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Urban Mass Transportation Administration

Innovative Solutions for Disabled Transit Accessibility

Prepared by

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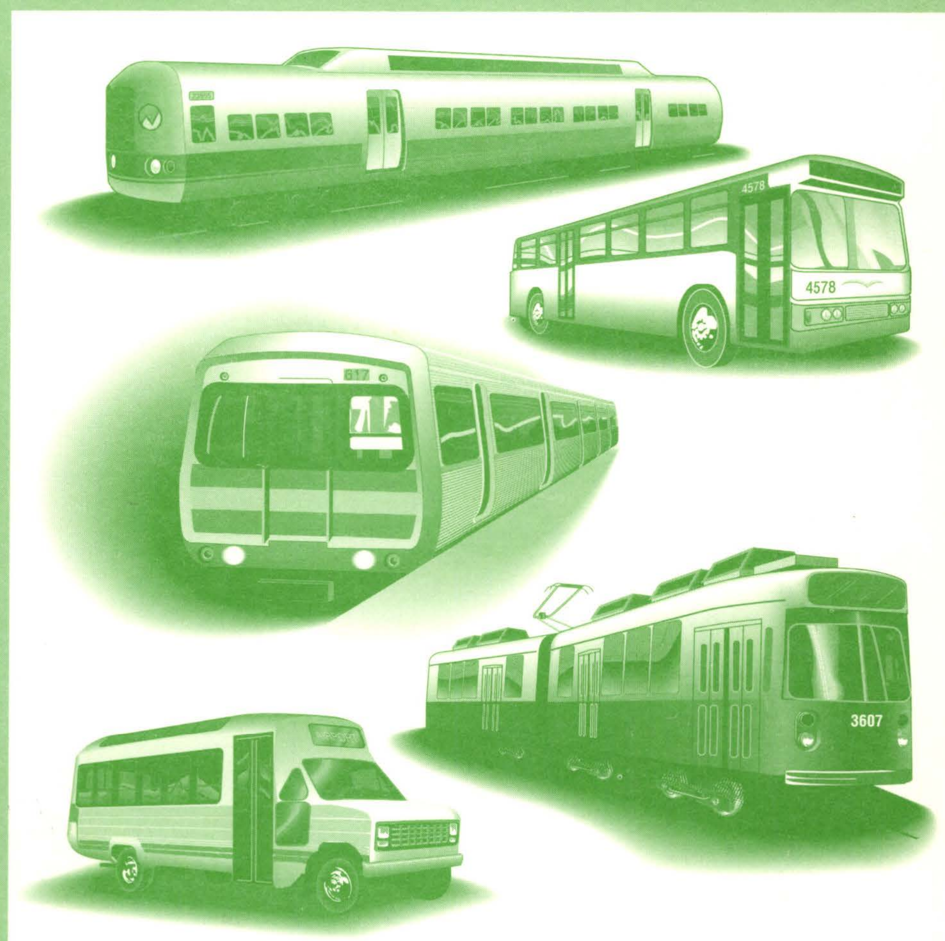

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16. Abstract

This report identifies major innovative technology developments which show promise for provision of transit accessibility in compliance with the Americans with Disabilities Act (ADA) while at the same time being compatible with economic constraints and with the broader mission of transit to serve the general public. Key developments include:

Low Floor Vehicles. The report summarizes potentially revolutionary innovations in the design of European light rail cars which are resulting in floor heights only 12 to 14 inches above top of rail. It also summarizes considerable innovative development in low floor bus technology in Europe and Canada with applicability to ADA accessibility.

Miniplatforms. Short high platforms providing wheelchair accessibility to one set of doors on the lead car of a train show promises as an economical solution for both commuter rail and light rail. Miniplatform installed costs run $10,000-$30,000 a unit.

Platform Edge Warning Systems. ADA regulations require either detectable warning strips or barriers for the platform edge at all new transit stations. The report identifies numerous warning materials now in use or under consideration by transit agencies at installed costs of $10-$30 per square foot. It also discusses the use of electronic detection systems and platform barriers, ranging from simple railings to full coordinated station/vehicle doors as used for automated guideway transit systems.

In all cases, the report provides information on cost, maintainability, acceptance by operators and the disabled community and regulatory implications. It also recommends fruitful areas of research, development and demonstration activity.

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METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32) (5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

PREFACE

Recent passage of the Americans with Disabilities Act (ADA) makes transit accessibility a civil right of all Americans. Imaginative solutions are needed which will comply with the letter and spirit of the law while at the same time being compatible with the severe economic constraints faced by transit today and with the broader mission of transit to serve the general public.

With these needs in mind, the author contacted and in many cases visited transit agencies and suppliers throughout the United States and Canada in search of creative and innovative products and technologies which would be of use in complying with the ADA act. In addition, a thorough literature search and numerous enquiries were made to document the considerable activity in low floor light rail and low floor bus development underway in Europe. This report documents some of the more promising solutions which were uncovered.

The report was prepared under sponsorship of the Urban Mass Transportation Administration (UMTA) Office of Technical Assistance and Safety. The author wishes to thank Franz Gimmler, Ron Kangas, and Roy Field of the UMTA Office of Safety for their direction, guidance and encouragement during the preparation of this document.

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Gene Lozano of the American Council of the Blind deserves special thanks not only for his guidance but for his evaluation of sample platform edge warning tiles provided by suppliers. In addition, thanks are due the following individuals for their assistance in providing information and/or hospitality on my visits: Charles Steward, Robert Adduci, Paul Hughes, and Gerald Morse of the Massachusetts Bay Transportation Authority, Mark

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CHAPTER ONE
INTRODUCTION, CONCLUSIONS AND RECOMMENDATIONS

Some 43 million Americans have one or more physical or mental disabilities and this number is increasing as the population as a whole is growing older. [1] The Americans with Disabilities Act (ADA), signed into law by President Bush on July 26, 1990 makes it a civil rights violation to deny transportation accessibility to disabled persons. The requirements of the statute apply to both public and private entities, whether or not they receive Federal financial assistance. This is expected to have significant impacts on virtually every transit system in the United States. In the words of Jack Gilstrap, Executive Vice President of the American Public Transit Association, "The ADA will clearly have a major effect on the public transit industry. We are very concerned about being able to implement all of the requirements." [2]

As a result, this is a timely moment to review the state of the art for providing accessible service on transit systems including bus, rapid rail, light rail, commuter rail and automated transit. This study surveys available technology and its suitability to accommodate all segments of the handicapped population with emphasis upon the elderly, wheelchair users, users with walkers and the visually impaired. Emphasis is upon current and innovative developments which could be of interest to transit agencies facing the need to meet accessibility requirements of the ADA Act in a cost-effective manner. Because of the large amount of information available on vehicle borne wheelchair lifts for buses and light rail, this option has been specifically excluded from the study.

1.1 CONCLUSIONS

This report has identified the following major innovative technology developments which show promise for provision of transit accessibility to all Americans in compliance with the letter and spirit of the Americans with Disabilities Act while at the same time being compatible with economic constraints and with the broader mission of transit to serve the general public.

1.1.1 Low Floor Light Rail

In Europe, there is extraordinary activity directed towards low floor light rail vehicles which could revolutionize the nature of light rail technology. Innovations include single axle trucks, individual motors for each wheel, and solid state AC propulsion. More important, these innovations go beyond subsystem improvements to represent a complete system level rethinking of traditional railcar design. Since floor height is only 12 to 14 inches above top of rail, wheelchair access can be provided by either raising the normal 6-8 inch curb height another six inches or using a short ramp. This approach to wheelchair accessibility not only fully "mainlines" the disabled but facilitates access by the elderly and infirm in general and also speeds up boarding by the general public. The faster boarding times mean faster service which provides a shorter trip time for all riders and makes more efficient use of equipment, thereby reducing operating costs. Program goals are also oriented to lighter weight, simplicity, energy savings and reduced capital and operating costs. Low floor vehicle technology thus holds the rare promise of being a "win win" situation where the disabled community, transit operators, the taxpayer and the riding public all benefit.

It should be stressed that the radical innovations contemplated have not yet been fully proven in revenue service. Among the issues which need to be addressed by ongoing testing are wheel rail wear, stability and ride quality, practicality of motor mounting arrangements, structural issues, impacts on maintenance facility design, overhang on curves, and adequacy of traction.

In North America, both the Massachusetts Bay Transportation Authority and the Toronto Transit Commission have made firm policy decisions committing their agencies to implementing low floor technology.

1.1.2 Mini-platforms

Mini-platforms, short platforms which provide access to only one set of doors on the lead car of the train, also show promise as an economical solution for providing accessibility for both light rail and commuter rail. Mini-platforms can be built for $10,000 to $30,000 per unit and improve access not only for wheelchair users but for the elderly and others such as persons with baby strollers. If, as in Buffalo, trains routinely pull up to the mini-platform and do not require a bridge plate, mini-platforms can actually speed up the boarding process. A number of inexpensive bridge plate solutions have been developed for commuter rail applications where the gap between the car and platform is unacceptably large. Bridge plates typically slow down the boarding process by a minute or two. The major drawback to mini-platforms is that they require the disabled to normally board only the lead car of a train.

1.1.3 Platform Warning Tiles

Department of Transportation ADA regulations will require either detectable warning strips or platform barriers for the platform edge at all new rail, light rail, commuter rail, automated guideway transit and monorail stations. This study has identified a number of materials either presently installed or under consideration by transit agencies for use as a detectable warning strip. None perfectly meet all of the conflicting requirements for detectability, including bump pattern, visual contrast, and difference in sound-on-cane contact while also being maintainable, durable and easy to clean. Installed costs for edge warning materials run $10 to $30 per square foot, excluding an allowance for engineering and contingency. Available research confirms the detectability of the pattern required by Federal regulations. A two foot edge has been shown to be detectable by 99 to 100% of all blind subjects compared with 89 to 91% for a conventional flamed granite edge. Also, before and after data on track falls at the Bay Area Rapid Transit Agency tend to confirm that platform warning tile reduces track fall incidents not only for the blind but for the general public. On their own initiative a number of transit agencies such as the MBTA and Sacramento have been doing a great deal of useful work on platform edge materials. However, further research is desirable to confirm the proper width of the warning strip and to assist transit agencies in evaluating edge warning materials to find cost-effective solutions.

1.1.4 Platform Barriers

It is possible to provide a simple platform barrier with openings which align with the doors of the stopped train. Such an approach has been urged on the transportation community by the National Transportation Safety Board for over twenty years. The combination of technological advancements in train stopping accuracy plus the new ADA requirements make it desirable to give careful consideration to this solution. A platform barrier provides the least expensive and probably most detectable way to comply with Federal ADA requirements for platform edge warning, provided that trains are able to stop accurately enough to make it a practical solution. Costs range from only $30 per platform foot to install a 3 1/2 foot steel railing to $220 per platform foot for a tempered glass window wall. In addition, platform barriers also eliminate the risk of mistaking the open space between cars as the door and falling between cars of a train. This is a major concern for the blind and visually impaired. Platform barriers have been in use on the West Virginia people mover since July 1979 with no passenger injuries or fatalities from track falls or passenger intrusions onto the guideway. Barrier systems can be made even safer by electronic detection systems located at the openings in the barrier to detect passenger intrusion. Infrared and microphonic detection systems are now available.

Complete separation of station platform areas from the guideway can be accomplished by floor to ceiling walls provided with elevator type doors which automatically open only when a vehicle is berthed in the station. This solution effectively eliminates the train/passenger collision as a safety risk and has been widely used on airport people movers. It is a costly solution ($2400/platform foot) and also adds a significant maintenance effort.

1.1.5 Low Floor Buses

Although U.S. bus operators tend to prefer lift mechanisms for wheelchair access, Europe and Canada are moving towards low floor buses without steps. This benefits not only wheelchair users but the elderly and others who find steps an inconvenience. It also speeds the boarding process, providing better service to all passengers and savings to the bus operator. Europe is considering legislation requiring low floor buses and a recent Toronto Transit Commission policy study concluded that lift equipped buses are not effective because of low utilization by the disabled community. There is a great deal of innovative development in low floor bus technology underway in Europe and Canada which, like developments in low floor light rail has the potential of being a "win win" situation for the disabled, transit operators and the riding public. However, concerns about adequate ground clearance are more serious for buses than for light rail, which typically operates in a more controlled right-of-way. Further evaluation of low floor buses under actual operating conditions is needed to determine needed ground clearances.

1.1.6 Commuter Rail

Commuter rail systems are moving rapidly to provide accessibility. Electrified systems are tending towards high platforms. The problem is more difficult for nonelectrified systems, especially those sharing track with freight. Some of these are using mini-platforms with bridge plates. Onboard wheelchair lifts are also being developed specifically for commuter rail equipment.

Low floor technology is also applicable to commuter rail. Bi-level cars with low floors, 18 inches above top of rail, can be equipped with simple ramps. Present Department of Transportation regulations provide definitive requirements for ramp geometry. However, handicapped persons have indicated difficulty negotiating currently used ramps. It appears that further research is desirable with regard to acceptable angles of incline for various length ramps, and also to determine width and surface friction requirements. Such research will also be useful if low floor bus and light rail equipment using ramps plays an increasing role in American transit.

1.2 RECOMMENDATIONS

Based upon this study, the following areas of potential research, development and demonstration have been identified. These future directions are consistent both with intrinsic trends in technology and the economic and social realities posed for transit by ADA.

1) Developments in low floor light rail technology in Europe should be closely monitored as the newer 100 percent low floor equipment accumulates revenue service. In addition, the U.S. should consider a demonstration of such equipment in conjunction with a local transit agency committed to low floor technology.

2) The Federal government should support research in the area of platform edge materials. This research should focus upon confirming the proper width of the warning edge and on assisting transit agencies to evaluate the various edge warning materials to find cost-effective solutions. In addition to detectability, issues to be addressed should include ease of retrofitting existing stations, maintainability, durability and cost.

3) If interest can be found at transit agencies, the Federal government should promote demonstration of a platform barrier system on an automated rapid rail system. Consideration should also be given towards encouraging development of low cost electronic intrusion systems which can be used in conjunction with platform barriers.

4) Further demonstrations of low floor bus technology should be encouraged. Future demonstrations should give increased emphasis to measurement of road clearances and required breakaway angles, and to determining any added maintenance costs specifically attributable to the low floor design.

5) Consideration should be given to assisting commuter rail systems to develop an onboard wheelchair lift which can be economically retrofit on existing gallery cars.

6) The Federal government should support research to confirm design parameters for ramps to be used in conjunction with low floor buses, light rail cars and commuter rail cars. Important design parameters which could benefit from further research are acceptable angle of incline for various length ramps, width, surface friction requirements, tie downs at ends, rigidity and structural load and safety factor.

1.3 SCOPE OF REPORT

This chapter contains the introduction, conclusions and recommendations. It is followed by four other chapters. Chapter Two discusses innovative solutions for guideway transit boarding. These solutions, which represent alternatives to vehicle borne wheelchair lifts on the one hand, or full high level platforms on the other hand, are primarily of interest for light rail operation. The chapter begins with a discussion of the many recent efforts in Europe to develop low floor light rail cars. It continues with a discussion of mini-platforms. These are short platforms which provide high level access to only one set of doors on the lead car of the train. The chapter closes with a discussion of wayside lifts, wheelchair lifts permanently mounted at the station stop, instead of onboard the vehicle. This approach is being used in both Santa Clara and Portland.

Chapter 3 treats the issue of train/platform safety. This area is of special concern to the blind and visually impaired, who have great difficulty avoiding the hazardous platform edge. This chapter discusses a number of edge protection materials which can meet new ADA regulations, including the "Pathfinder" warning tile which has been installed at rapid rail systems in Miami and San Francisco as well as the Sacramento light rail system. It also discusses other solutions which can be used either in conjunction with or in place of warning tile. These include microphonic and infrared electronic intrusion detection systems, railings and platform barriers, and full separation of the platform from the guideway using station doors coordinated with those on the train. The latter approach has been widely used on automated people movers operating in airports. The report provides information on capital cost, reliability, and maintenance required for these various alternatives as well as data on their effectiveness at improving platform safety.

Chapter 4 addresses innovative solutions for disabled access to commuter rail trains. Approaches parallel those for other fixed guideway systems and include simple mobile wayside lifts, low floor cars with ramps, mini-platforms and full high level platforms. Even the vehicle borne lift can be looked at as an innovation when applied to commuter rail because of the ingenuity required to adapt these lifts, originally designed for bus and light rail use, to the different commuter rail environment. The report summarizes solutions being used by different commuter rail systems and provides estimates of cost, boarding time, and disabled usage data for the various alternatives.

Chapter 5 discusses innovative solutions being used to provide disabled access to roadway transit vehicles. Buses are the most ubiquitous form of mass transit and face a major effort in providing the full accessibility mandated by ADA. While wheelchair lifts will obviously play the major role, both Europe and Canada are moving rapidly towards low floor buses. Buses are available with 12 to 14 inch floor heights and boarding heights with kneeling can be as low as 4 to 8 inches above street level. The report provides information on these developments, as well as on earlier developments in the 1970's which were geared to using either mechanical guidance, electronic guidance, or the operator's own driving skill to align with a high level boarding platform.

CHAPTER ONE REFERENCES

[1] "Americans with Disability Act of 1990", Public Law 101- 336, July 26, 1990, Section 2a, Finding 1.

[2] "Transportation System and Consumers Share Goal: Best Possible Service for Lowest Possible Fare", Jack Gilstrap, Project Action Update, Spring 1991, page 3.

CHAPTER TWO
INNOVATIVE SOLUTIONS FOR GUIDEWAY TRANSIT BOARDING

This chapter discusses innovative approaches now being used to provide for disabled access to guided transit equipment. Before considering these innovative concepts, it is useful to first describe briefly the more conventional approaches to disabled access now in fairly widespread use. One conventional approach is to provide full high level platforms as are commonly used for rapid rail systems. Elevators are installed to provide access to the platform area itself. This approach, using elevators and high platforms, was first used on the Washington Metro in 1976 and has been adopted for all new rapid rail systems since. It is also used for most people mover systems, and has been used for the Los Angeles light rail system. In the future it will continue to be used for rapid rail and people movers; however the cost and physical size of the platforms are impediments to their widespread use for light rail systems.

A major reason for selecting light rail as a transit alternative is cost. Light rail has traditionally been viewed as a compromise between full rapid rail and conventional bus operations. In addition, light rail often operates in constricted rights-of-way, sometimes shared with automobile and/or pedestrian traffic. The combination of space and cost constraints have led designers to search for alternatives to full high level platform access. In some cases (e.g. San Diego), the solution has been to provide wheelchair lifts on every vehicle, much as is done with conventional buses. This is a perfectly workable solution which shares the same advantages and disadvantages as lifts used on buses. The advantage is that lifts developed for the larger bus market can be readily adapted and will do the job. On the other hand, lifts require maintenance, the added weight on the vehicle increases energy consumption, and the time required to operate the lift disrupts vehicle schedules.

For these reasons, designers have been searching for other solutions which can be used for the intermediate capacity applications commonly served by light rail. We have identified three innovative approaches presently in use.

The first approach, originally developed in Europe, uses low floor cars whose floor height is typically 12 to 14 inches above top of rail. By raising the normal 6-8 inch curb height another six inches, full high level platform access can be provided with minimal infrastructure impacts. In North America both Toronto and Boston are committed to moving towards low floor vehicles on key light rail routes.

