes in the Pedestrian Environment. It is likely that construction of a modern AGT system in any particular urban center will require relocation and redesign of various existing pedestrian facilities. Such an effort provides the rare opportunity for a city to reassess and augment the quality of service provided to all pedestrians in the downtown areas, especially since the AGT system is often considered an extension of the pedestrian mode (Kornhauser and Philip, 1975).

It is recommended that walkways leading to terminals be at least 48 in. (1.22 m) wide; a width of 54 in. (1.37 m) is even more desirable. Widths of 60 in. (1.52 m) are recommended where wheelchairs are likely to pass each other. Walks should be nearly level (grade of 5% or less) and devoid of steps. They should provide minimum distances to access points. Walks should be of a contrasting shade to adjacent ground to aid visually impaired pedestrians. If the walk surface is dark, a white line at least 5 in. (13 cm) wide should be painted down the middle. Walks must be made of a hard, smooth, non-skid surface in order to be accessible to the handicapped and elderly.

Pylons or other visual displays denoting the presence of the terminal should be large, illuminated at night, and visible to a person with 20/20 vision at 100 yd. (91 m). They should be designed to contrast rather than blend with surrounding architecture and lighting patterns. Snow melting coils and bright lighting should be used in areas directly bordering access points.

Street signs in the vicinity of the terminal should have metal plates attached no higher than 5 ft (1.52 m) from the ground with raised letters or Braille. Traffic lights might be accompanied by directionally oriented sounds of different pitches to indicate the green and amber signals to the blind. The amber light should never be less than 5 sec in duration.

Wheelchair passengers will require 36 in. wide curb cuts, ramps over gutters, and cutaway areas in the middle of pedestrian islands in order to cross streets in the vicinity of the terminal. Drains should be located underneath ramps and crossovers or away from the corner side of ramps. Textured "caution strips" (Kirk, 1974) should be laid 36 to 60 in. (0.91 to 1.52 m) before and 12 in. (30.5 cm) to either side of ramps, curb cuts, and drains to warn the blind. Pedestrian crossings should be indicated by textured or striped markings at least 84 in. (2.13 m) wide. A refuge area (e.g., pedestrian island) is recommended for any crossing exceeding 50 ft (15 m) in length.

Construction of the AGT system may require major destruction of sidewalks and streets, which may then be rebuilt to better accommodate the expected pedestrian flow brought into the urban area by the system. Sidewalks should be widened wherever possible and obstructions to pedestrian traffic relocated to improve circulation. Pedestrian connectors bisecting long blocks may be built contiguous with the AGT guideway. Pedestrian malls and plazas which exclude all vehicular traffic would seem most suitable for certain urban areas with AGT systems (Fruin, 1971).

Parking areas near AGT systems must provide enough space to accommodate all of the additional parking requirements generated by systems use. Such parking areas might be located in various suburbs, the size of each proportional to the number of people expected to drive to that area to obtain access to the system. Feeder terminals at the outskirts of the urban area must be within walking distance of designated parking areas.

Twelve ft (3.6 m) wide parking spaces reserved for the handicapped must be accessible and approximate to terminal entrances and exits. Signs at the entrances of parking lots should indicate the location of such reserved spaces and give directions to them. Parking spaces for the handicapped should have hard, smooth surfaces suitable for wheeling and walking with a cane or crutch. They should be located near walkways with 36 in. (92 cm) wide curb cuts or ramps so that individuals will not be required to wheel or walk behind parked cars to reach the terminals (Hilleary, 1969).

6.1.3 Crime and Accident Prevention. It is a common assumption that construction of a new mass transit system in an urban area provides new opportunities for crime, vandalism, and the migration of "undesirable elements" of the population from the inner city to relatively low crime areas in the suburbs. This is not necessarily the case, especially if steps are taken by the system to "crime-proof" areas around terminals and guideway within the community in question.

It has been suggested that while the coming of a new transit system may result in a statistical increase in crime in the community, the actual crimes contributing to this increase are committed against the system itself rather than against the public, and consist of such offenses as fare evasion and guideway crime and vandalism (Arthur Young and Company, 1974). While this conclusion may be true of rapid transit systems with operators or other systems personnel on board at all times, no evidence on changes in community crime rate is presently available for completely automated systems. Although one might expect similar increases in crimes against the system in AGT communities, it might also be expected that crime against isolated passengers such as muggings, theft, rape, and assault, would also increase, especially at night in run-down areas. Thus, the maximum feasible number of crime preventive design features (e.g., video surveillance, emergency telephones, etc.) should be included in AGT systems. K-9 or other security patrols might also be necessary in certain parts of the community.

Stations which are located in run-down areas are highly susceptible to crime. Attention should seriously be paid to land use and condition of surrounding buildings in choosing the location of a potential station. The best location for a station in relation to other buildings on the street is in the middle of the block, since only two directions of escape are available to a felon. Corner stations provide criminals with multidirectional escape routes; however, it is recognized that many other considerations go into the choice of station location besides security. Entrances and exits to stations should not be concealed by shrubs, trees, parked cars, fences, signs, or billboards.

Streets and parking lots surrounding the station should be well lighted. High levels of illumination (8-10 ft-cd) have been found to reduce pedestrian accidents, and improve the security and public image of an area in several large and medium-size U.S. cities. At the very least, illumination levels in urban AGT areas should be maintained at 2.0 ft-cd for major thoroughfares, 1.2 ft-cd for collector streets, and 0.9 ft-cd for local or minor streets. Light poles should be spaced so that illumination from one lamp overlaps that of the next lamp; this will help to achieve a uniform distribution of light on the street (Fruin, 1971).

Guideways must be adequately protected against vandalism to prevent vehicle derailment. This is especially important in completely automatic systems where there is no operator present to handle emergencies. Perimeter fencing along guideways is suggested to keep children and other obstructions off tracks and roadbeds, and to prevent vandals from tampering with track system components. Alarms and video surveillance might be used to inform Command and Control center personnel of intrusions into guideways. Emergency exits off the guideways which are one-way only could also reduce opportunities for vandalism. Overpasses should be either completely eliminated or kept under constant surveillance to guard against objects falling or being thrown onto tracks and moving vehicles.

6.1.4 Aesthetics of AGT Systems. It is assumed that many AGT systems will have elevated guideways running above a large number of streets and thoroughfares in the urban area. Such guideways could be considered a disruption of the cityscape to which most urban dwellers have become accustomed, unless the design of the AGT system is flexible and complementary to the existing aesthetics of the urban area. Although elevated guideways may be a cost-effective and practical solution to various other system problems, they present the a significant aesthetic problem in terms of integration of the system into the community. The impact of the AGT system upon the immediate visual environment depends upon the consideration and preservation of certain architectural characteristics which are unique to each urban center.