The second approach employs mini-platforms. These short platforms provide high level access to only one set of doors on the lead car of the train. Access to the mini-platform itself is usually provided by a ramp, although when space is constricted a hydraulic lift can be installed instead. Mini-platforms are presently used on light rail systems operating in San Francisco, Sacramento and Buffalo, as well as the system now under construction in Baltimore. These platforms are popular with passengers because of their ease of use, both by the disabled and by others such as the elderly or persons with baby strollers. Operators like mini-platforms because of the speed of boarding which minimizes impact on schedules. The major limitation is that the disabled are normally required to board only the lead car of a train.

The third approach uses wayside lifts. By locating the lift at the wayside instead of onboard the vehicle two advantages are obtained. First, the lift is removed from the vehicle, eliminating the weight penalty and often reducing the total number of lifts required. Second, it is sometimes possible for the passenger to board the lift in advance of the vehicle arrival, reducing embarrassment to the user as well as delay to other train riders. The major drawback to wayside lifts has proven to be the difficulty of stopping light railcars with an accuracy of plus or minus 3-7 inches to properly align with the wayside lift device. This problem is serious enough that transit agencies now using wayside lifts are seriously considering mini-platforms for future stations.

The following sections discuss experiences with these three innovative solutions to guideway transit boarding.

2.1 LOW FLOOR LIGHT RAIL CARS

There is presently considerable activity in Europe concerned with development of low floor light rail vehicles. The first system began operation in Grenoble, France in 1987 using a fleet of Alsthom-De Dietrich vehicles designed to provide handicapped access from a low-level station platform. [1] In addition to Grenoble, low floor cars are now operating or undergoing testing in Amsterdam, Bern, Geneva, Basel, Turin, Milan, Munich, Bremen, and Freiburg and orders have been placed by numerous other cities. New light rail vehicles, some involving radical departures from conventional truck design, are being developed by the French, Germans, Italians Belgians, Austrians and numerous European consortia.

2.1.1 Types of Low Floor Vehicles

Table 2-1 summarizes major low floor vehicle developments, categorizing them into three major groups based upon the amount of truck redesign required. Group 1 involves no changes in truck design and lowers only 10 to 15% of the floor area. Group 2 limits redesign to the unpowered trucks under the articulation sections. In this manner it is possible to lower 50-70 percent of the floor area. Group 3 involves radical new truck designs affecting both powered and unpowered trucks and achieves a 100 percent low floor design. Group 1, the simplest approach, is based upon a straightforward modification of an 8-axle dual articulated car in which the middle articulation section is dropped between the two center trucks to a height of 11-13 inches. Conventional trucks are used. Floor height in the front and rear articulated sections and over the trucks remains the usual 34-36 inches. This approach involves minimal change in design, but results in only 10-15 percent of the interior floor space being at the low floor level. Steps inside the vehicle are provided between the high floor and low floor sections. The 45 "LRV Stadstram" cars made by BN and now operating in Amsterdam are a good example of a Group 1 design (Figure 2-1). [2] In addition, Schindler has retrofit a single six axle car to eight axles and lowered the floor in the center section only. This prototype is presently operating in Basel. [3] Linke Hoffman

TABLE 2-1. TYPES OF LOW FLOOR LIGHT RAIL VEHICLES

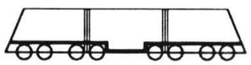
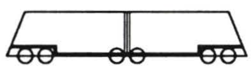
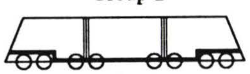
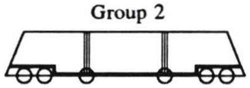
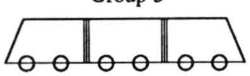
Configuration	Car Name	Supplier	Cities	No. of Cars	Status	Floor Height Inches	Percent Low Floor	Gauge	Trucks
Group 1 	LRV "Stadstram"	BN	Amsterdam	45	Operating	34/11	14%	Standard	Conventional
	Type GTW 8/8	Linke Hoffman Busch	Wurzburg Freiburg	14	Delivery	36/12	10%	Meter	Conventional
		Schindler	Basel	1	Operating (Retrofit)	34/13	- - -	Meter	Conventional
Group 2 	Grenoble	GEC/Alsthom	Grenoble	55	Operating	34/14	61%	Standard	Special independently attached wheels for unpowered center truck
		Fiat	Turin Rome Napoli	54 60	Operating	34/14	56%	Standard	
		ACM/Vevey Duewag	Geneva	45	Operating	34/19	60%	Meter	Small wheeled "Transporter" trucks for center section
	St. Etienne	GEC/Alsthom	St. Etienne	15	Design/ manufacturing	28/14	60%	Meter	
Group 2 		ACM/Vevey Duewag	Bern	12	Delivery	28/14	72%	Meter	2 small wheeled "Transporter" trucks for center section
Group 2 		Duewag	Kassel		Manufacture	28/14	70%	Standard	Conventional powered end trucks. Special 2 wheel truck for center section
	Very Light Rail Car	Breda			Concept	14	100%	Standard	
Group 3 	GT6N LRV	BSAG-MAN Kiepe Electric	Bremen Munich Augsburg	1 3 11	Testing	14/12	100%	Standard	Axleless trucks with 2 powered wheels connected to body mounted motor through Cardan shaft

TABLE 2-1. TYPES OF LOW FLOOR LIGHT RAIL VEHICLES (CONTINUED)

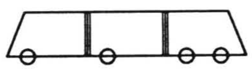
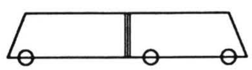
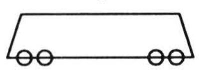
Configuration	Car Name	Supplier	Cities	No. of Cars	Status	Floor Height Inches	Percent Low Floor	Gauge	Trucks
Group 3 	Stadtbahn 2000	German Consortium	Manheim Ludwigshafen		Prototype	14/11	100%	Meter	4 self steering two wheel trucks, 2-3 powered with individual motors
	LRV 2000	BN	Amsterdam		Test	14	100%	Standard	BAS 2000 truck. No axles self steering wheels
Group 3 	Stadtbahn 2000	German Consortium	Dusseldorf Munich Bonn	3	Prototype	14/11	100%	Standard	3 self steering two wheel trucks, 2 powered by individual motors
		Socimi			Development	14	100%	Standard	Trucks with no axles with motors and brakes outboard of wheels
		GEC/Alsthom	Brest and Roey		Development	14	100%	Standard	Side mounted motors
Group 3 		Socimi	Milan		Testing	14	100%	Standard	Trucks with no axles with motors and brakes outboard of wheels

FIGURE 2-1. LRV STADSTRAM IN AMSTERDAM

Busch is supplying cars of the Group 1 type to Wurzburg and Freiburg. [4] Cars using the Group 1 approach are in revenue service and the technology may be considered proven.

The Group 2 low floor designs carry the concept a step further by modifying the non-powered trucks beneath the articulation joints to be compatible with low floor operation. In this way the low floor can be extended through the articulation sections. Conventional higher floor heights are necessary only over the powered trucks at each end of the vehicle. Group 2 designs have been implemented on both single articulated six axle cars and dual articulated eight axle cars. The 55 Alstholm-De Dietrich cars operating in Grenoble are a good example of a single articulated light rail car (Figure 2-2). [5] Another single articulated Group 2 design has been produced by Fiat for Turin, Italy. A fleet of 54 of these cars is now operating in Turin. The cars are 20 feet shorter than the Grenoble cars and configured for unidirectional rather than bidirectional operation. [6] A consortium of ACM, Vevey and Duewag has also developed a single articulated Group 2 car for Geneva as well as a dual articulated Group 2 design for Bern, Switzerland. [7]

There are two approaches which have been taken to lowering the unpowered center trucks. The approach taken by ACM Vevey Duewag simply uses a bogie with smaller diameter wheels. The design is based on the ACM "transporter" bogie, originally developed to move standard gauge freight cars over narrow gauge lines. [8] The other approach, taken by Alstholm and Fiat, uses regular size wheels independently mounted on the legs of a pair of "U" shaped axles which cradle the carbody. Group 2 designs are able to provide a low floor for 50 to 70 percent of the floor area. As with Group 1 cars, steps within the car connect the high floor and low floor sections. Cars of this design have been in revenue service since 1987.

Another Group 2 approach under development is geared specifically to dual articulated vehicles. This approach replaces the conventional truck at the two articulations with a new two-wheel truck (Figure 2-3). The "Very Light Rail Car" (VLRC) a design concept proposed by Breda is based upon this design approach. [9] A unique feature of the Breda concept is that equipment would be located in the ends of the car above the powered trucks. Since this eliminates passenger accommodations above the trucks, the Breda design would achieve a 100 percent low floor (14 inches), even though conventional powered end

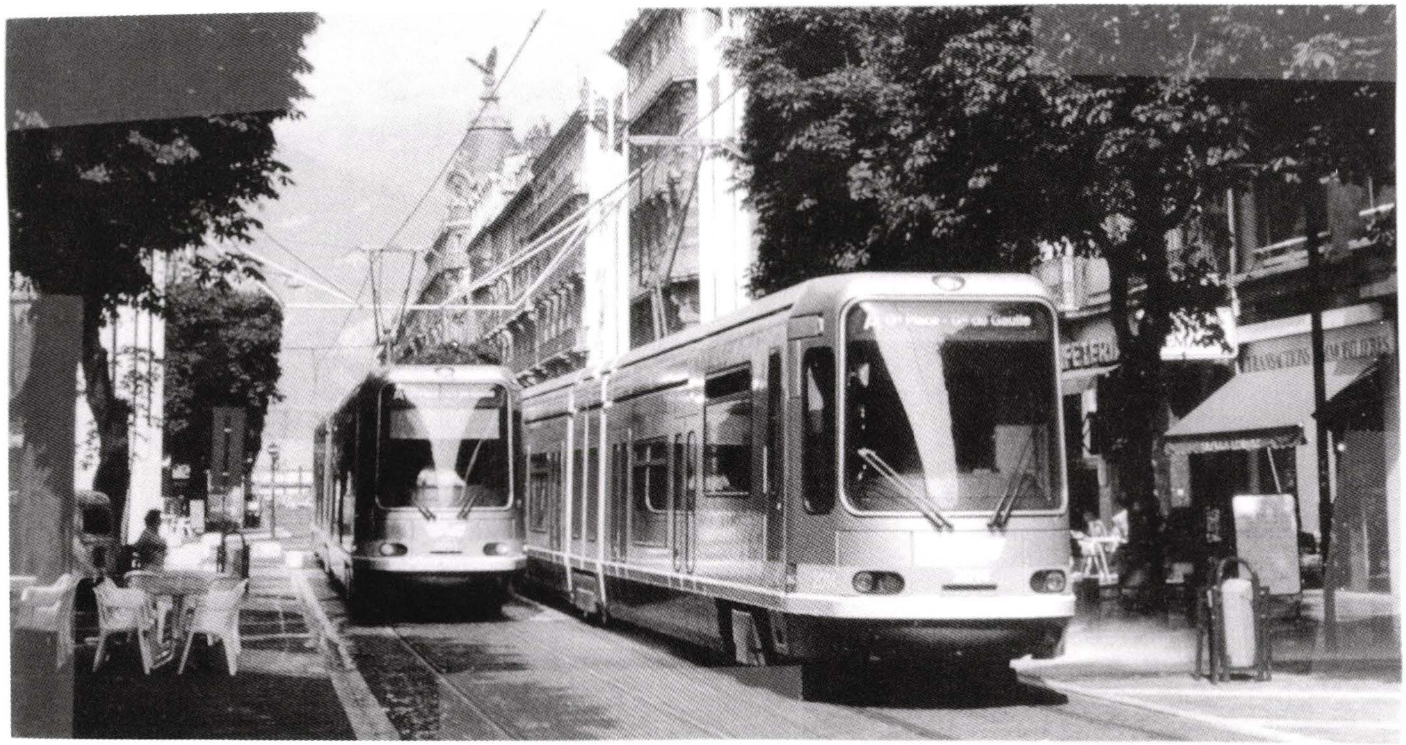


FIGURE 2-2. GRENOBLE LIGHT RAIL CAR

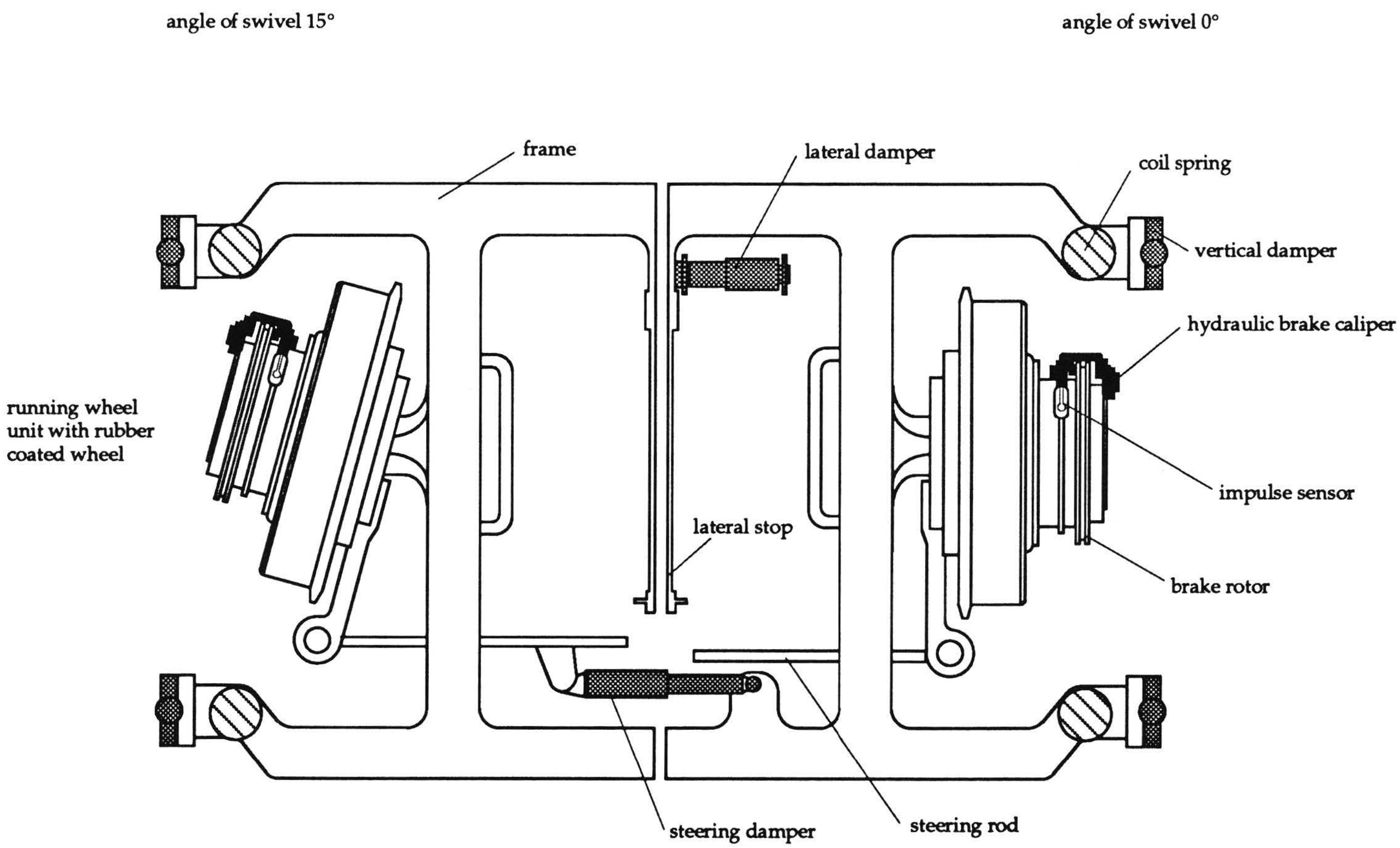


FIGURE 2-3. KASSEL TWO-WHEEL TRUCK

trucks are used. The Germans are also working on this approach and have gone beyond the conceptual phase. Duewag is presently testing a design of this type in Kassel. [10] In the Kassel design, the articulations are supported by self-steering two-wheel trucks providing a 14-inch floor height through 70% of the car length. At each end, conventional powered two-axle trucks with 22 inch wheels provide a 28 inch floor height for the rest of the car. Light weight is a feature of both the Breda and Duewag designs. Total car weight for the VLRC is projected at 372 pounds per passenger and for the Kassel car 345 pounds per passenger (including standees at 4 persons per square meter). This can be compared with 550 pounds per passenger for the Grenoble cars and 710 pounds per passenger for the Portland light rail car, typical of current North American designs. [11,12]

Group 3 represents the most radical low floor design concept. The powered trucks are redesigned as well as the unpowered center trucks, thereby making possible a true 100 percent low floor car. Group 3 designs are being developed for nonarticulated cars, single articulation cars and dual articulation cars. A nonarticulated car is being developed by Socimi for Milan, Italy. [13] The design achieves a 14 inch floor height throughout the car using a novel axle-less truck with a 20 kW motor and disc brakes located outboard of each of the wheels.

Since 1990, MAN-GHH has been testing a prototype of the GT6N LRV, an innovative 100% low floor dual articulated car, on routes in Bremen (Figure 2-4). [14] MAN-GHH also has contracts for three of these cars for Munich and 11 for Augsburg. This low floor design has a single centrally arranged bogie beneath each of the three car sections. Each bogie has one pair of independently mounted wheels and another pair of wheels interconnected by a torsionally stiff low-slung shaft. Power from an AC asynchronous motor underslung longitudinally from the carbody is transmitted to this shaft through a flexible cardan shaft.

An even more revolutionary German design is the Stadtbahn 2000, being developed under the auspices of the German Association of Public Transport Operators (VOV). The program is targeted at developing light weight, low floor cars with life cycle costs comparable to buses performing the same task. [15] Most German car builders and equipment suppliers are involved in the program which will demonstrate standard gauge cars

FIGURE 2-4. MAN-GHH GT6N

in Dusseldorf, Munich and Bonn and meter gauge cars in Mannheim and Ludwigshafen. Standard gauge cars will all be single articulated. Cars will be configured for single direction operation in Dusseldorf and Munich and dual direction operation in Bonn. Meter gauge cars will be dual articulated and configured only for single direction running. Specifications call for a 14 inch floor throughout the car. The heart of the Stadtbahn 2000 project is development of a self steering two-wheel truck. The truck has two independent wheels which pivot around a vertical axis and are designed to automatically align themselves tangent to the track. The truck is essentially a powered version of the two-wheel trucks being used on the cars now under testing in Kassel. An independent 60 kW three phase induction motor drives each powered wheel, providing car speeds up to 44 mph. Only end trucks will normally be powered although it may be necessary to power up to six wheels for the double articulated railcar. To be able to maintain the same torque on the inside and outside wheels of a truck when they are operating on curves at different wheel speeds, separate AC inverters are provided for each motor. Both inverters on a single truck are controlled by a single drive controller. Vehicles are provided with regenerative braking supplemented with electro-hydraulic disc brakes and magnetic track brakes.

In Belgium, BN Industrie is developing its own LRV 2000. A double articulated car with a full length low floor 14 inches above top of rail is planned. [16] The car will be designed around the BAS 2000 independent wheel truck which consists of two independently motored and braked large wheels plus two smaller guiding wheels. A prototype will be tested in Amsterdam. In addition to these designs, Alsthom is planning a 100% low floor car for proposed LRT lines in Brest and Rouen. Design features are said to include short wheelbase motorized trucks with 16.5 inch diameter wheels and side-mounted 70 kW motors. Both single and dual articulated versions are planned.