In general, it should not be assumed that slender guideway structures with few supports and long spans are ideally suited for all cities. In some cases, such structures may intrude aesthetically because they are different in nature from the solid, rectilinear designs of many older urban buildings. Guideways, particularly when they are high, will often blend in better with existing urban architecture if spans are not too long. As in the case of most aesthetic questions, however, this must be resolved on a specific, local basis.

For many applications, it is suggested that pairs of guideways be considered rather than single direction guideways in isolation from each other. The squarer proportions of double guideways supported on pairs of slender columns create an appearance which is more compatible with many older urban structures. Double guideways which are about 16-17 ft (5 m) wide also make emergency passenger evacuation easier and decrease the number of streets on which guideway structures are required. They could also provide protection from the elements for pedestrian facilities (e.g., shops, kiosks, malls) built beneath them.

Visual obstruction of building facades may create aesthetic problems, especially when the guideway rises at an angle and appears to sever the middle of buildings unevenly. For the best aesthetic effect, guideway height should approximately equal the level of ground floor ceilings of buildings in the same area. When the height of horizontal structures exceeds about 10 ft (3 m), visual intrusion increases sharply. This height may obviate the possibility of taller vehicles such as trucks passing underneath; however, it is also conceivable that communities may decide to restrict commercial traffic in pedestrian/AGT downtown areas.

Ideally, curves and restricted speed sections of the route should be located close together on the guideway. The view of important community landmarks should be preserved. Guideway structures themselves should be designed for ease of cleaning and resistance to dirt and splashing. Drainage areas which do not collect rubbish should be included in the design.

Lightweight shop facia may be interposed between guideway piers, and street furniture such as mailboxes, newstands, telephone booths, signs, etc., may also be incorporated into the guideway design to make it appear more attractive. Local businesses should be encouraged to extend their premises toward AGT guideways, and stations may be put in new buildings with various commercial establishments. AGT systems and local businesses might even wish to share the cost of escalators and elevators connecting systems platforms to upper level shops (Russell, 1975).

In general, perhaps the most important rule of thumb to be applied in designing AGT systems to interface aesthetically with the existing community is that no single architectural or structural solution will be uniformly successful over the whole length of the system (Russell, 1975). The design of AGT subsystems such as guideways and stations must be responsive to the architectural demands of the various areas of the community in which they are located. Each individual station should be tailored to its particular site; however, there is no reason why similar station components and design features could not be functional across the board (Bayer and Grimwade, 1975).

Finally, the AGT system should be capable of making a positive contribution to the urban visual environment. It should be designed in keeping with the basic aesthetic values of the community, whether these are oriented toward the restoration of old, historic urban structures or the development of a modern, stream-lined architectural system. The integration of the AGT system into the urban environment may also facilitate a number of environmental improvements such as landscaping and provision of new pedestrian facilities, which will upgrade and enhance the visual aesthetics of the community as a whole.

6.1.5 Land Use. It is expected that widespread implementation of AGT systems will have a significant impact upon the urban environment, including the way land is used in a community. The impact of previous transportation systems like the highway/automobile on land use in various communities has been profound, particularly in terms of spreading out urban populations among the suburbs. Thus, it is important to explore the ways in which AGT systems will affect the size, density, and quality of establishment in most urban areas.

Kornhauser and Philip (1975) have tried to make such predictions regarding land use and transportation trends within the community for cities with PRT systems, which may be summarized as follows:

1) It is expected that total transportation efficiency in the community will increase, since the addition of a new mode generally increases total system capacity, especially in traffic peaks. Automobile use may decrease, thus improving the efficiency of automobile performance and decreasing the cost of driving in the urban center.

2) The system may provide increased mobility to that segment of the population who do not presently own cars.

3) The size and scope of existing, automobile-based urban transportation systems will probably be maintained with the advent of PRT systems, although increased speeds and decreased travel times are expected for this mode.

4) The PRT is expected to increase the size of urban areas, due to improvements in automobile system performance resulting from decreased auto use in the PRT service area. However, higher intensity land use may be expected in the area directly served by the PRT system.

5) On a macro-level, a more uniform density pattern is expected throughout cities, due to the ubiquitous character of the PRT.

6) On a micro-level, densities near stations and other modes within the service area will become more varied.

7) Functional separation and specialization of urban areas (e.g., residential, commercial, etc.) initiated with the rise of the automobile will continue under PRT implementation, supported by increased personal mobility and the ubiquity of PRT transportation service.

Everett (1975) further predicts that AGT systems will reinforce the urban dispersion and individual trip planning which grew out of the widespread use of the automobile. Whether this is an advantage or disadvantage of systems implementation must be determined by the community itself; Everett suggests that while these effects may be advantageous for the individual in the short run, they may adversely affect the masses in the long run.

Other recent studies of the land use impacts of post-World War II rail rapid transit systems indicate that the greatest intensifications of land use have occurred near transit stations and in central business districts rather than in outlying fringe areas of the subject cities (Knight and Trygg, 1977). However, the authors emphasize that installation of a transit system is not generally sufficient to cause a significant intensification in use of adjacent properties. Rather, where positive land use impacts have occurred, these appear to have resulted from the combined effects of a number of factors complementary to the transit system's installation, such as a compatible local land use policy, strong public support, land availability, and so on.

It may also be expected that construction of an AGT system will ultimately increase the value of surrounding property in the community, primarily because of increased access but also due to concomitant improvements in and restoration of surrounding buildings, streets, landscapes, and pedestrian facilities necessary for systems implementation. The construction of new transportation systems such as the AGT may have some negative economic impact on a community by removing a certain amount of land from local property tax rolls. However, studies in the San Francisco Bay area and other regions have shown that "substantial increases in adjacent property values result from [the development of] new transit systems" (Arthur Young and Company, 1974, p. 28). Increased initiation of commercial development on properties surrounding the system may also be expected, especially if the system is designed to include terminals within buildings and storefronts integrated into guideway design.

6.2 The Effects of the Community on AGT Systems

Community reaction to the implementation of an AGT system is extremely critical in terms of the systems' ultimate survival. Community support for a system may provide an important measure of protection against crime and vandalism and result in a thorough integration of the system into the surrounding community, high levels of ridership, and ultimate cost-effectiveness which will benefit both the system and the community alike. The system must therefore initiate and maintain a positive public image during the conceptual, design, construction, and operational stages of systems development.