The latest entry in the low floor light rail competition is now under development in Austria by a consortium of SGP, WVB, and Elin. The floor height is a remarkable 8 inches from the surface of the pavement with no interior steps or ramps. A prototype is now being tested in Vienna. [17]

As will be noted, innovations on the various Group 3 designs are truly revolutionary including axle-less trucks, self steering trucks, individual motors for each wheel, and propulsion motors mounted on the carbody powering the wheels through flexible shafts. Because of these innovations, Group 3 cars cannot yet be considered service proven designs. Among the issues which need to be addressed by ongoing testing are the following: [18]

Wheel Rail Wear. Smaller diameter wheels result in higher contact pressures and greater stress on the wheels. The impact on wheel flats, rail corrugation, and other wheel/rail wear issues needs to be evaluated.

Stability and Ride Quality. The stability and ride quality of the new truck designs needs to be evaluated, including hunting and propensity to derailment.

Motor Mounting Arrangements. The reliability and maintainability of hub-mounted motors and flexible shaft connections from motors on the carbody need evaluation.

Structural Issues. The new cars are much lighter than traditional light rail cars, with buffing loads about a fifth that of older cars. It is unlikely it will be possible to mix new Group 3 low floor cars with older cars. Fatigue life of the new trucks also needs to be confirmed by operating experience.

Maintenance Facility Changes. Existing systems may have to make infrastructure changes to accommodate low floor vehicles. Overhead power systems in the shop may have to be modified to allow for frequent access to roof mounted units.

Overhang On Curves. The ability of low floor cars to stop on curves with adequate front overhang needs to be carefully considered if raised curbs are planned to eliminate the need for ramps or bridge plates.

Traction. Since not all wheels are powered and braked, it will be necessary to confirm the ability of these vehicles to climb hills and stop safely on grades.

The following sections describe representative car designs from the various vehicle groups.

2.1.2 Group 1 - The LRV "Stadstram"

The Belgian supplier BN has produced 25 single direction and 20 dual direction Group 1 low floor cars which have been operating in Amsterdam since 1989-1990 (Figure 2-5). [19] Track gauge is standard. The dual articulated cars have all eight axles on the four trucks powered. AC propulsion is provided with inverter control and regenerative braking. Motor braking is augmented by hydraulic drum brakes and also by eight magnetic track brakes for emergency stopping. The cars have 64 seats and space for 93 standees (unidirectional) or 52 seats and room for 89 standees (bidirectional). Standees are based on a standard of four passengers per square meter. Cars are 84 feet long, have an empty weight of 37 tons, a maximum speed of 44 mph and a minimum curve radius of 54 feet. The floor area between the articulation sections, (14 percent of the total floor area), is at a height above the running rails of 11 inches. The remaining floor is at a height of 34 inches. At the center of each of the three car sections there is a set of sliding plug type double doors; these are on both sides of the dual direction cars and on one side only for the unidirectional cars. The double doors in the middle section provide low floor access into the car. In addition there is a single door opposite the operator's cab, at one end for the unidirectional cars and at both ends for the dual direction cars.

2.1.3 Group 2 - The Grenoble Light Rail Vehicle

In 1987, the first of the new wave of low floor cars began operation in Grenoble, France (Figure 2-6). The standard gauge Grenoble cars are of the Group 2 design and are single articulated cars with an innovative low slung center truck permitting a low floor

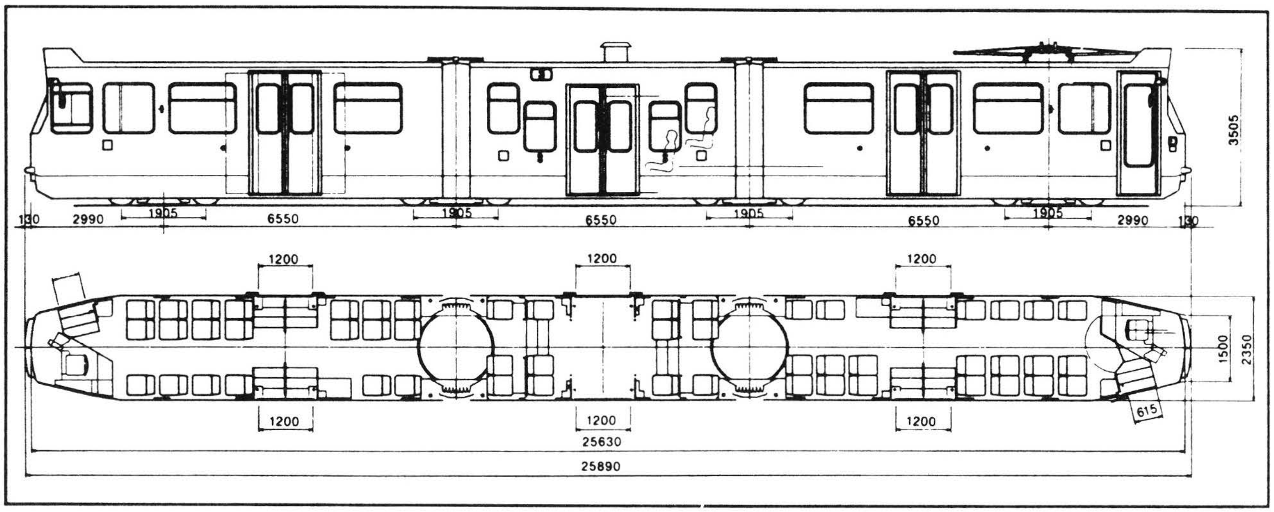


FIGURE 2-5. GROUP 1 BN LIGHT RAIL CAR

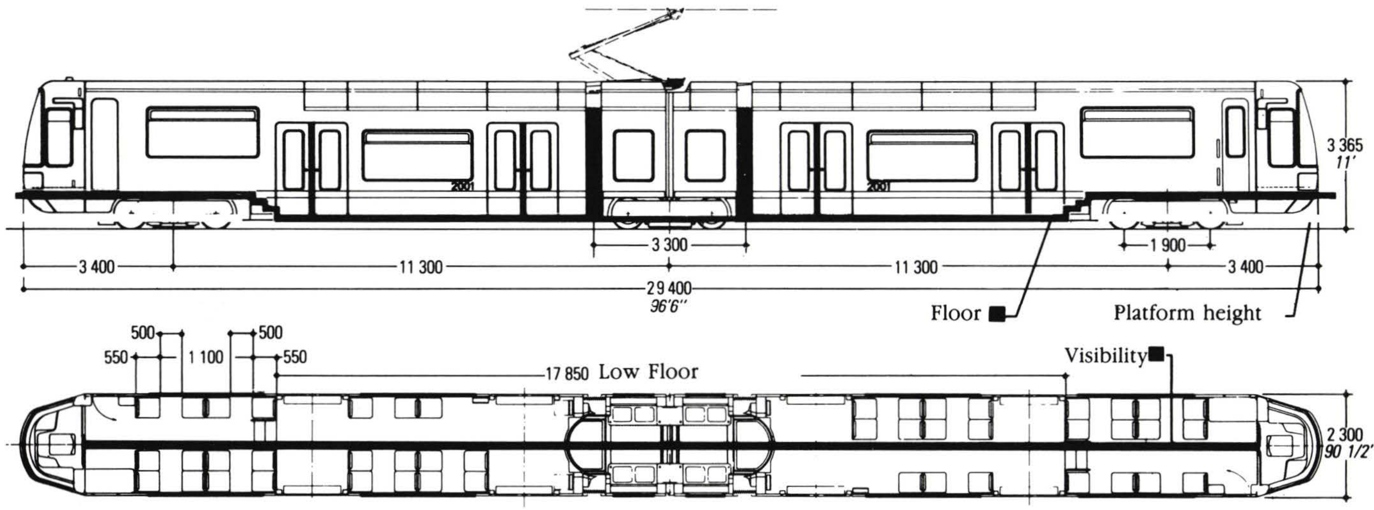


FIGURE 2-6. ALSTHOM GROUP 2 LIGHT RAIL CAR

throughout 61% of the car. The design is based upon the light rail vehicles supplied by Alsthom to Nantes, but with a modified center truck to permit a low floor height of 14 inches above the rail. [20] At either end of the car, three steps lead up to a raised floor 34 inches above top of rail which accommodates the motorized trucks below. Cars have four plug type double doors on each side, all of which provide low floor accessibility. Only the two end trucks are powered, each with a single 275 kW DC traction motor provided with chopper control and regenerative braking. Motor braking is augmented by electrohydraulic disc brakes with the addition of magnetic pads for emergency stopping. The dual direction all electric cars have 54 seats and space for 120 standees, based on a standard of 4 passengers per square meter. Cars are 96 feet long, have an empty weight of 48 tons, and a maximum speed of 44 mph. Operating with ten inch raised platforms as the cars do in Grenoble, there is a 3-4 inch step up into the car which can be compensated for either automatically or upon request with an extendable ramp or bridge plate (Figure 2-7). The Grenoble design will also be used for cars for the St. Denis-Bobogny line being built in suburban Paris.

Alsthom in cooperation with Vevey of Switzerland, is also providing a lighter, unidirectional meter gauge version for operation in Saint-Etienne (Figure 2-8). This version has small wheels under the center section, as used by Vevey in Geneva, instead of the "U" shaped axle approach. [21] Vevey is supplying the bodyshells, bogies and articulation system while Alsthom supplies the motors, traction equipment and system integration.

2.1.4 Group 3 - The MAN GHH GT6N LRV

The GT6N LRV, developed by MAN GHH and marketed in the United States by AEG is the first articulated full length low floor light rail vehicle to be in revenue operation (Figure 2-9). The novel bogie has one pair of free wheels and one pair of torsionally stiff connected wheels. [22] The latter are driven by two spur gears interconnected by a low slung shaft, which causes these two wheels to act as though they were connected by an axle. Power is transmitted via a flexible cardan shaft from a single three phase A.C. motor mounted on the carbody. Motors are powered from inverters installed in the roof area. The

FIGURE 2-7. GRENOBLE BOARDING RAMP

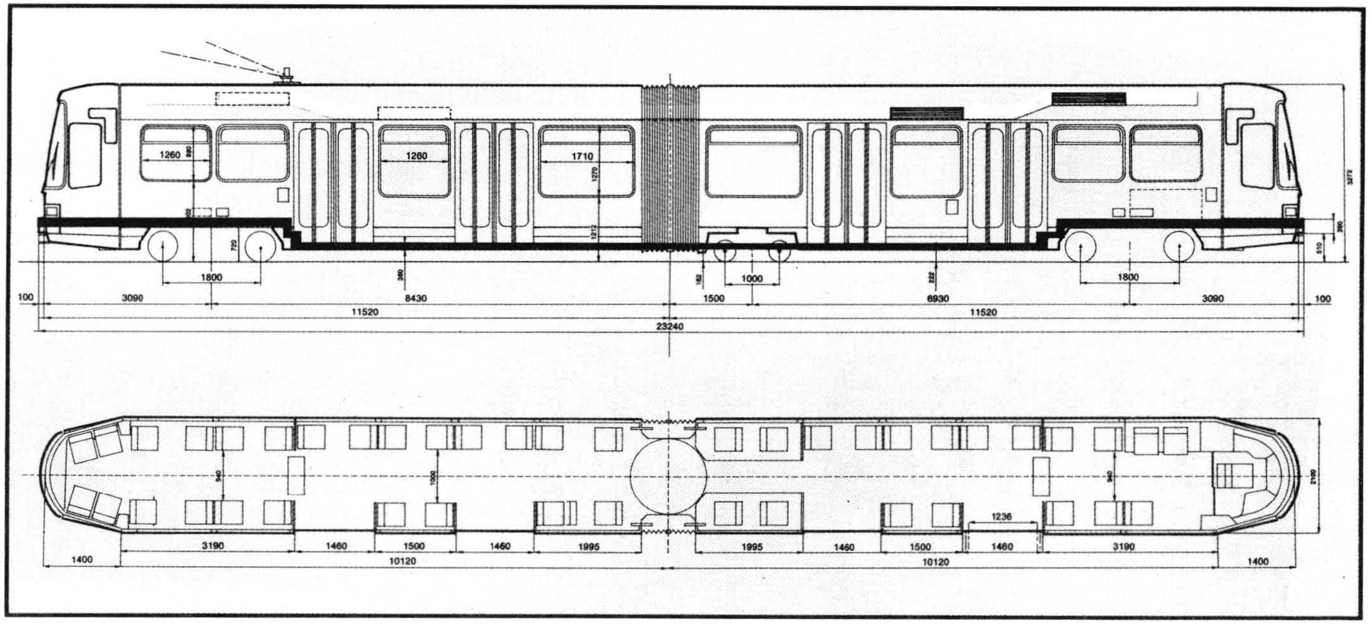


FIGURE 2-8. SAINT-ETIENNE LIGHT RAIL CAR

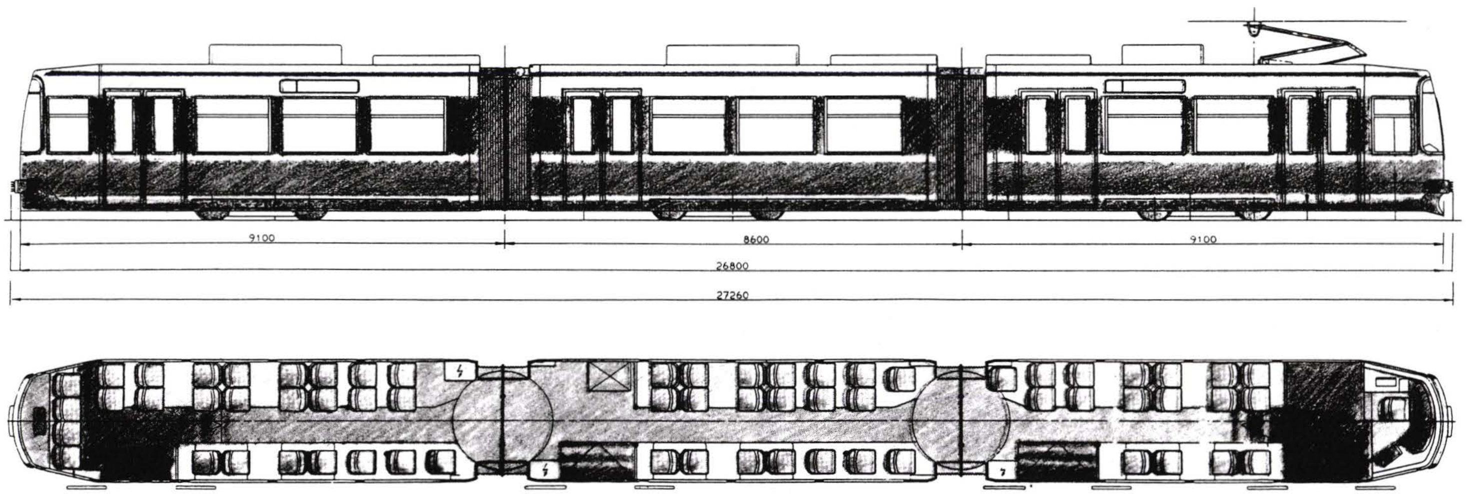


FIGURE 2-9. GROUP 3 MAN LIGHT RAIL CAR

standard gauge vehicle has a maximum speed of 44 mph, an empty weight of 28 tons, and an overall length of 89 feet. The stainless steel cars hold 67 seated passengers and 103 standees at 4 persons per square meter. The floor is 14 inches above top of rail but slopes towards the entryway so that the door is only 12 inches above top of rail. A meter gauge version is under development.

2.1.5 North American Low Floor Vehicle Activity

No indication of any low floor activity by North American suppliers of light rail equipment was uncovered. There are two North American transit agencies that have made a serious commitment to low floor light rail. These are the Toronto Transit Commission (TTC) and the Massachusetts Bay Transportation Authority. (MBTA)

The Toronto Transit Commission has made the policy decision to go forward with low floor cars on the Spadina line, a four mile light rail line extending north along Spadina Avenue from the waterfront to Bloor Street where it connects to the Toronto subway system. [23] There will be 13 transit stops. The Toronto Metropolitan Council has adopted the policy that "Metropolitan Toronto undertake, through appropriate channels, to research currently existing low-floor or modified low-floor streetcars, both prototype and revenue service, to determine which is likely to most closely meet Metropolitan Toronto needs and TTC specifications." Further, the Council has specifically recommended that "Rather than waiting until the year 2000, Metropolitan Council make the commitment to acquire low-floor or modified low-floor streetcars in time for the opening of the Spadina LRT line, presently projected to be in 1996." [24] It is the Toronto Transit Commission's preference to use 100 percent low-floor vehicles for the Spadina Line; that is vehicles of the Group 3 type. The TTC recognizes that this decision entails a "significant degree of technical risk" and that in order for low floor vehicles to be capable of operating on existing lines "modifications to the existing 100 percent low-floor designs will have to be made." [25] Historically the TTC has shown a preference for Canadian built equipment so it is likely that this decision will serve as an impetus for Canadian suppliers such as Bombardier and UTDC to become involved with low floor technology.

The other major North American transit agency active in low floor LRV is the Massachusetts Bay Transportation Authority (MBTA). The MBTA commissioned a major study of light rail accessibility which considered full high level platforms, mini-platforms, wayside lifts, and on-board vehicle lifts in addition to low floor vehicle technology. [26] The study concluded that the recommended method of achieving accessibility on the Green Line would be through the use of low floor vehicle technology. (Mini-platforms were recommended for the Mattapan-Ashmont High Speed Line). The Directors of the MBTA have since voted to move ahead with purchase of low- floor cars and modifications to stations and surface stops on the Green Line. The cost of station and stop modifications is estimated at $158 to $247 million and the cost of 100 low floor cars is estimated at $160 to $190 million. [27] Time for implementation is expected to be six to 10 years with the first low-floor cars available in four years.

The MBTA is interested in obtaining low floor cars which can be operated in trains with existing Green Line rolling stock, which consists of 115 Boeing cars delivered in 1976-1978 and 100 Kinki Sharyo cars delivered in 1986-1988. This will enable the MBTA to meet the "one train rule" for accessibility as soon as possible. [28] The buffing load of the lighter 100 percent low floor (Group 3) light rail cars is too low to be compatible with mixed operation with existing MBTA cars. As a result, it is most likely that some sort of Group 2 design with conventional end trucks will be the preferred type of equipment. In addition to operation in trains, cars also should be articulated, capable of bidirectional operation with doors on both sides, have air conditioning, and electronic AC or DC propulsion. [29] The plan is to provide raised low level platforms which would permit level platform boarding at the 10-14 inch floor height of the low level cars. MBTA engineers are concerned with the overhang and side clearance of the front and rear ends of low floor vehicles when trains are stopped at low level platforms located on curved sections of track. [30] Undercar clearance for the low floor designs does not appear to be of concern. Present MBTA light rail cars have an undercar static clearance of only 5 inches because of equipment hung from the car frame. These cars operate successfully over MBTA trackage. Some key MBTA track, wayside and vehicle clearance data are summarized in Table 2-2.

TABLE 2-2. MBTA TRACK, WAYSIDE AND VEHICLE CLEARANCE LIMITATIONS

Minimum lateral curve radius at track centerline	42 feet
Maximum superelevation	6 inches
Radius of minimum vertical curve - crest sag	300 feet 400 feet
Track gauge	4 feet 8 1/2 inches
Maximum sustained grade	8 percent
Minimum running clearance including vertical curves after all wear and deflection:	
Trucks	2.5 inches
Undercar equipment:	
Between trucks, between rails Between trucks, outside rails Outside trucks (except couplers)	2 inches 5 inches 8 inches
Minimum undercar equipment clearance from top of rail to coupler over crest and sag vertical curves	2.375 inches

Information from reference [31]

The MBTA has requested letters of interest concerning their low floor car requirements from suppliers. It is notable that interest has been expressed by Japanese carmakers including Kawasaki, Kinki Sharyo, and Nippon Sharyo, in addition to the European firms known to be active in low floor technology. [32] Besides the MBTA and TTC, San Diego also studied low floor vehicles for its system but decided against them. The decision was based on the unavailability of 100 percent low floor designs and the risk of passenger falls on steps in the aisles while the car is in motion. Chicago is also studying low floor technology for a proposed downtown circulator. [33]

2.1.6 Capital Cost of Low Floor Designs

The MBTA has estimated the cost of low floor light rail vehicles at from $1.6 to $1.9 million each for an order of 100 cars. This is estimated to be 8 percent more than a conventional design LRV, with the added cost attributable to engineering. [34] By way of contrast, the Group 2 low floor cars operating in Grenoble cost about a million dollars each in 1987. [35]

It is not at all clear that low floor technology must be more expensive than conventional technology. The German Stadbahn 2000 light rail vehicle project has low purchase price and low operating costs as program objectives with the goal that "total vehicle costs with regard to service life are not to exceed those of comparable bus systems." [36] There are good reasons for hoping these goals may be achieved. The use of two-wheel trucks cuts the weight and complexity of running gear in half. It means there are half as many wheels to be reground and replaced. AC motors have lower maintenance costs than conventional DC motors with brushes. Finally, the greatly reduced weight of the cars should lead to reduced purchase costs and lower energy costs. The German target is a vehicle weight per square foot of useable floor space equal to that of an electric trolleybus.

While it is not possible to determine the ultimate success of the Germans in reducing costs, it is important to stress that contrary to much past experience, new technology does not necessarily mean higher costs. When program objectives are clearly and logically oriented towards reducing costs rather than increasing performance, it is quite reasonable to expect savings. The German low floor program is cost rather than performance oriented as is clearly indicated by the very modest target for vehicle speed of only 44 mph.* The same light weight and low cost objectives driving the German program are also evident in most other Group 3 projects.

Given these considerations, it would seem to be a realistic and conservative planning assumption to assume low floor cars should at a minimum cost no more to buy and operate than their higher floor brethren. In addition, there is a realistic possibility that the technology will reduce both the capital and operating costs for light rail systems. Given the pressing need for wheelchair accessibility resulting from the Americans with Disabilities Act, low floor vehicle technology holds the rare promise of being a "win win" situation where the disabled community, transit operators, the taxpayer and the riding public all benefit. It is important to note that low floor technology not only provides access for wheelchair riders, but facilitates access by the elderly and infirm in general, and also speeds up boarding by the general public. The faster boarding times mean faster service which benefits both riders and operators.

2.2 MINI-PLATFORMS

Mini-platforms are short (10 to 15 feet long) high level platforms which are the same height as the floor of the vehicle (Figure 2-10). One designated door of the vehicle stops at the mini-platform. On some transit systems, the train always stops so that one door is at the mini-platform while at others the train normally stops short of the mini-platform, only pulling up to it when required by a disabled passenger. Usually access to the mini-platform is provided by means of ramps. However in some cases, where space for ramps is not available, a hydraulic powered lift is used to provide access to the platform. Mini-platforms are currently used by Sacramento Regional Transit, the San Francisco Municipal

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* How acceptable this speed would be to U.S. operators remains a question, especially for San Diego and other new LRT systems.

FIGURE 2-10. TYPICAL MINI-PLATFORM

Railway, and the Niagara Frontier Transportation Authority (Buffalo). In addition, mini-platforms will be used by the Baltimore MTA on its new light rail system.

2.2.1 Description of Mini-platforms

Figure 2-11 shows a typical layout for a mini-platform. The platform itself is typically ten feet long and six to eight feet wide. Two ramps with an intermediate landing provide for wheelchair accessibility; stairs are also usually provided.

The technique used for access from the car to the mini-platform depends upon whether or not the car is designed for normal use at high level platforms. In Buffalo and San Francisco, where light rail cars operate at full high level platforms at some stations, mini-platform boarding essentially replicates the technique employed at full high platform stations. In Buffalo, light rail cars are equipped with retractable steps which actually fold out of the side of the car when the doors are opened to permit low level boarding. There is no stepwell within the vehicle. When trains operate at low level stations the right front end door is routinely aligned with the mini-platform when the car is stopped. The retractable steps are always deployed at all doors when the doors are open. However, at the mini-platform they deploy below the platform and are not used for boarding. There are 12 mini-platforms in the Buffalo system.

San Francisco MUNI also operates with both high level and low level stations. Eight key low level stations have been provided with mini-platforms for wheelchair access. These are Duboce Park, Carl & Cole, Ocean Beach, Zoo, Junipero Serra & Ocean, San Francisco State University, City College and Balboa Park. The end doors of MUNI cars are provided with stepwells for low level boarding. These doors remain closed and are not used at high level platform stations. Stepwells at all other doors can be converted to a flush level floor for loading at high level platforms (Figure 2-12). In order to make use of the mini-platforms it is necessary to convert the stepwells at the forward center door of the lead car to the flush high level loading position. Since the front end door cannot be used for mini-platform boarding, the process is more complicated and time consuming than in Buffalo.

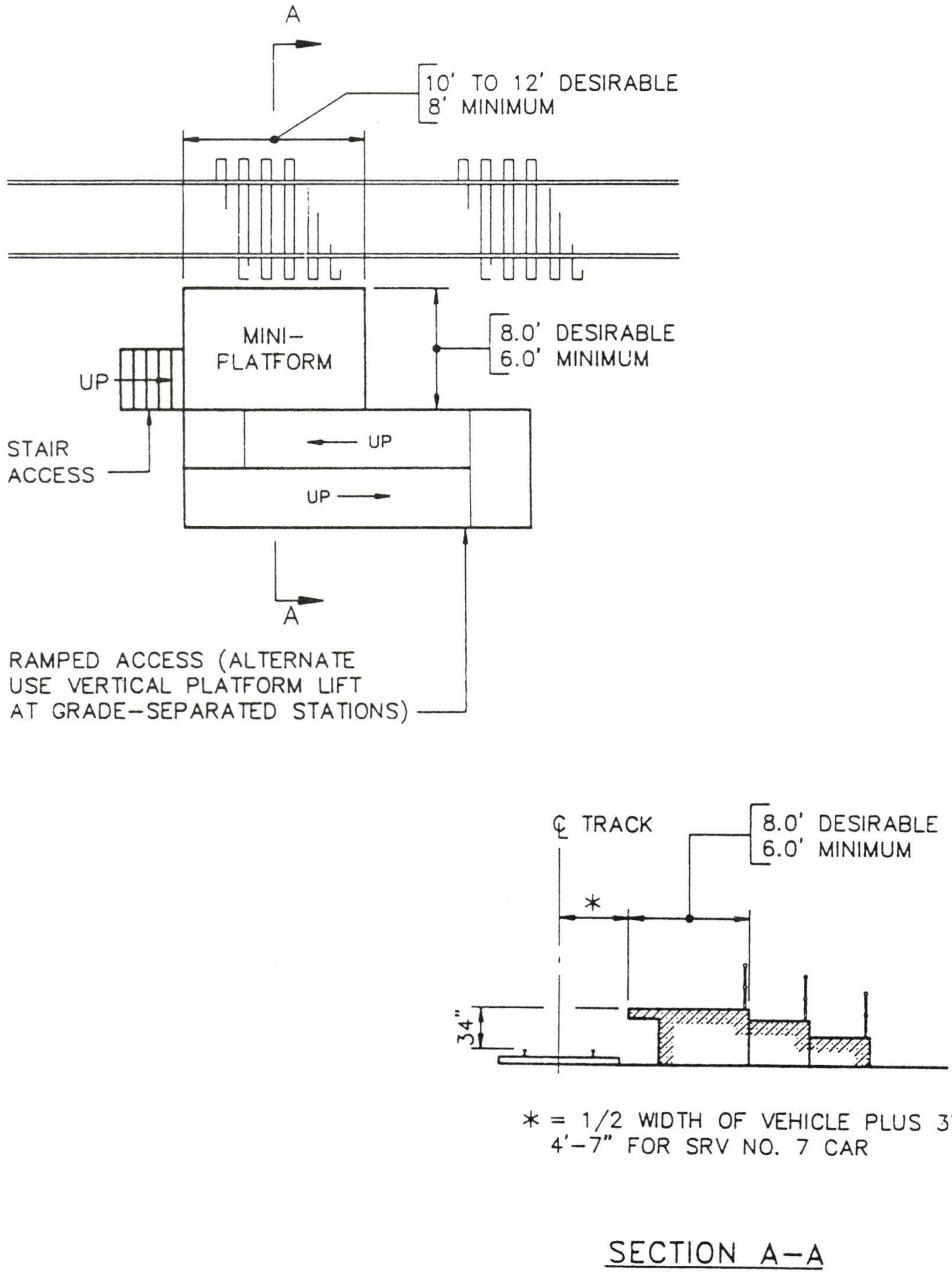

FIGURE 2-11. MINI-PLATFORM LAYOUT DRAWING

FIGURE 2-12. MUNI STEP CONVERTED
FOR HIGH LEVEL BOARDING

Mini-platforms are located at the far end of the station stop. MUNI trains normally stop short of the mini-platform, unless a handicapped person wishes to board or deboard. In this case two stops are required. The first stop is short of the mini-platform as would normally be the case (Figure 2-13). After regular passenger boarding and deboarding is accomplished, the operator then converts the stepwell at the forward center door of the lead car to high platform operation and pulls the train up to align that door with the mini-platform. After boarding or deboarding of the disabled passenger the steps must be returned to their low level position. This approach does not use a bridge plate to cover the gap between station platform and train. The horizontal gap is the same as for MUNI high platform subway stations, typically 4 - 4 1/2 inches. [37]

In Sacramento and at the system under construction in Baltimore there are no high platform stations and all doors of the light rail cars have conventional stairwells. For these systems an onboard bridging device is required to cover the stairwell (Figure 2-14). The same bridge plate also spans the gap between the light rail car and the mini-platform to further improve wheelchair accessibility. Both systems use the front doors nearest the driver for wheelchair accessibility. The operator stops the train so these doors are aligned with the mini-platform. The operator must then leave the enclosed cab and manually deploy the bridging device (Figure 2-15). After the disabled passenger is onboard, the bridging device is withdrawn, the operator returns to the cab, and normal operation is resumed.

In Sacramento bridging devices are provided for the front doors on both sides and at both ends of the reversible cars. These devices may be stowed in the rear wall of the operator's cab making the stepwell accessible for normal low level use (Figure 2-16). However, normal practice in Sacramento is to leave the bridge plate at both front doors covering the stairwell throughout the trip. It is then a simple matter for the operator to drop the bridge plate to cover the gap between car and platform using the handle visible in Figure 2-17. In Sacramento mini-platform use has been extended not just to the disabled, but to any persons desiring more convenient boarding. This includes the elderly as well as persons with strollers or packages. As a result, operators always stop at the mini-platforms. In Baltimore, it has not been decided whether or not trains will normally stop aligned with the mini-platform. Figure 2-18 is a sketch of the Baltimore mini-platform.

FIGURE 2-13. MUNI TRAIN MAKING NORMAL STOP SHORT OF MINI-PLATFORM

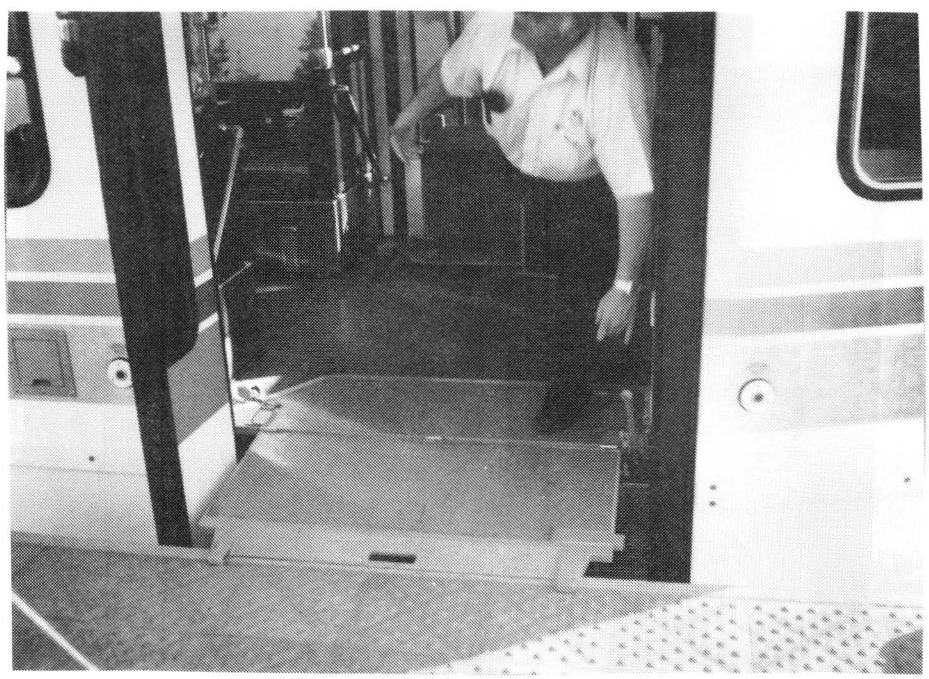

FIGURE 2-14. BRIDGING DEVICE ON SACRAMENTO LIGHT RAIL CAR

FIGURE 2-15
← **OPERATOR DEPLOYING BRIDGING DEVICE**

FIGURE 2-16
FULLY STOWED POSITION OF SACRAMENTO BRIDGING DEVICE →

FIGURE 2-17. PARTIALLY DEPLOYED POSITION OF
SACRAMENTO BRIDGING DEVICE
USED DURING NORMAL OPERATION

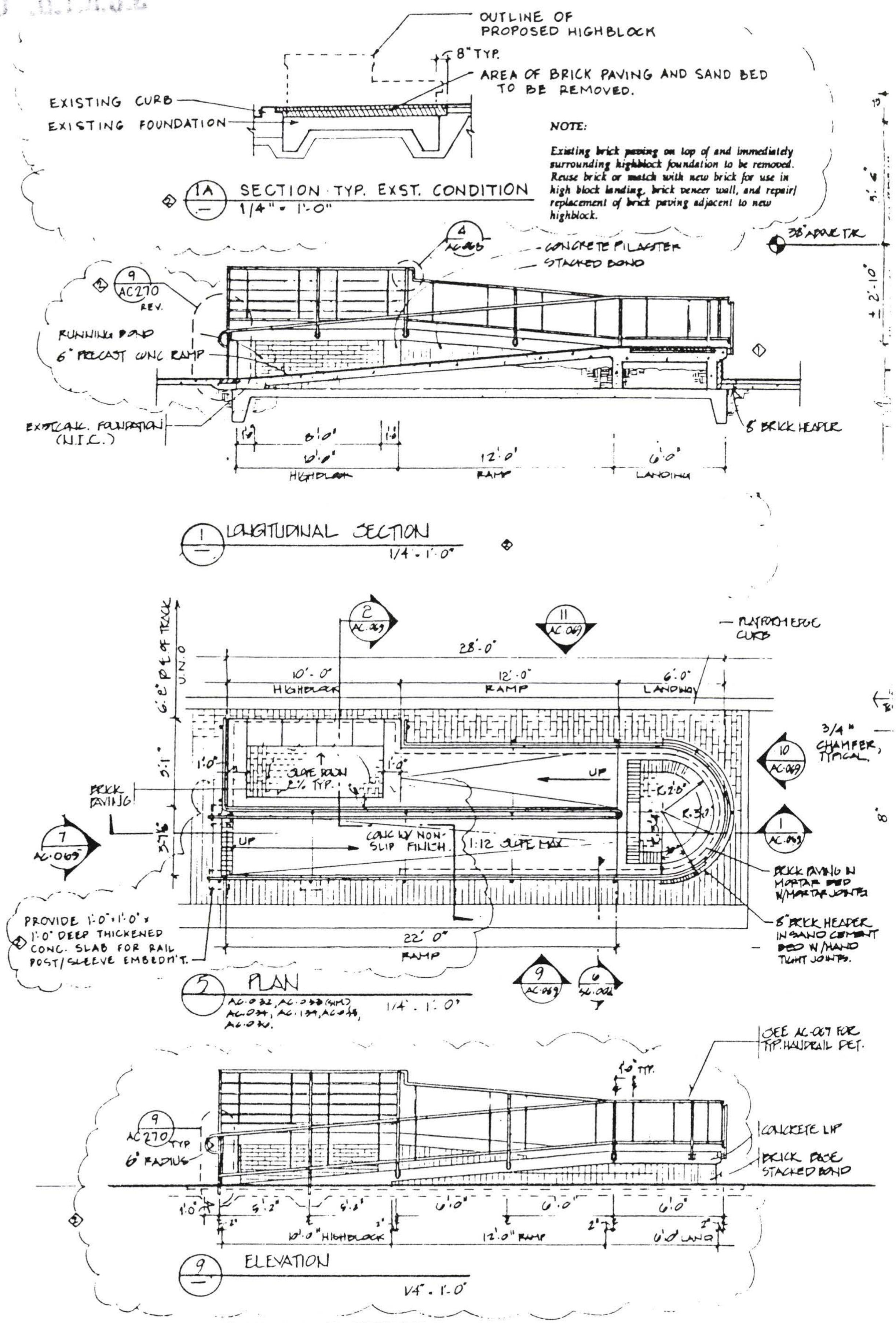

FIGURE 2-18. SKETCH OF BALTIMORE MINI-PLATFORM

Sacramento employs vertical lifts to access four of its 55 mini-platforms where space for a ramp is not available. The hydraulic scissors lifts were made by Southworth Machine Company. These lifts have a 3 1/2 by 4 1/2 foot table, a 2000 pound capacity and operate at a speed of eight feet per minute.

2.2.2 Regulatory Aspects

Ramp access to the mini-platform is constrained by requirements of section 4.8 of the Architectural and Transportation Barriers Compliance Board ADA Accessibility Guidelines for Buildings and Facilities as incorporated in Department of Transportation regulations. [38] These guidelines require three foot wide ramps with a maximum slope of 1:12 and a maximum rise or change in height of 30 inches. This limits the horizontal ramp length to thirty feet. Five foot landings are required at the top and bottom of all runs. Where the ramp changes direction the landing must be at least five feet square. Handrails are required on both sides of the ramp.

The floor height of standard light rail cars is slightly greater than 30 inches, ranging from 34 inches for the San Francisco MUNI cars to 39 inches for the Sacramento Duewag U2 cars. As a result, two ramps with an intermediate landing are typically required to access the mini-platform. System designers should note that the mini-platform space requirement can be significantly lessened simply by specifying a vehicle floor height above rail of less than 30 inches so that a single ramp will suffice.

New Federal Regulations to implement the Americans with Disabilities Act provide a "one car per train rule" which states that "...each public entity providing light rail or rapid rail service shall ensure that each train, consisting of two or more vehicles, includes at least one car that is readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs, as soon as practicable but in no case later than July 25, 1995." (49CFR37.93(b) reference [39]) Another section of the regulations states that new, used and remanufactured vehicles "...designed for, and operated on, pedestrian malls, city streets or other areas where level boarding is not practicable shall provide wayside or car-borne lifts, mini-high platforms, or other means of access..." (49CFR38 Subpart D

38.71(b)(2)). Although 49CFR37.79 requires all vehicles purchased after August 25, 1990 to be accessible, the Urban Mass Transportation Administration Office of the Chief Counsel has advised us this is not intended to disqualify mini-platforms and that they are an acceptable means of complying with ADA accessibility requirements.