6.2.1 The Community's Role in Crime and Vandalism Control. AGT vehicles, stations, guideways, and security control facilities should of course be designed to deter criminal activities without reliance upon public intervention. However, if passengers can be motivated to a point where they are willing to provide surveillance over its physical components as well as over one another, a powerful extra measure of security control will be afforded. An effective plan of action to combat public apathy toward crime in the AGT will save on maintenance costs and encourage widespread use of the system in the long run.

In order for the public to care enough about a transit system to want to make it safe and preserve it from vandalism, it has to identify with the system and feel some sense of ownership. Stations and vehicles should be endowed with the different values of the community and become areas of display for social interests and activities. Art shows may be staged in stations and in vehicles. Local news and music may be broadcast periodically throughout the system. Vehicles may be named after ordinary people in the community. Children and teen-agers should also be permitted to have activities of interest located within the system. Such measures may conceivably turn potential vandals and other criminals into protectors of the system. Community activities may also be staged during off-peak hours to maintain an optimal security passenger density level within the system.

Another way of combatting public apathy toward crime is by publicizing the various crime and vandalism countermeasures designed into a system. The participation of passengers in the implementation of these countermeasures should also be publicized, although care should be taken not to identify the individuals. This will contribute to the passenger population's feelings of well-being when using the system, and may encourage the reporting of crimes and passenger intervention to help others. If passengers know that help will be on the way soon after a crime is committed, and that they can help with little risk to their own safety, they might not be as reluctant to offer immediate aid to a victim.

Knowing that the system is designed to protect passengers will contribute to their identification with the system and promote good public relations. It will also discourage potential felons and vandals from using the system as an outlet for their crimes.

The community can also facilitate crime control on AGT systems through the cooperation of local police and other authorities. It would be advantageous for both the AGT system and the community if systems security personnel were able to communicate directly with and rely upon the local police for help in apprehending transit criminals, especially youthful gangs of offenders who terrorize the elderly in vehicles and stations, and then escape into the streets. It is recommended that some type of liaison with the police be established by the system prior to construction in a community, so that the appropriate information about systems operation and existing crime countermeasures can be exchanged before major crimes begin. If local police are understaffed or under severe budget restrictions, perhaps some joint effort against crimes commonly committed both inside and outside the system (e.g., robbery, purse-snatching, assault) could be implemented.

It is likely that only large AGT systems will be able to afford their own fully equipped police force. It is therefore most important that the system maintain good relationships with local police, judges, and school officials. Transit criminals apprehended by the authorities should be prosecuted, lest the local police feel they are wasting their time. Juvenile court judges will appreciate the cooperation and interest of local transit systems such as the AGT in developing methods of deterring vandalism. Educational programs against vandalism and tours of the system for juveniles might be arranged with local schools, to increase young people's identification with the system and make them aware of the results of stonethrowing, guideway obstruction, and other transit crimes.

6.2.2 Community Attitudes Toward AGT Systems. While it is true that the community's attitudes and behavior may make or break the AGT system, it is also true that the AGT system can do a great deal to shape community attitudes toward itself. Passive measures of molding such attitudes include the minimization of ongoing community activity disruptions and intrusions on the environment which have already been discussed in Section 6.1. Active measures include the assessment of public expectations and attitudes toward the new system, and the shaping of these toward a well informed, realistic, and hopefully positive regard for the system through the use of advertising and marketing research. The quality of systems design and level of public expectation must dovetail to a certain extent if the AGT system is expected to survive as a cost-effective transportation alternative in a community.

The AGT system should not be "sold" to the public as a panacea for all community problems. While this approach may be tempting in order to win initial public support, it will be detrimental to the system's image in the long run when these promises remain unfulfilled in the face of unrealistically inflated public expectations. Systems planners should consider a widespread preliminary advertising campaign to show the expected results of systems construction and implementation. This should include information about the actual construction process, including the ripping up of streets, rerouting of traffic, and relocation or renovation of community buildings. Actual photographs rather than line drawings or "blue prints" should be used wherever possible. The general idea is to minimize the discrepancy between the public's perception of what will happen to the community and what actually will happen.

Similarly, the public may make certain assumptions about what the AGT system will do and how it will work. For instance, many people may expect the system to embody the positive characteristics of both automobile (privacy, comfort, speed, flexibility) and public transportation (reduced urban congestion and pollution), with none of the disadvantages of either mode. They may also expect the AGT system to include dual-mode operations (Everett, 1975). The public will undoubtedly have many other expectations which cannot be anticipated here and which may seem unfounded and unreasonable to systems planners. It is therefore extremely important to provide the public with as much information as possible prior to and during systems implementation; this is the only way systems planners can expect public expectations to be in line with the actual product.

Different segments of the population may want and expect different types of service and amenities from the AGT system. Thus, it is recommended that marketing research be conducted to identify prominent segments of the public who are potential AGT systems users. Advertising, pricing, and design of actual systems features and trip characteristics should be conducted in response to the results of such studies. For example, systems in cities with large retirement communities may find it useful to incorporate many design features for the handicapped and elderly in stations and vehicles. Other systems accommodating a large number of commuters may wish to advertise their extra-capacity shorter headway service during rush hours. The best strategy for successful implementation of the system depends upon knowing the identities and relative numbers of various special interest groups who are potential system riders; thus, the perfect mix of design, trip, and advertising features to maximize public acceptance and utilization of the system will vary from community to community.

There is sufficient evidence in the psychological literature to conclude that while an individual's attitudes do not always correspond to his behavior, there is often a strong relationship between them.

Charles River Associates (1978) have explored this relationship in an attempt to generate a mathematical model of user attitudes toward transportation systems, based upon questionnaire responses of over 1000 Chicago area bus and train users. According to their results, external variables such as household income, number of automobiles, etc., influence an individual's perceptions of a system's attributes and availability, which subsequently influence his modal affect (i.e., whether or not he likes the system). It is this attitude toward the mode which then influences the passenger's behavior to use the mode.

The Charles River Associates' theory (1978) predicts that ridership on a particular mode will not increase merely because the public's perceptions of that mode have become more favorable; rather, these favorable perceptions must be translated into an increased <u>liking</u> of the mode in order to effect any behavioral change. Thus, merely adding a number of attractive new design features to a system is no assurance that ridership will increase, since the public may perceive these attributes positively but still not like the system any better. Also, there appears to be a strong feedback relationship between perception and behavior, such that experience using the system contributes to the public's perceptions of systems attributes. It may therefore be worthwhile for a new AGT system to offer initial complimentary rides or discounts to steady customers as a means of building public support for the system.