Hydraulic lifts used to access mini-platforms are another regulatory question. Part XX Section 2000 of the Safety Code for Elevators and Escalators (ANSI A17.1-1987) covers vertical lifts. [40] However, in California lifts with less than a five foot travel are covered by a separate California code (see Section 2.3.1.2 of this report) and do not need to be certified like an elevator.

2.2.3 Safety Issues

The Sacramento system has been operating since 1987. Staff recalled only one significant accident when a blind passenger tried to board before the bridge plate was in place and got his foot caught in the gap. [41]

2.2.4 Acceptance

Mini-platform acceptance by the disabled has been positive. Wheelchair use in Sacramento during 1990 was 6760 or 563 persons per month. [42] Since APTA operating data indicates Sacramento ridership at about four million per year [43], this is a utilization of 1.7 wheelchair users per 1000 passengers carried. However, in addition to these wheelchair users, the Sacramento mini-platforms were used for boarding in 1990 by an additional 38165 persons. [44] These include the elderly, persons with disabilities who are not in wheelchairs, persons with packages and baby strollers and others who would be inconvenienced by conventional steps. (It is Sacramento policy to allow use of the mini-platforms by the general public.) Thus for every wheelchair user, there are nearly six other persons making use of the mini-platforms, leading to a total utilization of 11.2 persons per 1000 passengers carried, or about one percent of total ridership. This minimizes the social stigma to the wheelchair user and also provides added service to the public to help justify the additional cost of the mini-platforms. Sacramento reports that operator acceptance has also been good.

2.2.5 Reliability and Maintenance

Mini-platform maintenance is normally limited to cleaning and repair of platform edge warning tiles. Bridge plates are manually operated and maintenance for a properly designed system should be negligible. Sacramento has had a design problem leading to stress cracks at the bridge plate hinges. A retrofit program is underway to solve the problem. [45] The stress cracks have not caused any reliability problems or interfered with operations.

In view of the above, barring a design defect, the mechanical reliability of a mini-platform system should have negligible impact on the dependability of service to the disabled. Of more concern than mechanical reliability is the need to provide sufficient wheelchair locations on the light rail car, especially since only the lead car is available for this purpose. Sacramento originally provided two wheelchair positions on each light rail car. Complaints were received when disabled passengers had to wait for another train because both positions were occupied. The problem has been solved by adding a third wheelchair position on each car.

Reliability and maintainability experience for Sacramento's hydraulic scissors lifts was also investigated. These lifts, described in Section 2.2.1, are used to access four mini-platforms where space for a ramp is not available. There are on the average about five to eight failures per year for all four Sacramento lifts, about one or two failures per lift each year. Maintenance requirements are minimal and estimated at ten personhours per year for each lift. Once a month it is necessary to clean debris out of the lift pit, lubricate pivot points, check hydraulic fluid and perform similar routine preventive maintenance actions. [46]

2.2.6 Capital Cost

Capital cost data could not be readily extracted for mini-platforms since it is embedded in overall project civil costs. The capital cost of the Sacramento mini-platform was estimated to be approximately $15000 in $1991 by an engineering unit cost buildup from layout drawings (see Appendix A). This estimate does not include any engineering costs.

2.3 WAYSIDE LIFTS

Wayside lifts locate the wheelchair lift at the wayside instead of onboard the vehicle. This eliminates weight and complexity on the vehicle, frees the wheelchair mechanism from being subject to vehicle borne vibrations and reduces vehicle weight improving fuel consumption. The major problem with the wayside lift is accurately stopping the light rail car so it is properly aligned with the lift. To date wayside lifts have been used on only two light rail systems (Santa Clara and Portland). We were unable to identify any other existing or planned systems considering use of wayside lifts. The following sections describe the history and operating experience with these lifts in Santa Clara and Portland.

2.3.1 The Santa Clara Wayside Lift

The Santa Clara County Transit Agency operates a fleet of 50 articulated light rail cars built by UTDC operating on two routes. The original Guadeloupe route, opened in 1987-1988 is nine miles in length with 15 stations. The recently opened Santa Teresa route is eleven miles in length with 13 stations. All stations are equipped with wayside lifts provided by Mobility Unlimited Inc (Charles Williams Enterprises, Inc.). The custom lift, designed by Gregory Pachlan, is based on a Ricon R30 vehicle lift modified and provided with lift enclosures by C. E. Tolan (Figure 2-19). There are 36 lifts on the Guadeloupe line and 31 on the Santa Teresa line.

Prior to selecting a disabled access solution, Santa Clara County Transit Agency personnel reviewed experience with light rail lifts in both Portland and San Diego. Lift-U,

FIGURE 2-19. SANTA CLARA
LIGHT RAIL CAR STOPPED AT LIFT

the supplier of the Portland lift, had gone bankrupt and so could not supply wayside lift equipment. [47] SCCTA was not completely satisfied with San Diego's experience using vehicle borne lifts. The decision was therefore made to issue an RFP for a wayside lift to meet the County's requirements. Two bids were issued for delivery and installation of wayside lifts. When no responses were received from either bid, SCCTA entered into sole source negotiations with Mobility Unlimited, a local firm representing Ricon, a well known supplier of vehicle lifts. The contract asked Mobility Unlimited to modify a Ricon vehicle lift for wayside operation.

2.3.1.1 Description of Lift

The SCCTA wayside lift combines a lift mechanism based upon the Ricon R30 vehicle borne lift and a bridging device. Both of these mechanisms are mounted on a concrete pedestal whose centerline is located 6 feet 9 3/4 inches to one side of the track centerline (Figure 2-20). The lift raises and lowers the disabled traveler to the level of the vehicle floor. The bridge plate spans the space between the pedestal and the light rail car doors, and also spans the vehicle stairwell providing level access to the car floor area. In their stored position, the bridge and lift mechanisms are protected by a rolltop sliding door which is locked when the lift is not in use (Figure 2-21).

To operate the lift it is first necessary to stop the light rail train in proper alignment with the wayside pedestal. Trains normally are brought to a stop short of the pedestal area. However, if a disabled traveler is waiting, the train operator aligns the train front door with the lift. In order to fit the bridge plate through the front door of the light rail car, the car must be aligned with the pedestal within a very tight tolerance of plus or minus three inches. Stopping a 90,000 pound light rail car to this tolerance is not an easy task. It is made more difficult since, should the operator overshoot the mark, he or she must move to the other end of the train in order to back up. According to Gregory Pachlan, the designer of the modified lift, the initial plans would have permitted the lift to move longitudinally to align with the stopped vehicle door. [48] This feature would have added

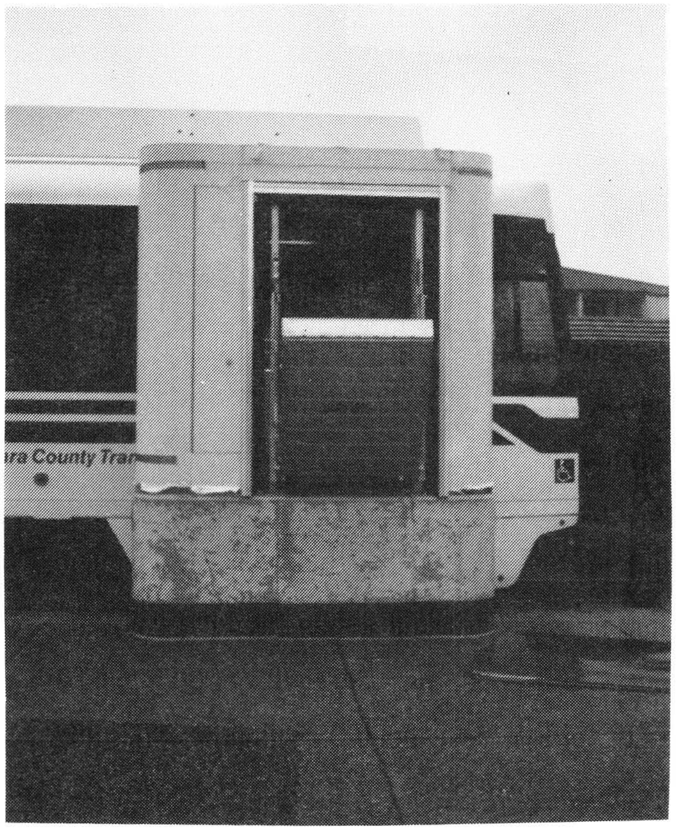

FIGURE 2-20
← **SANTA CLARA LIFT**

FIGURE 2-21
ROLLTOP SLIDING DOOR →
ON SANTA CLARA LIFT

several thousand dollars to the cost of each lift and was eventually deleted, requiring the train operator to align the train with the wayside lift pedestal.

Once alignment has been verified, the operator opens all doors on the platform side and walks down the front car steps to the platform. [49] The control box located on the outside of the lift enclosure is unlocked and the operator throws a switch to raise the rolltop sliding doors to their fully open position (Figure 2-22). A pendant control unit is removed from the control box and the operator walks back into the train, standing clear of the area where the bridge plate will land. The operator then actuates the pendant controls to lower the bridge plate to cover the car stairwell and the gap between the train and the wayside lift pedestal. With the bridge plate in position, the operator walks across the bridge to access controls for the lift mechanism proper, which are located on the inside of the lift frame (Figure 2-23). These controls are used to first extend the lift mechanism and then to lower it to the ground (Figure 2-24). The disabled person then enters the lift platform area and the lift is moved to its raised position, where it aligns with the pedestal and bridge plate to provide a continuous level "gangplank" into the light rail car (Figure 2-25). The disabled passenger then moves across this "gangplank" into the car. With the passenger safely on board, the train operator still holding the pendant control walks across the "gangplank" into the train area. The pedant controls are actuated to fold the bridge plate and lift mechanism back into their stored position. The train operator then leaves the car to return the pendant control to the control box, lower and fully close the rolltop doors, and shut and lock the control box. With the lift properly secured, the operator returns to the cab and proceeds to continue his/her route. According to SCCTA records, the average delay or added station stop time required for the entire operation averages six minutes [50], most of which is involved with accurately aligning the car with the wayside lift pedestal.

2.3.1.2 Regulatory Aspects

Marie McDonald, chairperson of the Inclined Stairway Chairlifts and Inclined and Vertical Wheelchair Lifts Committee (Part XX of ANSI 17.1 Safety Code for Elevators and Escalators) challenged the SCCTA sole source procurement on the grounds that the modified

← FIGURE 2-22
ROLLTOP DOOR
ON SANTA CLARA LIFT
IN OPEN POSITION

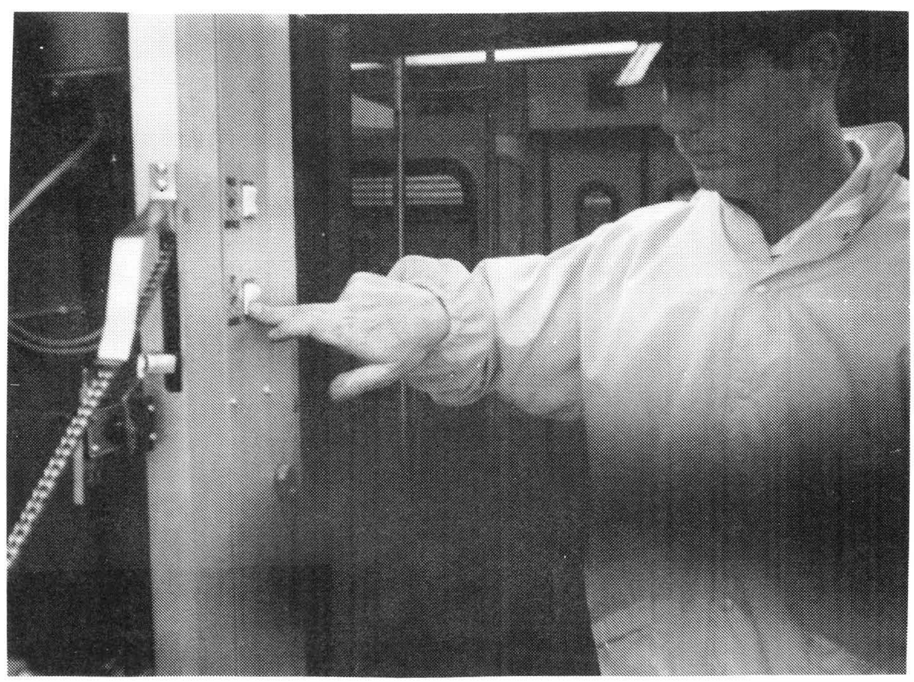

FIGURE 2-23
OPERATOR PREPARING
TO LOWER
SANTA CLARA LIFT →

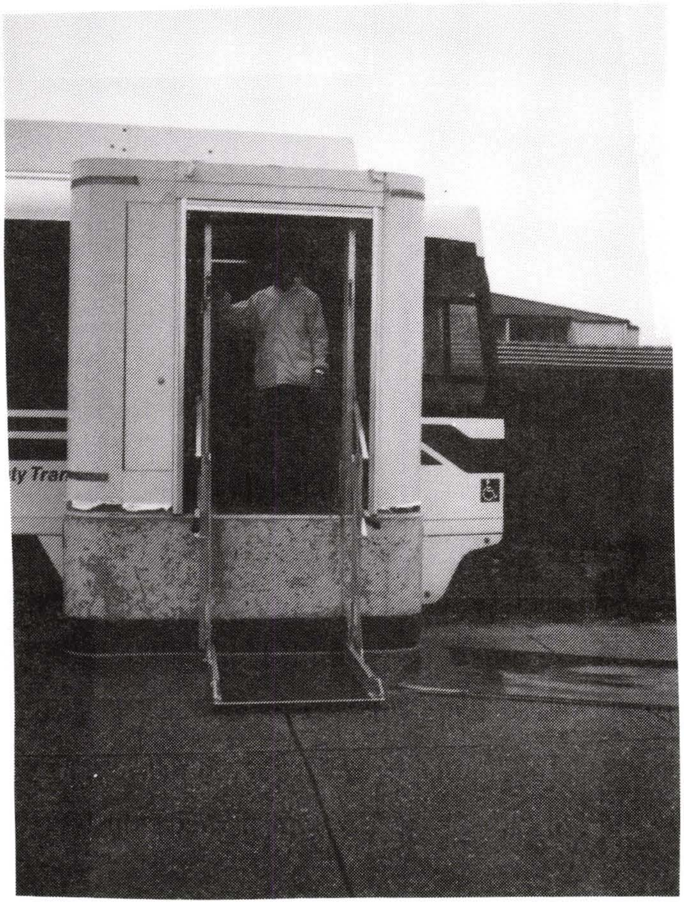

FIGURE 2-24
← SANTA CLARA LIFT
LOWERED TO GROUND LEVEL

FIGURE 2-25
FULLY DEPLOYED
SANTA CLARA LIFT
IN RAISED POSITION →
PROVIDES CONTINUOUS
"GANGPLANK" ONTO
LIGHT RAIL CAR

Ricon lift failed to meet Part XX of the national elevator code covering vertical wheelchair lifts. [51] (While California has written its own Elevator Safety Orders which govern elevator safety in the state, the national code is often cited in litigation involving installations not currently covered by state regulations.) The California Occupational Health and Safety Administration has for the past 17 years specifically exempted wheelchair lifts with five feet or less of vertical travel from the Elevator Safety Orders (Title 8 Chapter 4, Subchapter 6, Article 1 Section 3000(c)(13)). SCCTA therefore did not have to satisfy the Elevator Safety Orders. This left such devices effectively unregulated in California. In 1988, the California OSHA proposed adding a new Article 15.1 Sections 3094 through 3094.315 to the Elevator Safety Orders and a new Article 7- 15.1 to the State Elevator Safety Code to govern special access lifts including those with less than five feet of vertical travel [52]. The proposed regulations were developed with the use of ANSI A17.1 Part XX, but are not identical to these national standards. Since the regulations have not been adopted, the current regulatory situation in California remains unclear.

Development of the Santa Clara wayside lift was closely coordinated with an adhoc group of County disabled transit users as well as the Disability Advisory Committee of the city of San Jose. Their understanding and support was invaluable in dealing with the regulatory process.

2.3.1.3 Safety Issues

Marie McDonald's concern that the lift did not meet Part XX of the elevator code has already been mentioned. Her main concern was safety of the passengers due to the lack of 42 inch high guards on each side of the lift to enclose ambulatory passengers and lack of interlocks requiring these guards to be in the raised position when the lift is in motion.

Concerns have also been raised about compliance with sections governing exposed machinery and pinch points, some of which are visible in Figure 2-26. Notwithstanding these concerns, SCCTA staff have assured us there have been no serious injuries since the lifts were first used in 1988.

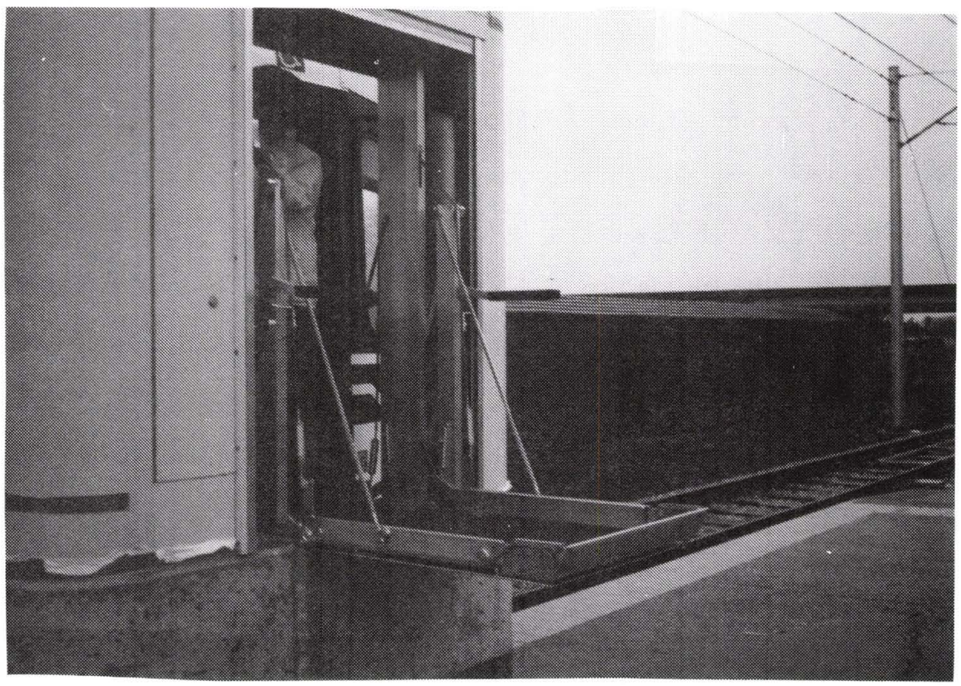

FIGURE 2-26. "PINCH POINTS" VISIBLE ON LIFT MECHANISM

2.3.1.4 Acceptance

SCCTA has had good acceptance of the lift from the disabled community, which was closely involved in development of this solution from its inception. In terms of number of passengers using the system, utilization has been less than for Portland and Sacramento. During September 1990, 107 disabled passengers used the 67 lifts on the SCCTA system. During January 1990, the figure was 128 passengers. [54] According to APTA operating statistics, [55] SCCTA carries approximately 170,000 riders a month, so this is a utilization of about 0.7 lift users per 1000 passengers carried. Because of the difficulty experienced in aligning the light rail car with the wayside lift and the average six minutes of schedule delay involved with lift operation, acceptance of the wayside lift by train operators has been less than enthusiastic. We were advised that SCCTA does not plan to order additional wayside lifts for any future extensions to the light rail system.