BIBLIOGRAPHY

Abernethy, C.N., Plank, G.R., and Sussman, E.D. Effects of deceleration and rate of deceleration on live seated human subjects. U.S. Department of Transportation. Final Report No. UMTA-MA-06-0048-77-3, Transportation Systems Center, Cambridge, MA, October, 1977.

Abt Associates. Accessibility of the Metropolitan Washington, DC Public Transit System to the handicapped and elderly. Cambridge, MA, Feb., 1974.

American National Standards Institute. American National Standard Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks. ANSI A17, 1-1971. The American Society of Mechanical Engineers. New York, NY, 1971.

American Public Transit Association. Moving people safely: Safety guidelines for urban rapid transit systems (3rd edition). Washington D.C.: American Public Transit Association, November 197

American Society of Heating, Refrigerating, and Air Conditioning Engineers. ASHRAE handbook of fundamentals. New York: ASHRAE, Inc., 1967.

American Standards Association. American Standard Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Hadicapped. ASA A117, 1-1961. New York, NY, 1961.

Arthur Young and Company. An analysis of alternative police plans for rapid transit systems: Bay Area Rapid Transit District. Report prepared for B.R. Stokes (General Manager, BART). Sacramento, CA, May, 1974.

Bayer, M. and Grimwade, W. The design of elevated guideways & stations for Minitram in Sheffield. Technical Papers: 1975 International Conference on Personal Rapid Transit Vol. II, No. 31. University of Minnesota Continuing Education and Extension/University of Colorado Center for Urban Transportation Studies. Denver, CO, Sep 1975.

Carstens, J.P. and Kresge, D. Literature survey of passenger limitations of high-speed ground transports (Report D-910353-1). United Aircraft Research Laboratories. East Hartford, CT, July 1965.

Charles River Associates. On the development of a theory of traveler attitude-behavior interrelationships. Final Report No. DOT-TSC-RSPA-78-14, I-II U.S. Department of Transportation, Research and Special Programs Administration. August, 1978.

Everett, P.B. The psychological impact of personal rapid transit. Technical Papers: International Conference on Personal Rapid Transit Vol. II, No. 27. University of Minnesota Continuing Education and Extension/University of Colorado Center for Urban Transportation Studies. Denver, CO, Sep 1975.

FM Transportation Systems. Dual Mode Transit System: Phase II - Technical Proposal. Vol. 2, Part 1 - "Technical Approach in New Areas". For DOT-UMTA, Contract No. DOT-UT-40010, May 1974, Section 3.6.1 Security and Vandalism Control Study.

Fruin, John J. Pedestrian planning and design. Metropolitan Association of Urban Designers and Planners, Inc. New York, NY, 1971.

Griffin, M.J. Proposed ammendments to ISO 2631-1974. International Organization for Standardization Doc. No. ISO/TC 108/SC 4/WG 2 54. July, 1977.

Harris, Oscar L. A Methodology for Developing Security Design Criteria for Subways. Transportation Research Institute, Carnegie Mellon University, Pittsburgh, PA, UMTA-URT-5(70)-71-4, October, 1971.

Hilleary, J.F. Buildings for all to use. American Intitute of Architecture Journal, March, 1969, 39+.

Hirshfeld, C. F. Disturbing effects of horizontal acceleration. Electric Railway President's Conference Committee, Bulletin No. 3. Sep 1932.

International Organization for Standardization. Guide for the evaluation of human exposure to whole-body vibration. ISO 2631-1974 (E). 1974.

International Organization for Standardization. Vibration and shock limits for occupants in buildings. Amendment to ISO Standard 2631-1974. Doc. No. ISO/TC 108/SC 4 46. Submitted by Deutsches Institut fur Normung EV (DIN). Jan., 1977a.

International Organization for Standardization. Guide to the response of occupants of buildings and off-shore structures to low frequency horizontal motion (0.063 Hz to 2 Hz). A proposal submitted by A. Irwin (United Kingdom). Doc. No. ISO/TC 108/SC 4/WG 2 58. April, 1977b.

Jacobson, I.D. A trade-off analysis design tool - - - Aircraft interior noise-motion/passenger satisfaction model. Department of Mechanical and Aerospace Engineering, University of Virginia (Charlottesville). Unpublished manuscript, 1977.

Jacobson, I.D. Barber, R.W., Pepler, R.D. and Vallerie, L.L. Comparison of passenger-comfort models in buses, trains, and airplanes. Transportation Research Record, No. 646, 1977, 1-6.

Kirk, L. Accent on access: HUD guidelines for accessibilities of the handicapped. HUD Memorandum to Pat Cass. Jan 1974.

Knight, R.L. and Trygg, L.L. Land use impacts of rapid transit: Implications of recent experience. Final Report, U.S. Department of Transportation. Office of Policy, Plans and International Affairs. DeLeuw, Cather, and Co., DOT-TPI-10-77-29. August 1977.

Kornhauser, A.L. and Philip, C.E. PRT in the land-use environment: The implied changes. Technical Papers: 1975 International Conference on Personal Rapid Transit Vol. II, No. 25. University of Minnesota Continuing Education and Extension/ University of Colorado Center for Urban Transportation Studies. Denver, CO, Sep 1975.

Military Standard of Human Engineering Design Criteria for Military Systems, Equipment and Facilities, MIL-STD-1472A, May 1970.

Murrell, K.F.H. Ergonomics. London: Chapman and Hall, 1969.

Pepler, R.D., Vallerie, L.L., Jacobson, I.D., Barber, R.W., and Richards, L.G. Development of techniques and data for evaluating ride quality. Vol I, II, and III. Final Report No. DOT-TSC-RSPD-77-1, I-III Dunlap and Associates, Inc., Darien, CT March, 1977.

Peterson, A.P.G. and Gross, E.E. Handbook of noise measurement (7th ed.). Concord, MA: General Radio, 1974.

Ravera, R. J. and Anderes, J. R. Factors in lightweight guideway costing. MITRE Technical Report MTR 6969. July 1975.

Russell, W. Visual and environmental effects of minitram guideways. Technical Papers: 1975 International Conference on Personal Rapid Transit Vol. II, No. 30. University of Minnesota Continuing Education and Extension/University of Colorado Center for Urban Transportation Studies. Denver, CO, Sep, 1975.

Schnell, J.B., Smith, A.J., Dimsdale, K.R., and Thrasher, E. J. Vandalism and passenger security. A study of crime and vandalism on urban mass transit systems in the United States and Canada. Final Report No. DC-06-0017. National Technical Information Service. Springfield, VA Sep 1973.