2.3.1.5 Reliability and Maintenance

At the time of this report the first 36 lifts were still in the third year of their warranty and any repairs were being made by the supplier. Preventative maintenance is required every six months. It involves cleaning and lubricating, checking microswitch adjustments, and checking batteries. As with mini-platforms, wayside lifts constrain the wheelchair disabled to normally boarding only the lead vehicle of a train. Therefore, the same concerns exist as for mini-platforms with regard to having sufficient wheelchair locations on the car (see Section 2.2.5).

2.3.1.6 Capital Cost

The contract with Mobility Unlimited for the first 36 lifts was entered into December 29, 1987 for $797,846. [56] It covered manufacture, testing, installation and training, but excluded cost for the concrete pedestal foundation. This amounts to a cost in 1988 dollars of $22,000 per unit. On March 12, 1990 a second contract was signed for 31 additional lifts, again excluding the concrete pedestal. [57] This contract was for $910,604, equivalent to $29,000 per unit.

2.3.2 The Portland Max Wayside Lift

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) operates a fleet of 26 articulated light rail cars built by Bombardier over a single 15.1 mile long route from downtown Portland to Gresham. The line opened for service in 1986. There are 27 stations, all of which are equipped with two wayside lifts (one for each direction of travel). The lifts were contracted for and designed by Lift-U which subcontracted their production with Hogan Manufacturing. During production, Lift-U went bankrupt. Eventually Hogan Manufacturing assumed the contract and Lift-U is now a division of Hogan Manufacturing.

The wayside lift procurement was a two-step process. First, potential bidders were invited to submit technical proposals. Based on the proposals, more detailed specifications were drawn up by Tri-Met and a formal invitation to bid was issued. [58] The final contract, issued to Lift-U in 1981, included provision for detailed final design, prototype development, fabrication and testing prior to manufacture of 60 production lifts. The prototype was subjected to a 100,000 cycle endurance test and went through several design iterations prior to production.

2.3.2.1 Description of Lift

The Tri-Met wayside lift is an electro-hydraulic mechanism designed to make the light rail vehicles accessible to disabled passengers (Figure 2-27). The major components are the lift platform, a bridging device, a ramp, and two frames which cradle the platform on each side. The left main frame contains virtually all the electrical and hydraulic components. Both frames have fiberglass covers with access doors for normal service and provision for manual operation in the event of an electrical failure.

The bridging device spans the space between the platform and the light rail car and also spans the vehicle stairwell providing level access to the car floor area (Figure 2-28).

FIGURE 2-27. PORTLAND WAYSIDE LIFT
(PIONEER SQUARE)

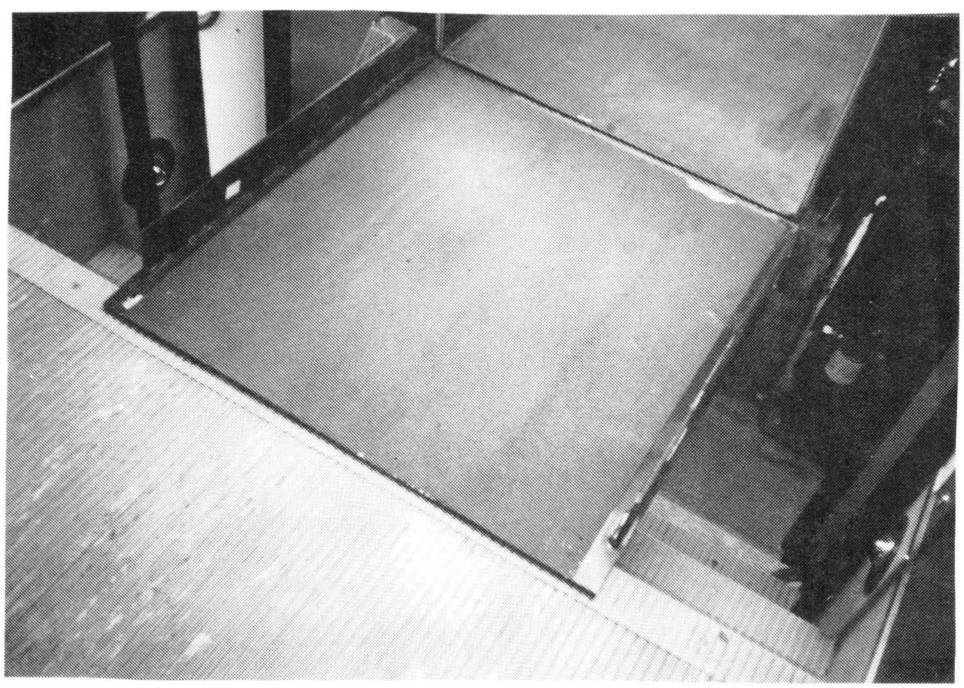

FIGURE 2-28. PORTLAND BRIDGING DEVICE

The ramp provides access to the platform in its lowered position. Both the bridging device and the ramp can be folded up into a raised position in which they serve as a front and rear barrier to contain the wheelchair while the lift is being raised or lowered.

Two 1-1/2 inch bore, 15 1/2 inch stroke hydraulic cylinders are used to raise and lower the platform a total distance of 29 1/2 inches. A system of eight stainless steel cables redundantly stabilize the platform in both lateral and longitudinal directions. Hydraulic cylinders are also used for lowering and raising the bridging device and ramp.

Light rail cars normally stop short of the lift. If a disabled passenger is waiting, it is necessary to stop the train in proper alignment with the wayside lift mechanism. The bridging device is 35 inches wide and the door opening is 49 inches wide providing an alignment tolerance of plus or minus seven inches. [59] This is not as tight as the three inch tolerance for the Santa Clara wayside lift, but is still a tight constraint within which to manually stop the 90,000 pound cars. Alignment typically takes about a minute but if the driver overshoots then he or she must go to the other end of the train in order to back up.

The actual lift process is fairly simple. Normally, the platform is in its lowered position with the ramp deployed and the bridging device folded up (Figure 2-29). This makes it possible for the disabled passenger to position him or herself on the lift platform at leisure, prior to arrival of the light rail vehicle. Once the light rail car arrives and is properly aligned, the operator leaves the car and activates the system from a locked control box on the side of the lift. As the operator presses the "Up" button, the ramp folds up (Figure 2-30) and the platform raises to the level of the floor of the light rail car. It takes 2-4 seconds to fold up the ramp, and another 6-12 seconds to raise the platform to car floor level. [60] At the end of the "Up" cycle, the bridging device lowers to span the area between the platform and the floor of the light rail car (Figure 2-31). It takes between 4 and 7 seconds to deploy this bridge plate. With the bridge plate in position, the passenger maneuvers him or herself into the car and the operator then reverses the cycle to lower the lift to its normal down position. The entire process takes about a minute, plus whatever time was required to align the vehicle. Lift specifications are provided in Table 2-3.

FIGURE 2-29. NORMAL LOWERED POSITION OF PORTLAND LIFT

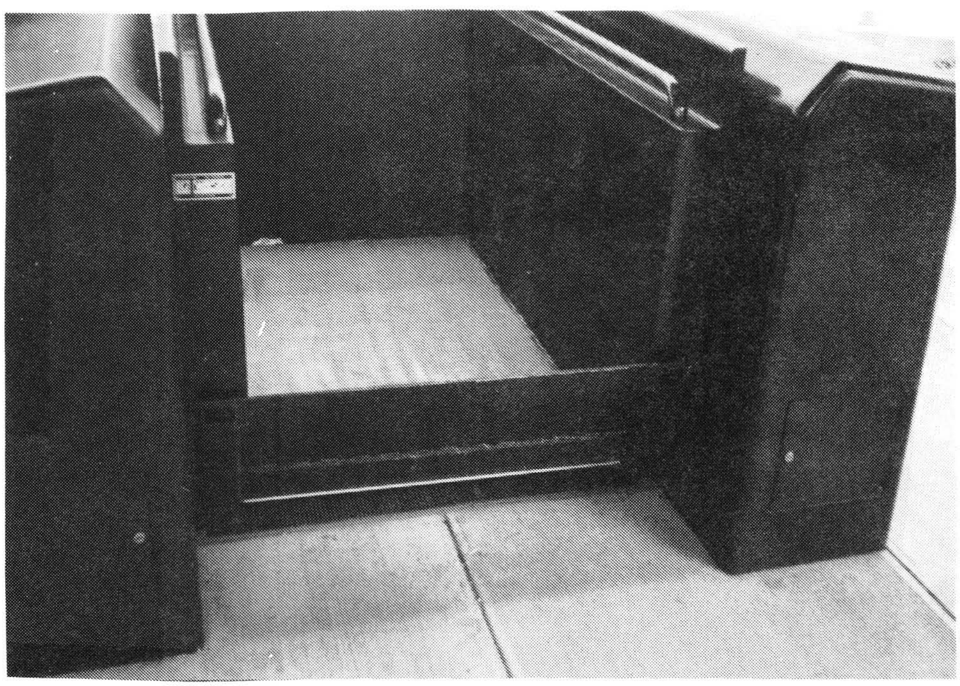

FIGURE 2-30. BOARDING RAMP IN FOLDED UP POSITION

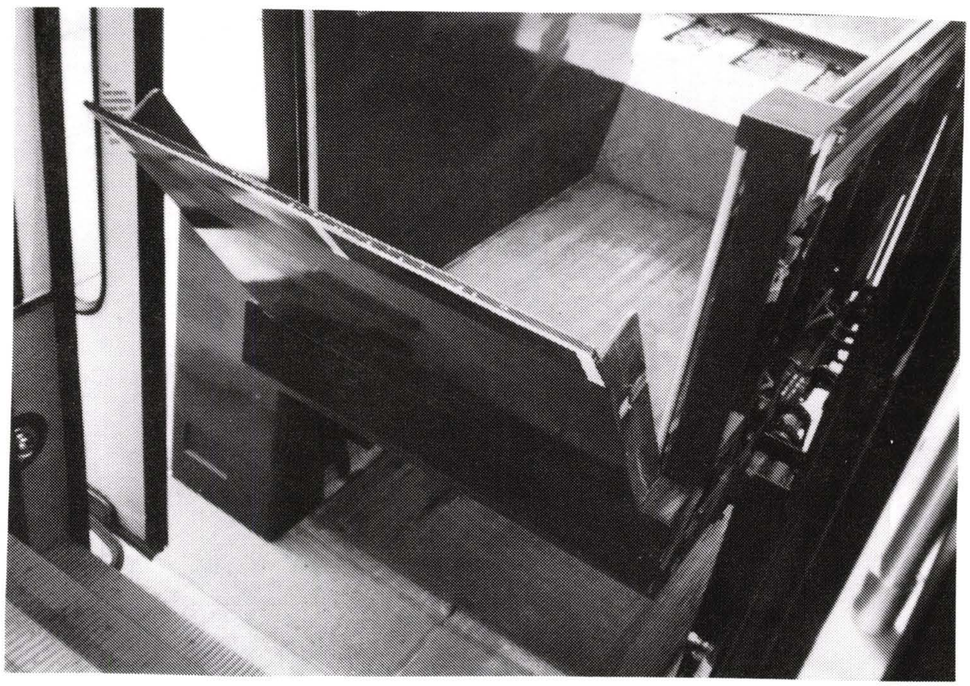

FIGURE 2-31. BRIDGING DEVICE
BEING LOWERED INTO LIGHT RAIL CAR

TABLE 2-3. PORTLAND WAYSIDE LIFT SPECIFICATIONS

Model: A001

Transit System: Tri-County Metropolitan Transportation District of Oregon

General:

Maximum Load:	600 pounds
Maximum Travel Up:	29.5 inches
Ramp/Barrier Angle:	8 degrees at ramp position
Bridge/Barrier Angle:	Plus or minus 5 degrees at bridge position

Cycle Times with 600 Pound Payload:

Lift Platform (Up/Down)	6-12 seconds
Ramp/Barrier (Up/Down)	2-4 seconds
Bridge/Barrier (Up/Down)	4-7 seconds

Hydraulic System:

Pressure	1100 plus or minus 50 psi
Flow Rate	1.0 - 2.8 GPM
Fluid Type	H5606 Aircraft Hydraulic Fluid
Filter	10 Micron

Electrical System:

Voltage	120/208-230 Volt Single Phase

2.3.2.2 Regulatory Aspects

Regulatory control has been under the Oregon Department of Commerce. Originally, the department ruled that the wayside lift was an elevator and required an elevator permit. Tri-Met paid $11,000 for permits in order to open the light rail system for revenue service. The Department of Commerce issued the permits subject to addition of further safety features to the lift. An emergency stop button for the passenger was required as well as a sensing device to stop the lift from going down if there was any obstruction. These safety features were added by Tri-Met. However, Tri-Met went to court to obtain exemption from elevator certification requirements. Tri-Met's position was that since the upper platform (the floor of the light rail car) was not stationary but mobile, the wayside lift did not constitute an elevator. The court agreed with this interpretation, and Tri-Met has obtained a waiver from elevator certification requirements.

2.3.2.3 Safety Issues

As with the Santa Clara wayside lift, pinch points are a potential safety concern for the Portland design. Tri-Met staff recalled one case where a person's finger was pinched between the fiberglass cover panel and the handrails. However, the overall safety record to date is reported to have been excellent.

A release valve is provided which can manually lower the lift in the event of an electrical or hydraulic malfunction. There is no manual way to complete the "up" cycle, nor is there an emergency brake device to control lowering speed in event of a hydraulic line rupture.

2.3.2.4 Acceptance

During development of this system, Tri-Met worked closely with the Committee on Accessible Transit (CAT), a local organization. Tri-Met staff stated that CAT prefers the wayside lifts to the more traditional vehicle mounted lifts used on Portland buses. Utilization by the disabled has been good averaging 1000 passengers per month during the period July 1990 to February 1991. [61] According to APTA operating statistics, Tri-Met carries approximately 515,000 riders a month [62] so this is a utilization of about 1.9 lift users per 1000 passengers carried. There are positions for two wheelchairs on each light rail car and a securement system is provided (Figure 2-32). Perhaps 2-3 times a day these two wheelchair locations will be occupied and a disabled passenger will have to wait for the next train.

Acceptance by train operators has been less positive because of the need to align the light rail car with the wayside lift and get out of the cab to operate the lift. Also the delay of typically 2 minutes involved with operation of the lift can disrupt rush hour schedules. Tri-Met may order 5 or 6 additional wayside lifts but is considering using mini-platforms for future system expansion to Beaverton.

2.3.2.5 Reliability and Maintenance

Since the 54 lifts carry 1000 passengers a month, and each passenger requires two lift cycles (one for boarding and one for deboarding), each lift is used on the average 37 times a month. Records indicate a mean cycles between failure of 274 or about seven failures per month on a systemwide basis. [63] During a one year period from March 1, 1990 to March 5, 1991 corrective maintenance required 474.6 personhours, or about 0.7 personhours/month for each lift. During the same period preventative maintenance required 701 personhours, or 1.1 personhours per month for each lift. [64] Tri-Met uses the same persons to maintain lifts, ticket machines and fare validators; their job title is "Fare/lift Maintainer".

Tri-Met keeps records of service dependability. During the period August 1990 to February 1991, disabled users were unable to either board or deboard because of equipment failures 51 times or about 7 times per month. [65] This means a disabled user has a 99.3% probability of a mechanically reliable trip. However, we were told that 2-3 times a day a disabled user is delayed because there is no room for his or her wheelchair on the light rail car. With about 33 users per day, the disabled user has only a 92.4% probability of

FIGURE 2-32. TRI-MET WHEELCHAIR SECUREMENT DEVICE

obtaining space on the train. The combined trip dependability for the disabled user from both of these causes is 91.7%.

Tri-Met also keeps records of train delays of greater than two minutes attributable to wayside lift operations. [66] Over the seven month period August 1990 to February 1991 there were 157 service delays of over two minutes, an average of 22 per month. The average service delay was 5.7 minutes. Tri-Met operates about 6000 vehicle-hours a month [67] so the average of 125.4 minutes added delay per month from the wayside lifts represents only a 0.03% increase in schedule time. Since it is rare for any light rail system to achieve better than 99% on-time performance, this penalty is actually fairly negligible. (It should be kept in mind that delays of two minutes or less have not been included in these statistics.)

2.3.2.6 Capital Cost

The initial contract with Lift-U in 1981 was for $896,090 which covered design and prototype development plus production of sixty lifts. The final contract price including changes and addons was $963,060. [68] This represents an overall price per lift including development costs of about $16,000 in 1981 dollars. This price excludes installation of the lift. It is estimated to take a crew of three working for a period of three hours to install one lift.

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[4] Ibid., page 6.

[5] Data Sheet and Brochure, Grenoble Car, Alsthom, Paris, France.

[6] "Overview of New Developments in Light Rail Vehicle Design", LTK Engineering Services, July 1990, Prepared for San Diego MTDB, pages 5 and 9.

[7] Ibid. page 9.

[8] Ibid. page 9.

[9] Data Sheet and Brochure, Breda, Pistoia, Italy.

[10] See Reference 3, page 7.

[11] Ibid.

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[18] "Spadina LRT Environomental Assessment", Appendix A, Toronto Transit Commission, August 1990.

[19] See Reference 2.

[20] See Reference 5.

[21] Data Sheet and Brochure, St. Etienne LRV, Alsthom, Paris, France.

[22] Data Sheet, "Low-Floor-Level Light-Rail Vehicle for Munich", MAN GHH, Nurnberg, Germany.

[23] Telephone conversation, C. Wheeler, Toronto Transit Commission, January 17, 1991.

[24] "Spadina LRT Environmental Assessment", Economic Development and Planning Committee Report No. 12, August 1990, Exhibit 1.

[25] Ibid. page 12.

[26] "Feasibility Study: Light Rail System Accessibility", Final Report, Executive Summary Draft, Parsons Brinckerhoff Quade and Douglas, January 1990, page 3 and 30.

[27] "Boston Could Buy 100 Low-Floor Railcars", Metro Magazine, Nov. Dec. 1990, page 16.

[28] Telephone Conversation, Gerry Morse, Manager of Rail Vehicle Engineering, Massachusetts Bay Transportation Authority, April 26, 1991.

[29] Letter from Thomas B. Furmaniak, Deputy Director of Materials for Engineering, Massachusetts Bay Transportation Authority, to LRT Equipment Suppliers, June 6, 1990.

[30] Telephone Conversation with Paul Hughes, Deputy Project Manager for Low-Floor Cars, Massachusetts Bay Transportation Authority, June 18, 1991.

[31] "Track, Wayside and Vehicle Clearance Limitations", attachment to letter, reference 29.

[32] See Reference 29.

[33] Telephone Conversation with John Priede, Deleuw Cather, Chicago, Illinois, May 1991.

[34] "Feasibility Study: Light Rail System Accessibility - Addendum to the Draft Final Report", Parsons Brinckerhoff Quade and Douglas, September 1990, page III-4.

[35] "It's Already The Year 2000 in Grenoble", Peter Salwen, literature supplied by Alsthom, Paris, France.

[36] See Reference 15, page 2-4.

[37] Trip notes, meeting with Paul Fichera, Accessibility Coordinator, U.S. Human Resources Corp., San Francisco Municipal Railway Field Site Office, San Francisco, CA., February 25, 1991.

[38] "ADA Accessibility Guidelines for Buildings and Facilities", Federal Register, Vol. 56, No. 173, September 6, 1991, pages 45670-45673.