Southeastern Pennsylvania Transit Authority. Vandalism suppression by helicopter. The effectiveness of the 1974 program in SEPTA area on Penn Central and Reading commuter lines. 1974.

U.S. Army MIL-HDBK-759. Human Factors Engineering Design for Army Material. March 1975.

U.S. Department of Transportation. The additional cost of providing mobility for the elderly and handicapped on the Washington, DC Metropolitan Rail Rapid Transit System. May, 1973.

Van Cott, H.P. and Kinkade, R.G. (ed.) Human engineering guide for equipment design. Washington, DC: U.S. Government Printing Office, 1972.

Woodson, W.E. and Conover, D.W. Human engineering guide for equipment designers. Berkeley, CA; University of California Press, 1970.

Wormley, D.N., Hedrick, J.K., Eglitis, L., and Costanza, D. Elevated guideway cost-ride quality studies for group rapid transit systems. U.S. Department of Transportation. Final Report. No. DOT-TSC-OST-77-54. Massachusetts Institute of Technology, May 1977.

APPENDIX
HUMAN FACTORS CHECKLIST
FOR AGT SYSTEMS DESIGN

This appendix is intended for use as a tool in the planning and evaluation of AGT systems. In essence, the checklist is a summary of the preceding guidelines which have been reduced to a convenient operational format. Space has also been provided for comments regarding other features of the system not covered in the checklist, and explanations of alternative design solutions to the human factors problems addressed here. Criticisms and suggestions for systems improvements may also be recorded.

INSTRUCTIONS: Answer "YES" or "NO" to the following questions. If the answer to any question is "NO," or if a question does not pertain to the system under consideration, explain in the space marked "COMMENTS" in the section below.

THE VEHICLE

1. General Interior Design

_____ a) Are insulation, sound attentuation and decorative materials solidly attached to the vehicle enclosure?

_____ b) Are the cars permanently enclosed, without openings for passengers' heads and limbs to protrude?

_____ c) Are walls and seats permanently mounted by bolts or rivets?

_____ d) Are partitions permanently bolted in place and arranged to provide for dynamically balanced loading of the vehicle?

_____ e) Are sharp edges and corners absent from the interior, along with materials which shatter and break?

_____ f) In vehicles accessible to the handicapped, is there

_____ 1. a 60 x 60 in. (1.54 sq m) space immediately inside doors?

_____ 2. a 32 x 54 in. (0.82 x 1.38 m) rest area for wheelchairs?

_____ 3. a 32 in. (82 cm) wide aisle?

_____ 4. spatial symmetry about doors to aid the blind?

_____ g) Are floors made of non-skid materials?

COMMENTS: ______________________________

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2. Entrances and Exits

_____ a) Are one or two entrances provided in vehicles carrying fewer than 17 passengers?

_____ b) Are entrances equipped with horizontally closing doors?

_____ c) Are doors operated by automatic closing and re-opening devices which release in the event of an obstruction, but remain closed on impact?

_____ d) Are doors manually operable from inside and out?

_____ e) Is there a warning indicator which alerts the Command and Control Center to doors not securely closed?

_____ f) Is an audiovisual signal provided to indicate a closing door?

_____ g) Are glass panels flush with the inside surface of the door panel?

_____ h) Do door panels have flush surfaces?

_____ i) Are door panels strong enough to protect occupants adequately in case of damage to glass?

_____ j) Are doors strong enough to hold their shape when passengers lean on them (i.e., capable of withstanding a force of 250 lb (113 kg) applied at right angles to and approximately at the center of a panel, and distributed over an area of approximately

4 in. x 4 in., (10 cm x 10 cm), as dictated by ANSI A17.1-1971, Rule 110.11e-7)?

_____ k) Are door openings a minimum width of 32 in. (82 cm), free of protruding hardware?

_____ l) Are door dwell times sufficient to allow for disabled passengers' movements (minimum 7 sec)?

_____ m) Is an automatic vehicle stopping system which provides repeatable and accurate door positioning part of the system?

_____ n) Are vehicle floors near doors free of thresholds?

_____ o) Is the gap between the vehicle and platform floors at the doors less than 2 in. (5 cm) horizontally and vertically?

COMMENTS: ______________________________

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3. Passenger Supports

_____ a) Are vertical stanchions located away from doors?

_____ b) Are full-width seatback bars extending no more than 1 in. (2.5 cm) toward the aisle attached to each seat?

_____ c) Are horizontal handgrips 30 to 40 in. (0.76 to 1.02 m) from the floor located immediately inside doors to aid wheelchair passengers?

_____ d) Is grip circumference on all supports between 3 and 5 in. (8-13 cm)?

_____ e) Is there at least 2 in. (5 cm) clearance between support grip areas and adjacent surfaces?

COMMENTS: ______________________________

4. Seats

_____ a) Are bench-type seats in use?

_____ b) Are seat arms approximately 5 in. (13 cm) above the seat surface and 6 and 9 in. (15-23 cm) forward of the seat back?

_____ c) In vehicles serving the handicapped and elderly, are seats near doors reserved for their use?

_____ d) Do seats all face the same direction?

COMMENTS: ______________________________

5. Passenger Restraints

_____ Is a simple sliding bolt or other device provided for restraint of wheelchairs within the vehicle?

COMMENTS: ____

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6. Windows

_____ a) Are windows made of laminated or tempered glass, polycarbonate, or some unbreakable non-acrylic combination?

_____ b) Has window defogging been provided for by locating air outlets of the heating-air conditioning system around window frames?

_____ c) Is window glass tinted to add to passenger comfort and reduce the air conditioning load?

COMMENTS: ____

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7. Temperature and Ventilation

_____ a) Do temperatures range between 75 and 85 °F in summer and 60 and 68 °F in winter?

_____ b) Is a positive provision made for ventilation (e.g., air inlets and outlets around window frames)?

_____ c) Can the vehicle be vented to the outside in case of climate control system failure?

_____ d) Is air flow through vehicle propulsion and control equipment isolated from the passenger compartment?

_____ e) Are separate cooling or ventilation systems provided for electrical or mechanical components in the vehicle?

COMMENTS: ____

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8. Electrical and Lighting Systems

_____ a) Is all wiring grounded?

_____ b) Are all exposed electrical components covered?

_____ c) Are the following vehicle components insulated from electrical shock?

_____ 1. flooring

_____ 2. side boards

_____ 3. doors

_____ 4. handles

_____ 5. passenger supports

_____ d) Have signs been erected to indicate the presence of high voltages?

_____ e) Are 30 to 50 ft-cd of illumination (measured approximately 3 ft (93 cm) above the cab floor) provided in the vehicle's interior?

_____ f) Does illumination vary at most 30% between the lightest and darkest areas of the interior?

_____ g) Are diffuse lighting sources in use?

_____ h) Are reflecting surfaces painted with non-saturated colors?

_____ i) Are two or more lamps present in each vehicle? Are their bulbs protected from breakage?

_____ j) If light switches are provided in the passenger compartment, are they of the key-operated variety, or enclosed in a fixture with a locked cover?

COMMENTS: ______________________________

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9. Displays

_____ a) Do signs in the vehicle contrast well with their surroundings?

_____ b) Are signs visible from every standing and seated position in the car?

_____ c) Are schedules and/or taped audio announcements of stops available inside the vehicle?

_____ d) Are messages clear, concise, and comprehensible to those with below average verbal comprehension?

_____ e) Is an audio-visual warning signal available to alert passengers of emergency conditions?

_____ f) Are auditory signals at least 10 dB above the ambient noise level and functional on emergency power?

_____ g) Are visual signals hooded from direct sunlight and functional on emergency power?

COMMENTS: ______________________________

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10. Controls

_____ a) Does the vehicle have an emergency stop switch available to the passengers?

_____ b) Can able-bodied and handicapped passengers reach a manual door activation switch, emergency stop switch, and communication equipment to the Command and Control Center?

_____ c) Is the emergency stop switch manually operable and located in a conspicuous and accessible position in the vehicle?

_____ d) Does the emergency stop switch have a red actuating handle or button, spring-loaded to remain in position.

_____ e) Are the controls adequately illuminated and shielded from glare and reflection?

_____ f) Are controls arranged to minimize accidental activation?

COMMENTS: ______________________________

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11. Other Vehicle Equipment

_____ a) Is there a device in the car interior to automatically indicate passenger overload to the Command and Control Center (as previously determined by safe maneuverability, braking characteristics, and structural strength of the vehicle)?

_____ b) Are passengers provided with auditory and visual signals indicating overload?

----- c) Is the vehicle equipped with a fire detection system which can distinguish between overheat and fire conditions and relay this information to the Command and Control Center?

----- d) Are fire extinguishing devices or systems provided on the vehicles?

_____ e) Does each car have a permanent and durable capacity and data plate displayed in a conspicuous position, which states the rated load of the car, its weight, the manufacturer's name and address, and other pertinent information?

----- f) Is a vehicle obstruction sensor provided in the vehicle?

COMMENTS: ______________________________

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12. Special Security Provisions

_____ Is some type of security monitoring system (e.g., video surveillance, emergency push-buttons, passenger microphones, etc.) provided in the vehicle?

COMMENTS: ______________________________

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13. Vehicle Ride Environment

_____ a) Are starting and braking accelerations less than 0.35 g (all passengers seated) or 0.15 g (some passengers standing)?

_____ b) Do ride motions comply with a Comfort Index (C) value of 3.0 as evaluated according to the method described on p.___?

_____ c) Can impact accelerations feasibly be limited to 20 g with a maximum duration of 0.05 sec?

d) Do noise levels range between 60 and 65 dB in the 300-600, 600-1200, and 1200-2400 Hz octave band, with an over-all value of less than 70 dB?

COMMENTS: ____

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14. Maintenance Functions

1) Principles of Maintenance Hardware Design

_____ a) Are mechanical, electrical, and control systems periodically inspected, and faulty system components repaired and/or replaced?

_____ b) Is test equipment arranged in accordance with the principles of good anthropometric work place design?

_____ c) Do test instruments incorporate human-engineered display designs, proper labeling, quick release fasteners, and non-interchangeable cables, connectors and conductors?

_____ d) Are service areas and serviceable vehicle equipment designed within the functional reach envelope of a standing operator?

_____ e) Is the control system modularized with plug-in units?

_____ f) Does supporting equipment leave the operator's hands free to work, provide good visibility, and a non-skid surface? Can it be located at the appropriate level for work?

COMMENTS: ____

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2) Principles of Maintenance Software Design

_____ a) Are one or two workers assigned to perform routine inspection of all mechanical, electrical, and control systems in a vehicle, instead of using assembly line task assignment?

_____ b) Do maintenance personnel perform a variety of tasks to reduce monotony?

_____ c) Has an inspection performance payoff matrix of reinforcement been worked out to increase "hits" and decrease "false alarms"?

_____ d) Are maintenance training and brush-up courses provided?

_____ e) Are labeling and instructions aimed at the comprehension level of the least expert technician to service the equipment?

_____ f) Is etched or embossed lettering used on labels for maximum legibility even after exposure to the environment?

COMMENTS: ____

3) Vehicle Cleaning

_____ a) Are complex designs and delicate absorbent materials which may hinder cleaning avoided?

_____ b) Are interior surfaces made of smooth, washable, "vandal-proof" materials?

_____ c) Are exterior surfaces made of materials which can resist water, strong solvents and detergents, and high-pressure steams and sprays?

_____ d) Are surface projections and recesses which might complicate cleaning avoided in the design?

COMMENTS: ____

THE GUIDEWAY

1. Emergency Evacuation

_____ a) Is there some feasible means of passenger evacuation from vehicles disabled on the guideway?

_____ b) Is the power rail embedded in the sidewalls of the guideway, or otherwise located to minimize tripping, electrocution, etc.?

_____ c) Are guideway structures compatible with fire extinguishing equipment available in the surrounding community?

_____ d) Are combustibles periodically removed from all rights of way?

_____ e) Are high voltage areas along guideways marked with conspicuous signs?

_____ f) Is emergency lighting available in tunnels?

_____ g) Are any systems personnel specifically trained in emergency rescue techniques?

_____ h) Are contingency plans for rescue worked out and rehearsed in advance of emergencies?

_____ i) Are planned escape routes feasible for the evacuation of injured passengers in stretchers and wheelchairs, and for individuals dressed in heavy winter clothing?

_____ j) Are elevated guideways accessible to community rescue equipment which can reach heights of 30 ft (9.3 m) or less?

_____ k) If evacuation ramps are provided, are these at least 36 in. (92 cm) wide with 1.5 in. (4 cm) lateral flanges to facilitate wheelchair use?

_____ l) Is the gap between the evacuation ramp and vehicle or platform floor less than 2 in. (5 cm) horizontally and vertically?

_____ m) Are guideways laid out to provide numerous points of access for rescue equipment and a wide range of passenger escape routes?