[39] "Transportation for Individuals with Disabilities; Final Rule", 49CFR Parts 27, 37 and 38, Vol. 56, No. 173, September 6, 1991, page 45633.

[40] "Safety Code for Elevators and Escalators", ASME/ANSI A17.1-1987, American Society of Mechanical Engineers, New York, New York, pages 239-244.41) Trip notes, meeting with Mark Lonergan, Operation Support Manager, Sacramento Regional Transit, Sacramento, CA, February 28, 1991.

[42] Light Rail Department Monthly Operating Statistics, January 1990 through December 1990, supplied by Mark Lonergan, Operation Support Manager, Sacramento Regional Transit.

[43] "1990 Transit Operating and Financial Statistics", American Public Transit Association, Washington, DC, November 1990, page B-282 and B-283.

[44] See Reference 42.

[45] Telephone Conversation with Mark Lonergan, Operation Support Manager, Sacramento Regional Transit, Sacramento, CA, April 29, 1991.

[46] See Reference 41.

[47] "Award of Sole Source Procurement Contract for Manufacturing and Installation of Elderly and Handicapped Lifts on the Guadelupe Corridor Project", Memorandum prepared by Mike Griffis, Santa Clara County Transportation Agency to the Transit District Board, December 23, 1987.

[48] Telephone Conversation with Gregory Pachlan, February 1991.

[49] "Boarding Procedures for the Mobility and Visually Impaired", Light Rail Operating Procedures, Santa Clara County Transportation Agency. May 14, 1990.

[50] "Information Regarding Mobility Impaired Lifts", Memo from Bill Mususan, Management Analyst to Mike Griffis, Senior Civil Engineer Rail Projects, Santa Clara County Transportation Agency, May 3, 1991, item 2.

[51] Telephone Conversations with Marie McDonald, President, McDonald Elevator, February 19, 1991, and September 20, 1991.

[52] "Proposed Rulemaking Articles 1 and 15.1, Elevator Safety Orders", Memo to Steven Jablonsky, OSH Standards Board, Sacramento CA from R.W. Stranberg, Chief DOSH, September 2, 1988 with attached Standards Presentation.

[53] See Reference 39.

[54] "Light Rail Wheelchair Passenger Log", Santa Clara County Transportation Agency, September 1990 and January 1990.

[55] See Reference 43, pages B242 and B-243.

[56] "Sole Source Procurement of Elderly and Handicapped Lifts (Y300) -- E&H Access to LRT", Memo to Gordon Smith from Odila Rashid, Acting Supervising Engineer, Guadelupe Corridor Project, December 1, 1987 with attachments.

[57] "Santa Clara County Transit District Contract Documents for Wayside Lifts - UMTA Project No. CA-03-0254", March 12, 1990, page 21.

[58] "Contract #82-8090 Wayside Lift Procurement Documents", Prepared by Tri-County Metropolitan Transit District of Oregon, November 1981.

[59] Telephone Conversation with Ahmed Fazal, Mechanical Engineer, Tri-Met, March 27, 1990.

[60] Specifications provided by Ahmed Fazal, Mechanical Engineer, Tri-Met.

[61] Wayside Lift Statistics, July 1990 to February 1991, Provided by Ahmed Fazal, Mechanical Engineer, Tri-Met.

[62] See Reference 43, pages B-268 and B-269.

[63] See Reference 61.

[64] Computer Printout of Maintenance Activity for period March 1, 1990 to March 5, 1991 provided during visit to Tri-Met, March 5, 1991.

[65] See Reference 61.

[66] See Reference 61.

[67] See Reference 62.

[68] Trip notes, meeting with Ahmad Fazel, Mechanical Engineer, Tri-Met, March 5, 1991.

CHAPTER THREE
INNOVATIVE SOLUTIONS TO TRAIN/PLATFORM SAFETY

This chapter discusses important recent developments related to the train-platform interface. These issues have become an important matter with passage of the Americans with Disabilities Act. Department of Transportation regulations incorporate accessibility guidelines developed by the Architectural and Transportation Barriers Compliance Board which require that "Platform edges bordering a drop-off and not protected by platform screens or guardrails shall have a detectable warning. Such detectable warnings...shall be 24 inches wide running the full length of the platform drop-off..." The regulations further specify that the detectable warning surface shall consist of raised truncated cones with a nominal diameter of 0.9 inches, a nominal height of 0.2 inches and a nominal center to center spacing of 2.35 inches and that the warning strip shall contrast visually with adjoining surfaces. It is also required that detectable warning surfaces used on interior surfaces differ from the adjoining walking surfaces in resiliency or sound-on-cane contact. [1]

These regulations will require either detectable warning strips or platform barriers for the platform edge at all new stations for rail, light rail, commuter rail, automated guideway transit and monorail systems. This chapter discusses current developments and available methods for platform edge protection. It begins with a discussion of a number of edge protection materials either installed or being seriously considered by transit systems around the country which are candidates for both new construction and retrofit installations. This is followed by a discussion of several intrusion detection systems which have been used by transit systems to detect the presence of someone on the guideway and stop trains. Platform barrier solutions including railings and walls, some of which are used in conjunction with intrusion detection systems are described. The section concludes with the ultimate solution which has been used for many automated guideway transit systems; full barrier protection of all passengers from the guideway with coordinated station doors which only open when there is a train parked in the station.

Where information is available, this chapter provides information on capital cost, required maintenance manhours, reliability and safety. A closing section compares capital and maintenance costs for the various alternatives.

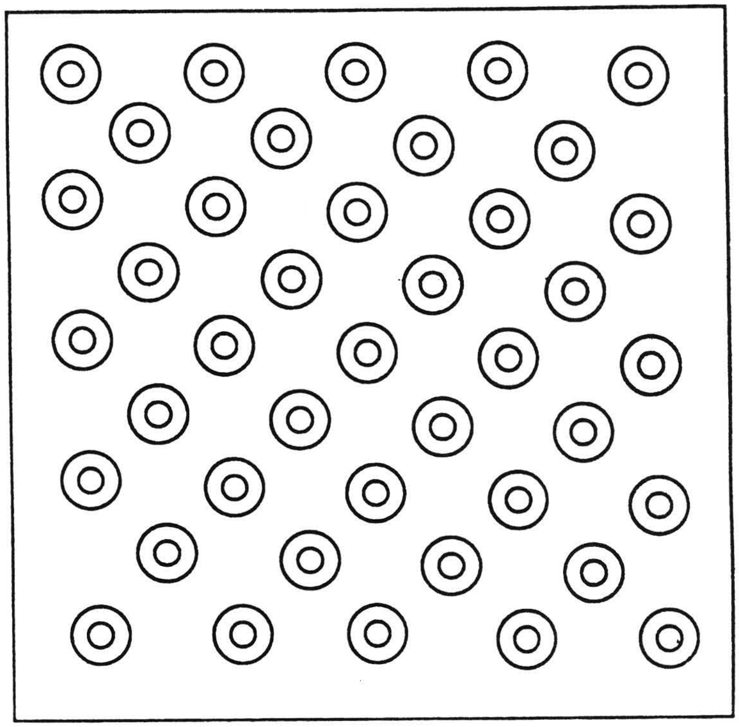
3.1 MATERIALS FOR DETECTABLE WARNING SYSTEMS

There are a great number of materials either presently installed or under consideration by transit agencies for use as a detectable warning edge. This section has been intentionally limited to highlight what appear to be some of the more promising, imaginative or controversial solutions. For further information, the reader is referred to the references at the end of this chapter.

3.1.1 Pathfinder Tile

Pathfinder tile, manufactured by Guidance Systems Incorporated, has been a pioneer in the introduction of detectable warning strips at rail and light rail platform edges. The Pathfinder tile pattern has been a key to its popularity (Figure 3-1). This pattern consists of raised truncated domes with a diameter of nominally 0.9 inches, a height of nominally 0.2 inches and a center to center spacing of nominally 2.35 inches. The tile is bright yellow in color. The pattern is similar to one which has been successfully used by blind and visually impaired travelers in Japan since 1968. Pathfinder tile was tested in a landmark UMTA funded study by Dr. Alec Peck and Billie Louise Bentzen of Boston College at the Bay Area Rapid Transit System Lake Merritt Station in 1985. [2] The BART experiments compared the detectability of Pathfinder tile with a PVC "corduroy" pattern and an epoxy aggregate "corduroy" pattern installed at the Berkeley, Montgomery and Rockridge stations. Thirty totally blind travellers participated in the experiments. The study found both the "corduroy" and Pathfinder surfaces to be effective but noted that the rate of detection of Pathfinder warning tile, within the limits of this one study, was significantly better.

Because of its high detectability, this pattern has long been popular with the blind community. The American Council of the Blind formally endorsed the use of warning and



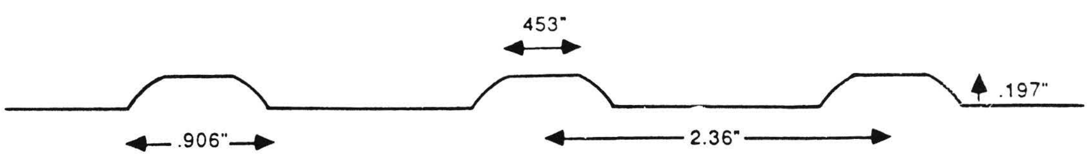


FIGURE 3-1. PATHFINDER TILE PATTERN

directional tiles with "...serious consideration given to 'Pathfinder' tiles" in its Resolution 85-22 adopted July 13, 1985. [3] A pattern of the general "Pathfinder" type will be required for all new construction platform edges by Sections 4.29 and 10.3.1 of the ADA Accessibility Guidelines for Buildings and Facilities. These guidelines have been incorporated as part of Federal regulations governing transportation for individuals with disabilities published in the Federal Register on September 6, 1991 (49 CFR Parts 27, 37 and 38). [4] It should be reiterated that this pattern has been widely used in Japan since 1968 and is not covered by any patent; nor is it proprietary to Guidance Systems Incorporated.

Pathfinder tiles are of two distinct types. The original tile studied by Peck and Bentzen has now been installed at all transit platforms for San Francisco's BART, Sacramento's light rail, and Miami's rapid rail and people mover systems. It is a synthetic rubber tile with a pre-applied pliant polymer adhesive with release paper. The subsurface must be carefully cleaned and primed. The tile is then positioned in place and gently tapped with a mallet. Transit agencies using this tile have experienced problems with adhesive failures and liftoff, usually resulting in curling of the corners of the tile. This problem is aggravated by inadequate cleaning, defective installation including failure to maintain a small gap between adjacent tiles, and by hot and possibly cold weather. The tile expands on warm days, and possibly creeps with age. If an insufficient gap exists between tiles this can cause the tiles to buckle. Figures 3-2 and 3-3 show typical liftoff problems observed at the BART and Sacramento systems.

The Operations Support Manager for Sacramento Regional Transit estimates that 10-20 percent of the tiles have been replaced since 1987 due to failure of adhesion and liftoff. [5] At BART, a survey of the Bay Fair Station conducted by the System Safety Department showed a third of the tiles had failed after a year and a half of use. Other BART stations fared much better, with failures ranging from one to ten percent of the tiles. [6] Guidance Systems Incorporated estimates that on the average five percent of the tiles have failed. [7]

Some transit agencies have also experienced difficulties keeping the tile clean. The key appears to be a rigorous schedule of frequent cleaning. In Sacramento, the transit agency routinely steam cleans all station platforms daily. The tiles are also steam cleaned

FIGURE 3-2. TILE LIFT-OFF
LAKE MERRITT STATION

FIGURE 3-3. TILE LIFT-OFF
SACRAMENTO MALL

during this operation, effectively at no added cost. First installed in 1987, these tiles remain clean and attractive (Figure 3-4). Conversely, the tiles used in the pedestrian mall in downtown Sacramento are not under transit agency maintenance and do not receive this daily cleaning. These tiles show severe accumulation of dirt and grime (Figure 3-5). This experience indicates that tile appearance can be maintained provided they are cleaned frequently.

Because of questions about cleaning, loss of effectiveness due to dirt and scuffing, adhesion and durability the Elderly and Handicapped Advisory Committee of the Washington Metro recommended against the use of "Pathfinder" tactile tiles and guide strips at the edge of platforms. [8] Also, a thorough study by the Toronto Transit Commission, while confirming the excellent detectability of Pathfinder tiles, rated them as having "great difficulty to maintain" and as being "extremely dirty" relative to the other 16 materials tested. The TTC also felt the tiles posed a tripping hazard. [9] It should be noted that comparable type studies by Miami and BART failed to surface serious concerns with cleaning or maintainability of the Pathfinder tiles. [10,11] And safety data collected by BART (see Section 3.1.1 of this report) indicates a reduction in station slips and falls after installing Pathfinder tile.

Guidance Systems Incorporated is working closely with the transit operators to address their concerns and has recently developed a new tile made of a fiber reinforced bonded ceramic composite. The tiles may be bonded to concrete, brick, granite, tile or asphalt platform surfaces using a two part epoxy resin. In a news bulletin, the company is "...urging our customers to recommend use of the composite tile for all types of applications, in the interest of eliminating potential maintenance problems associated with long-term use of the rubber tile." The bulletin adds that the company is "...maintaining an inventory of rubber tile to be used as replacement in applications where the rubber tile has been used." [12]

It would therefore appear that future "Pathfinder" installations will use this new composite tile. The new tile is currently being tested in limited sample installations at BART, Sacramento, and the MBTA. In Sacramento this tile has been installed on a high level mini-platform at the Roseville Road station. We observed some fading of the yellow

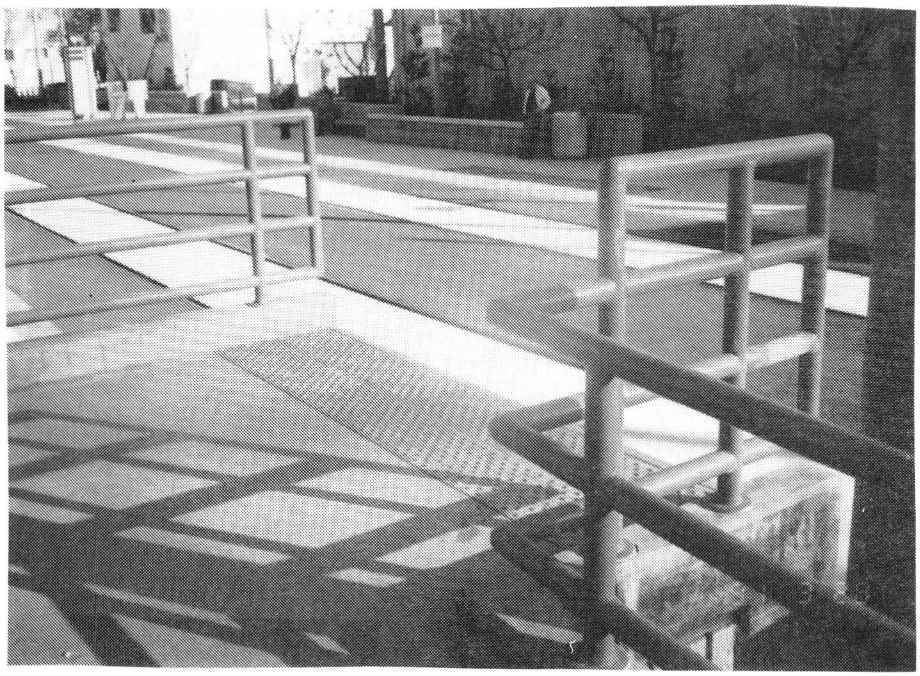


FIGURE 3-4. CLEAN, ATTRACTIVE TILE AT SACRAMENTO STATION

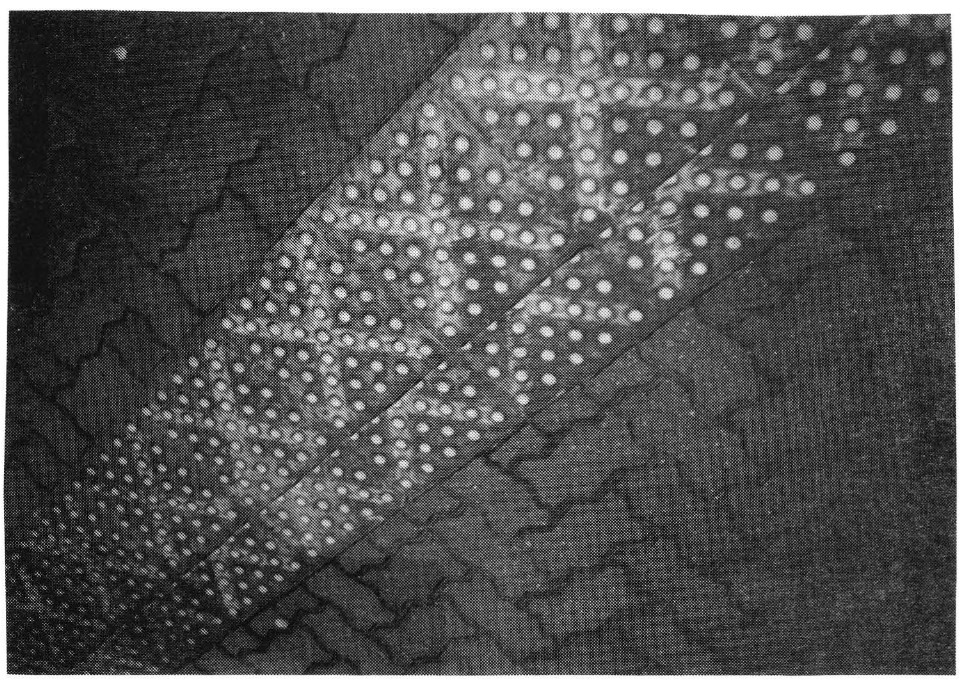


FIGURE 3-5. TILE ON SACRAMENTO MALL IS NOT CLEANED DAILY AND BECOMES UNSIGHTLY

color apparently caused by ultraviolet sunlight. Another concern at Roseville Road was difficulty in obtaining a level surface when the thin (1/16 inch thick), rigid tiles are bonded to an uneven concrete substrata. Guidance Systems has reduced the tile size from the 11.8 in. x 11.8 in. used in the Roseville Road installation to 6.5 in. x 6.5 in. to address this problem and also make it easier to lay a radius without cutting the tile. These new composite tiles will be installed in a demonstration at Sacramento's Arden del Paso Station and have also been installed on the inbound platform of the Chinatown Station of the Massachusetts Bay Transportation Authority (Figure 3-6). At this time formal results from tests of the new tile are not yet available.

Guidance Systems is also working with Bechtel on a new warning material for use on BART extensions. Instead of a tile, this material, made of a nonflammable modified polyurethane, will be supplied in two or three foot wide strips of from four to ten feet in length. It will also have the bright yellow color and the "bump" pattern. No information on its performance in use is presently available.

The Toronto Transit Commission tested a fiberglass tile referred to in the report as "Escort" tile. Guidance Systems staff advised us this tile is the same as the fiberglass "Pathfinder". The tile had a 99.6% detection rating (versus 100% for the rubber "Pathfinder"). The TTC found no improvement in ease of cleaning and maintaining over the rubber tiles. The TTC also tested a tile referred to in its report as "Access" tile, a yellow urethane material which appears similar to the new urethane "Pathfinder". It received a 99.3% detection rating. TTC again found no improvement in ease of cleaning and maintaining over the rubber tiles. [13] Guidance Systems has advised that it is continuing to research improvements in cleaning and maintenance.