_____ n) Is there enough light and ventilation in guideway areas to conduct rescue efforts?

COMMENTS: ____

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2. Ride Quality

_____ a) Are guideways kept free of obstructions and debris which may cause accidents and impair ride quality?

_____ b) Have critical resonant frequencies of vehicle and guideway components been considered in the design of guideway structures?

_____ c) Are vehicles required to maintain a fairly narrow pre-determined speed range to optimize ride quality?

_____ d) Does the guideway have control and communications channels and a means of vehicle power pick-up?

_____ e) Does the guideway design provide for positive retention of the automatically steered vehicle along the guideway sidewall/or center guide rail?

_____ f) Are regular braking and programmed stops signaled to passengers inside vehicles?

COMMENTS: ____

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3. Security

_____ a) Are guideways elevated or otherwise protected against vandalism (e.g., by fences, helicopter patrol, etc.) in high crime areas?

_____ b) Are systems properties adjacent to guideway structures periodically cleared of debris and junk?

_____ c) Are signals and switches adequately protected against vandalism?

_____ d) Is the guideway equipped with an automatic protection system to detect and communicate the presence of intruders and obstructions?

_____ e) Is any non-automated security protection (e.g., helicopter surveillance, K-9 patrol) provided in high crime areas?

COMMENTS: ______________________________

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THE TERMINAL

1. General Interior Design

_____ a) Are temperatures in large terminals maintained between 75 and 85° F in summer and 60° and 68° F in winter?

_____ b) Is there sufficient ventilation to eliminate smoke and odors from small terminal structures?

_____ c) Do small terminals provide protection from the elements?

d) Are floors made of a non-skid material and kept free of water and debris?

_____ e) Are textured floor surfaces used to warn blind passengers of heavy pedestrian traffic and danger areas?

_____ f) Can stations expand and contract in area to provide optimum security passenger density levels at different times of day?

_____ g) Does station design facilitate long sight lines and eliminate positions of concealment?

COMMENTS:

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2. Entrances and Exits

_____ a) Are doors at least 84 in. (2.13 m) high and 32 in. (82 cm) wide?

_____ b) Are emergency exits clearly marked and equipped with doors that push open from the inside?

_____ c) Are automatic sliding doors or swinging doors in use?

_____ d) Do swinging doors open in one direction only and have windows?

_____ e) Are swinging doors used in pairs separated by a post for two-way traffic?

_____ f) Are entrances and exits clearly labeled? Are the adjacent areas separated by railings?

_____ g) Can doors be opened by a single effort not exceeding 8 lb (3.6 kg)?

_____ h) Are floors level for at least 60 in. (1.5 m) on either side of doors?

_____ i) Have thresholds been eliminated?

_____ j) Are handles leading to danger areas readily identifiable by touch?

_____ k) Have raised letters been placed next to doors as an aid to the blind?

_____ l) Are doors preceded by a pavement of different texture?

_____ m) Are most if not all entrances accessible to the handicapped?

_____ n) Are these designated by a handicapped emblem visible to a seated individual before he arrives at the entrance?

_____ o) Can the system be "closed" to apprehend criminals?

COMMENTS: ____

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3. Aisles and Corridors

_____ a) Are they straight, clear of obstructions, and laid out to provide minimum distances between points?

_____ b) Are corners largely absent from the design?

_____ c) Are "traffic guides" (arrows, signs) provided for passengers?

_____ d) Are aisles and corridors to be used by wheelchair passengers at least 48 in. (1.22 m) wide?

_____ e) Are one-way traffic patterns, blind corners, and corridors with right angles or those forming "T's" largely absent from the design?

_____ f) Are ceiling fixtures suspended at a minimum height of 84 in. (2.14 m) above the floor?

_____ g) Has the passengers' probable line of sight to visual displays been considered in determining the shape and size of corridors?

_____ h) Is the public address auditory communication system design sufficient to allow all passengers to be within normal voice range of speakers?

COMMENTS: ____

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4. Platforms

_____ a) Have guardrails or textured materials been used next to platform edges to aid handicapped passengers?

_____ b) Is platform area sufficient to accommodate the expected level of crowding and still maintain at least 10 to 13 sq ft (1.1-1.3 sq m) of space per person?

COMMENTS: ______________________________

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5. Level Change

_____ a) Do stairs rise at an angle of 20-35° from the horizontal?

_____ b) Is riser height between 5-7 in. (13 8 cm)?

_____ c) Are every 10-12 treads separated with landings?

_____ d) Is tread depth between 9.5 and 10.5 in. (24-27 cm)?

_____ e) Is there a handrail on at least one side of the stairs?

_____ f) Are level change systems other than ramps or inclines provided for normal pedestrian traffic over elevations of more than 13 in. (33 cm)?

_____ g) Do above or below grade stations have a 8.33% grade ramp, lift, or elevator for easy accessibility to the handicapped?

_____ h) Are one-way traffic ramps for the handicapped at least 32 in. (82 cm) wide, with 4 in. (10 cm) high curbs along both sides to facilitate wheelchair braking?

_____ i) Is there a handrail 32 in. (82 cm) above the ramp surface?

_____ j) Do escalators and elevators comply with the American National Standard Safety Code for Elevators, Dumbwaiters, Escalators, and Moving Walks (ANSI A17.1-1971)?

_____ k) Do escalators move at the optimum speed of 120-138 ft/min (36.4-41.8 m/min)?

_____ l) Do escalator handrails move at the same speed as the steps, and are they clearly marked in white every 18 in. to emphasize this movement?

_____ m) Do escalator guard walls extend 5-6 ft (1.5-1.8 m) beyond the exit points?

_____ n) Are entrances to and exits from escalators illuminated at a level at least 20% greater than the surrounds?

_____ o) Are elevators employed to move large numbers of people at least three or more levels?

_____ p) Do elevator doors open at least 32 in. (82 cm)?

_____ q) Are the elevator and terminal floors separated horizontally by a gap smaller than 2 in. (5 cm)?

_____ r) Are the elevator and terminal floors completely level (no vertical gap)?

_____ s) Are elevators at least 63 in. (1.6 m) long x 56 in. (1.4 m) wide, or 60 in. (1.5 m) square to accommodate wheelchairs?

_____ t) Do elevators have force-activated door guards, electric eyes, and an audio-visual door closing warning signal?

_____ u) Are all elevator displays and controls located between 37 and 55 in. (0.94-1.4 m) from the floor and multisensory (e.g., audio-visual, visual-tactile) in nature?

COMMENTS: ____________________

6. Illumination

_____ a) Are light fixtures located at least 84 in. (2.14 m) above the floor?

_____ b) Are 20-40 ft-cd of illumination (measured at the floor level) provided?

_____ c) Have diffuse lighting patterns and pastel reflecting surfaces been used to eliminate glare and "hot spots

COMMENTS: ____________________

7. Displays

_____ a) Are time and location of the next vehicle's departure displayed at system entrances?

_____ b) Are emergency and other warning signals multi-sensory in nature?

_____ c) Are signs in terminals and stops located at least 72 in. (1.83 m) above the floor, with lettering at least 3 in. (8 cm) capital height, and visible from both standing and seated positions in the vehicle?

COMMENTS: ____________________

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8. Ancillary Facilities

_____ a) In terminals with restrooms, is a station agent available to let only one patron in at a time?

_____ b) Is a water fountain provided in each station at a 3 and 34 in. (76-86 cm) height from the floor, with hand-operated, lever-type controls?

_____ c) Are public telephones housed in alcoves (not booths) and located no higher than 48 in. (1.22 m) from the floor?

_____ d) Are concessions equipped with silent emergency buttons or foot pedals to alert security personnel or the Command and Control Center to crimes in the station?

COMMENTS: ____________________

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9. Fare Collection

_____ a) Have measures been taken to prevent the accumulatio[n] of large amounts of money in the system?

_____ b) Are faregates at least 32 in. (82 cm) wide and no more than 40 in. (1 m) high used in systems accommodating the elderly and handicapped?

COMMENTS: ____________________

10. Special Security Provisions

_____ Is some type of station security monitoring system (e.g., television surveillance, passenger microphones, K-9 patrols) provided, especially in high crime areas?

COMMENTS: ____________________

11. Cleaning and Maintenance

_____ a) Are walls made of smooth, "vandal-resistant," washable materials?

_____ b) Are fixtures easily accessible for cleaning and constructed to preclude "dust-catching"?

_____ c) Are doors and corridors wide enough for cleaning equipment to pass through?

COMMENTS: ______________________________________

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COMMAND/CONTROL TASK ASSIGNMENT

_____ a) Is automation used for tasks requiring extremely rapid decision-making, rapid and accurate computations, extremely precise control, high levels of force application, long periods of inactivity, exposure to adverse environments, and other qualifications exceeding normal human resources?

_____ b) Is manual control used for tasks with performance requirements within the normal human range, and especially for tasks which are difficult to automate, such as complex decision-making using incomplete data, qualitative judgments, and pattern recognition?

_____ c) Have control task requirements been assessed and task assignments made for abnormal situations and emergencies as well as for normal operating conditions?

COMMENTS: ____________________

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THE COMMUNITY

1. Vibration and Noise

_____ a) Have stringent efforts been made to eliminate transmission of vibration in buildings making physical contact with guideways or stations?

_____ b) Are commercial establishments rather than residences used as construction sites for guideways and stations whenever possible?

_____ c) Is blasting conducted during daytime hours only?

_____ d) Do vibrations resulting from system construction and operation comply with proposed ISC limits (ISO,1977a, 1977b)?

_____ e) Are noise levels restricted to 45 dB or less near residences, and 50 dB or less near commercial establishments during systems construction and operation?

COMMENTS: ____________________

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2. The Pedestrian Environment

_____ a) Are walkways leading to terminals at least 48 in. (1.22 m) wide?

_____ b) Are walks level and devoid of steps, providing minimum distances between points?

_____ c) Do walkways contrast well with their surroundings?

_____ d) Are walks made of hard, smooth, non skid surfaces?

_____ e) Are visual displays denoting the presence of the terminal visible to a person with 20/20 vision at 100 yd (91 m)?

_____ f) Are areas near terminals brightly illuminated at night?

_____ g) Are information displays in the terminal area (e.g., traffic lights, street signs) multi-sensory in nature?

_____ h) Are 36 in. (91 cm) wide curbcuts, ramps over gutters, and cutaway areas in pedestrian islands provided for wheelchair passengers?

_____ i) Are pedestrian refuge areas provided for crossings exceeding 50 ft (15 m) in length?

_____ j) Are pedestrian crossings indicated by textured or striped markings at least 84 in. (2.13 m) wide?

_____ k) Is there sufficient parking space near AGT "feeder" terminals to accommodate the expected influx of system users?

_____ 1) Have 12 ft (3.6 m) wide parking spaces near terminal entrances and exits been provided for the handicapped?

COMMENTS: ____

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3. Crime and Accident Prevention

_____ a) Have the maximum feasible number of crime preventive design features (e.g., video surveillance, K-9 patrols, etc.) been incorporated into the system to protect isolated passengers?

_____ b) Are stations located away from high crime areas and in the middle of the block whenever feasible?

_____ c) Are areas around station entrances and exits highly visible from the street?

_____ d) Are streets and parking lots near stations well lighted (preferably 8-10 ft-cd)?

_____ e) Are street lamps spaced to provide overlapping illumination?

_____ f) Are perimeter fencing and alarms used to prevent guideway vandalism?

_____ g) Are emergency exits off the guideway one-way only?

_____ h) Have overpasses been eliminated from guideway design wherever possible?

_____ i) Have measures been taken by the system management to encourage a public sense of system ownership (e.g., broadcast of local news and music, naming vehicles after local citizens, staging community activities in terminals, etc.)?

_____ j) Have crime and vandalism countermeasures and passenger participation in anti-crime efforts been well publicized in the community?

_____ k) Have systems security personnel established working relationships with local police, juvenile court judges, school officials, and other community authorities interested in the prevention of crime and vandalism?

COMMENTS: ____

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4. Aesthetics

_____ a) Is guideway span length compatible in appearance with the architectural design of surrounding structures?

_____ b) Have double guideways been constructed wherever this is feasible?

_____ c) Does guideway height generally approximate the ground floor ceiling level of adjacent buildings?

_____ d) Are curves and restricted speed sections of the route located close together on the guideway whenever possible?

______ e) Has the view of important community landmarks been preserved?

______ f) Is the guideway easy to clean and resistant to dirt and splashing?

______ g) Have individual stations and guideway areas been tailored to the aesthetic values of their particular sites?

COMMENTS: ______________________________

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5. Community Attitudes

______ a) Have public expectations been brought into line with predicted systems quality by realistic preliminary advertising and distribution of information?

______ b) Has the system realistically assessed the needs of the community for transportation service and amenities through the use of marketing research?

______ c) Has the system initiated a public relations program to attain a high level of positive public affect toward the system and to build up a high level of public experience with the system?

COMMENTS: ______________________________

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