3.1.2 Armour Tile

As has been mentioned, the Toronto Transit Commission, in association with the Canadian National Institute for the Blind conducted a very thorough research study comparing 17 different edge warning systems for detectability, maintainability and safety. [14] The major thrust of the study revolved around a detectability experiment carried out in

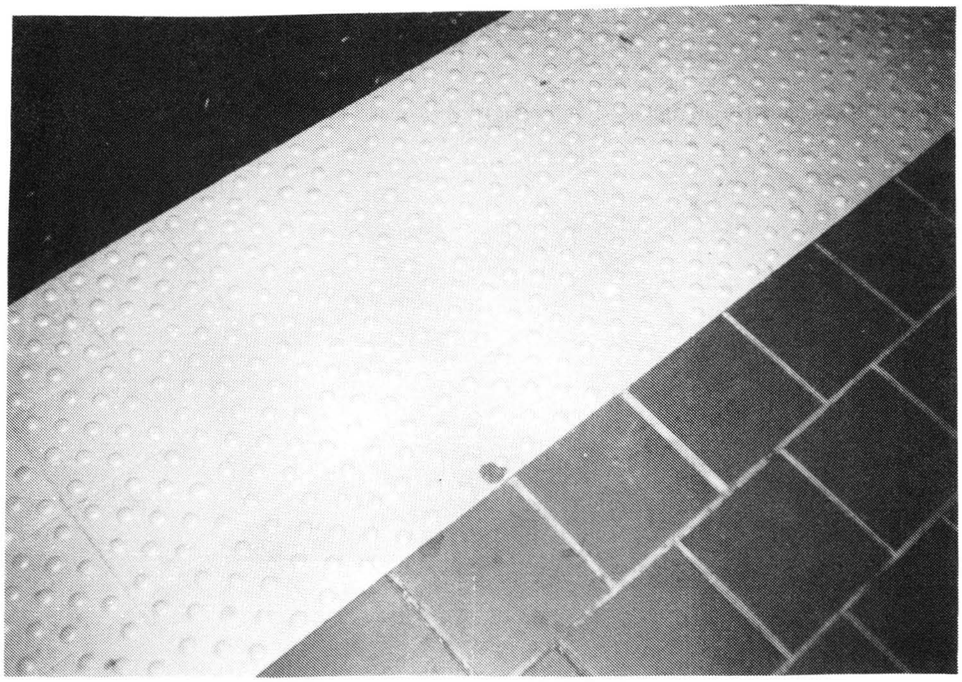


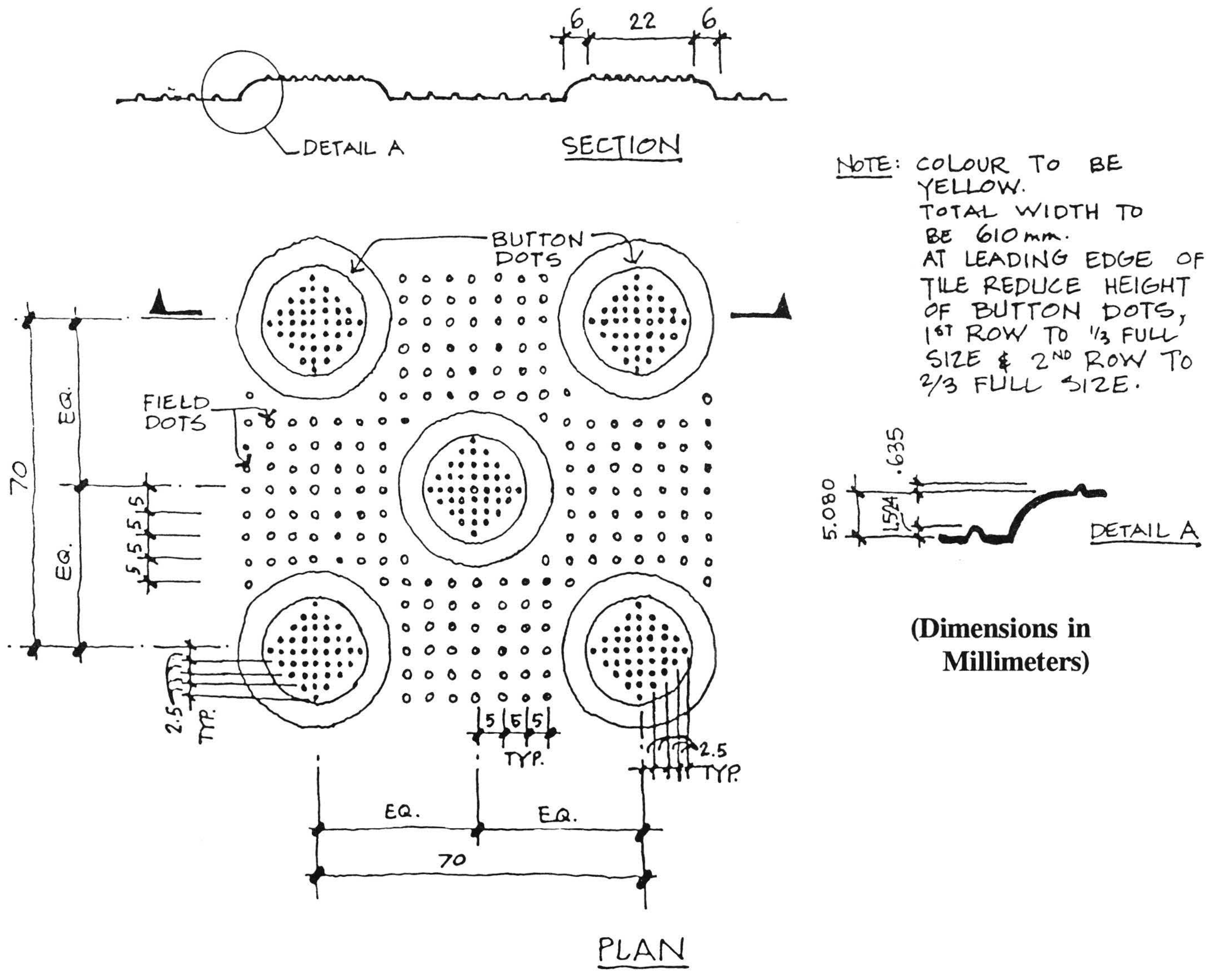
FIGURE 3-6. NEW PATHFINDER-COMPOSITE TILE INSTALLED AT MBTA CHINATOWN STATION

Bay Lower station and involving close to 100 visually impaired and blind volunteers. The large variety of surfaces tested included not only special "detectable" surfaces such as "Pathfinder", but more conventional granite and ceramic tile edging as well.

After reviewing the test results, the TTC/CNIB task force recommended "Armour-Tile", manufactured by Engineered Plastics Incorporated of Oakville, Ontario. (The firm also has manufacturing facilities in New York State.) The study gave this tile a 100% detectable rating, and found it was "extremely clean". "Some difficulty to maintain" was noted as compared with traditional granite and ceramic tile surfaces. "Armour-Tile" is made of a reinforced plastic composite, bright yellow in color, with a tactile detectable surface (Figures 3-7 and 3-8). The manufacturer is offering the tile in two different versions, one for retrofit over an existing floor surface and the other for new applications. Manufacturer supplied specifications [15] indicate the tile tested to the Underwriters' Laboratories ASTM-E84 Steiner Tunnel flame spread test has a flame spread less than 25. This meets a class I fire rating. The tile also is said to meet UMTA guidelines for smoke generation. As can be seen in Figure 3-7, the dot pattern used by "Armour-Tile" may not strictly meet the requirements of the Architectural and Transportation Barriers Compliance Board guidelines specified in Federal regulations for a detectable warning. The raised bumps are approximately 0.9 to 1.3 inches in diameter and 0.2 inches high on 2.8 inch centers.

The retrofit version of the tiles are 24.375 inch x 14.125 inch long x 0.1 inch thick. They are applied using an epoxy adhesive. Installation is not a simple matter. The existing structural slab or tile surface must be prepared by diamond cutting a 1/4 inch wide by one inch deep angled groove to accept the front edge of the tile. A straight edge is then diamond cut 2 1/4 inch deep along the outside edge of the platform to remove the varying tolerances of the existing edge. Then carbide cutters are used to make grooves 1/8 inch deep by 1/4 inch wide in the existing floor surface to permit a good mechanical and chemical bond of the epoxy adhesive.

Epoxy adhesive is troweled to both floor and tile surface. The tile is placed in position and then either clamped or weighted to maintain pressure while the adhesive is curing. Epoxy adhesive is used to fill in the leading edge of the tile and lock it into the one inch deep groove. This careful installation process is intended to eliminate tile lifting and



(Dimensions in Millimeters)

FIGURE 3-7. DIMENSION OF "ARMOUR-TILE"

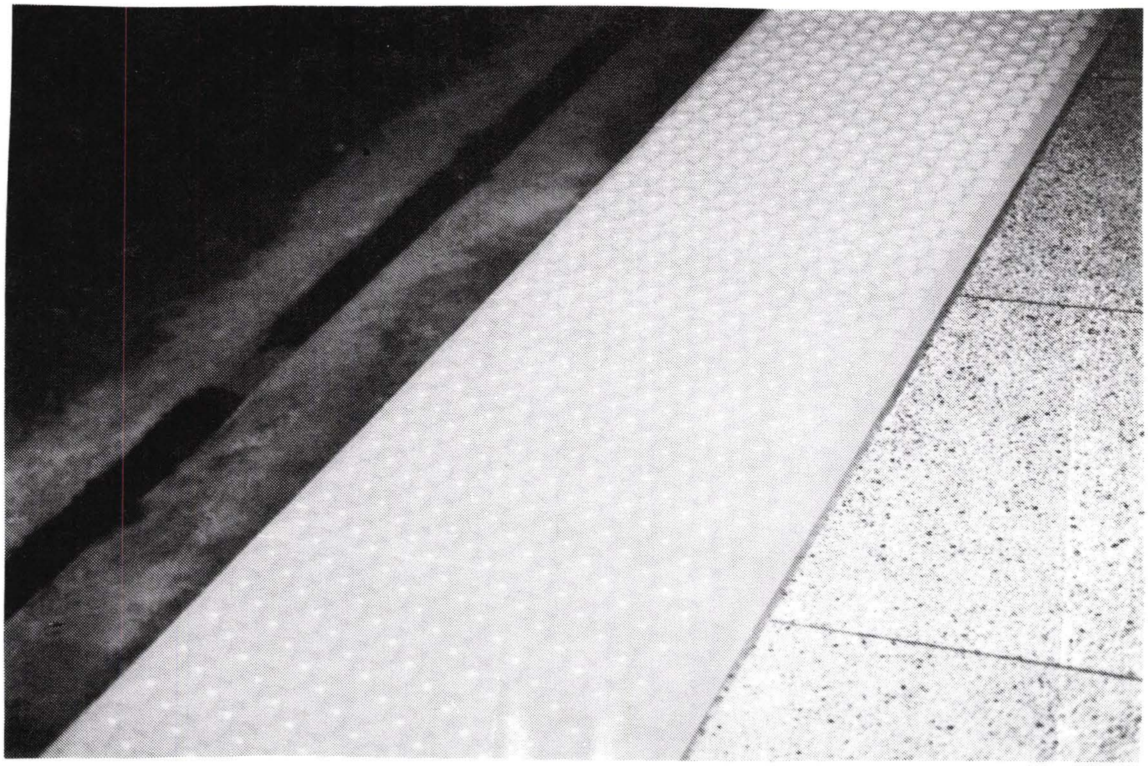


**FIGURE 3-8. "ARMOUR-TILE"
INSTALLED AT TRANSIT PLATFORM EDGE**

uneven joints as well as to minimize tripping. The manufacturer claims a wear resistance five to ten times greater than ceramic or granite tile. [16]

"Armour-Tile" also comes in a modular tactile tile designed for new installations. These tiles are 11.75 inches x 11.75 inches x 0.5 inches thick and installed using epoxy laid with a notched trowel.

At the present time, in addition to the original Toronto tests, the TTC is installing this tile in the Lawrence and Royal stations (underground) and the Davisville Station (above ground). The Vancouver Skytrain also plans to use "Armour-Tile" in new stations on its planned extension. In the United States, the Massachusetts Bay Transportation Authority has installed the tile at its North station and is planning a demonstration at its Wellington Station in the near future. Also, we understand the material is being specified by the architect for the Jacksonville Automated Skyway Express extension in Florida.

3.1.3 Kowa Tile

Kowa is a trading company with offices in Houston which represents several small Japanese ceramics suppliers. It is offering a ceramic tile which incorporates the dot pattern specified in Department of Transportation ADA regulations, essentially a similar pattern to the "Pathfinder" but in a conventional ceramic tile (Figure 3-9). The color of the tile is a buff yellow, not as bright as the "Armour-Tile" or "Pathfinder". Kowa sales representatives have advised us this is the tile selected by the Japanese Traffic Safety Research Institute in 1968 for use in transit stations in Japan. The Massachusetts Bay Transportation Authority (MBTA) is planning a demonstration test with Kowa tiles at the Andrew, Broadway and Sullivan Square stations. We have been unable to obtain any detectability tests conducted in North America on this tile. However, Gene Lozano of the American Council of the Blind has examined a sample and advised us that the bump pattern is excellent. On the other hand, he believes that the color contrast is inadequate and that there will be no difference in sound and resiliency between the tile and the platform proper.

Also, two members of the Washington Metropolitan Area Transit Authority's Elderly and Handicapped Transportation Advisory Committee had the opportunity to

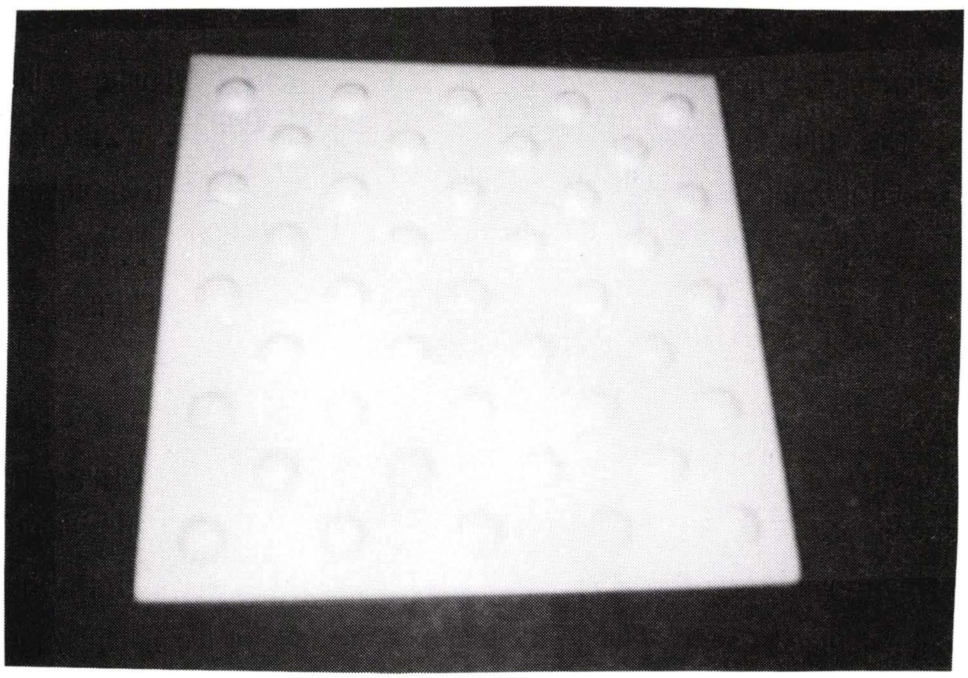


FIGURE 3-9. SAMPLE OF KOWA TILE

experience the use of tactile tile in Japan in August of 1989 during the third Japan/USA Conference for Persons with Disabilities. Both persons were visually impaired and both reported having difficulty negotiating the tactile surfaces at stairs, escalators and walkways while using their canes. [17]

3.1.4 AMS Stamped Steel Strip

A unique platform edge detection material has been developed by Advantage Metal Systems (AMS) of Brockton, Massachusetts with the cooperation of American Safety Technologies of Roseland, New Jersey and the Safety Department of the MBTA.* The material consists of two foot wide by ten foot long strips of 16 gauge (0.06 inch thick) galvanized steel sheet metal which is stamped with a raised dot pattern using a Cincinnati metal press (Figure 3-10). The "bumps" are 0.75 inch diameter, raised 0.125 inches high on 2.5 inch centers as compared with Department of Transportation regulations which call for 0.9 inch diameter "bumps" raised 0.2 inches high on 2.35 inch centers. However, AMS president Helmut Klohn has assured us the company intends to modify its tooling to produce a pattern in full compliance with Federal regulations. One edge of the stamped sheet is bent over to form a half inch lip (Figure 3-11). The sheet metal is cleaned and primed and then hand sprayed with AS-550 Non-Slip Floor and Deck Coating. This coating, manufactured by American Safety Technologies Inc. was originally developed for use in marine and industrial environments and contains an abrasive material suspended in epoxy resin. It is available in Safety Yellow.

The MBTA has installed this material at commuter rail mini-platforms for the handicapped at Yawkey Station, Attleboro Station, Reading Station, and Mishawum Station. A groove is sawed in the concrete or wood platform surface where the front edge of the sheet will lie. The rolled over lip of the sheet metal sets in this groove to provide a "non-trip" leading edge. The groove is then sealed with caulking compound. The sheet

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* Early work was done by KSK Engineering Corp. of Brockton, Massachusetts, but the product is now the property of AMS.

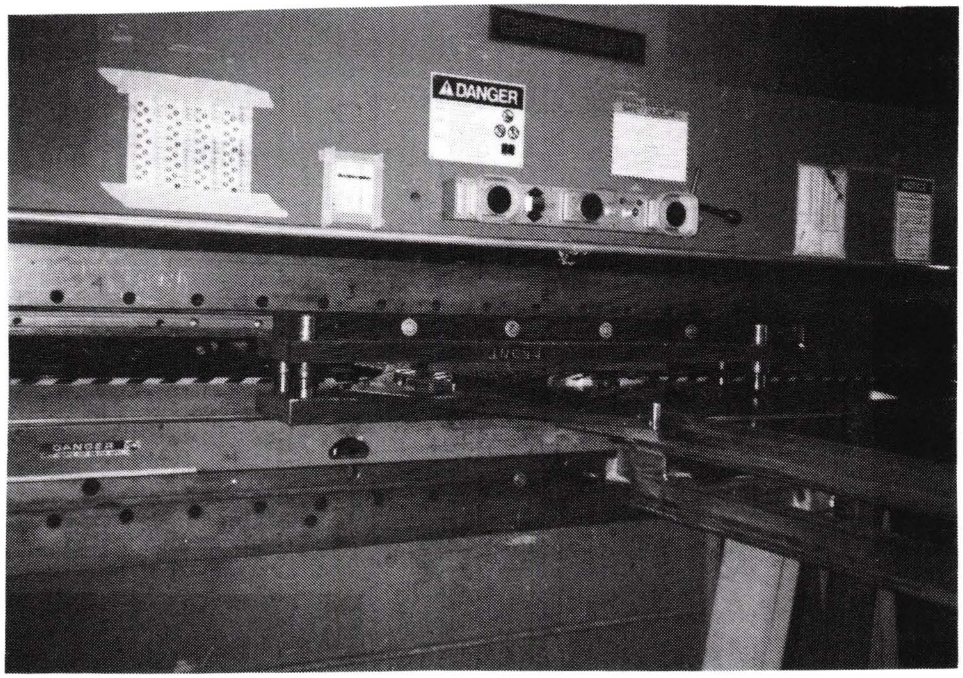


FIGURE 3-10. PRESS USED TO STAMP SHEET METAL TO MAKE AMS STRIP

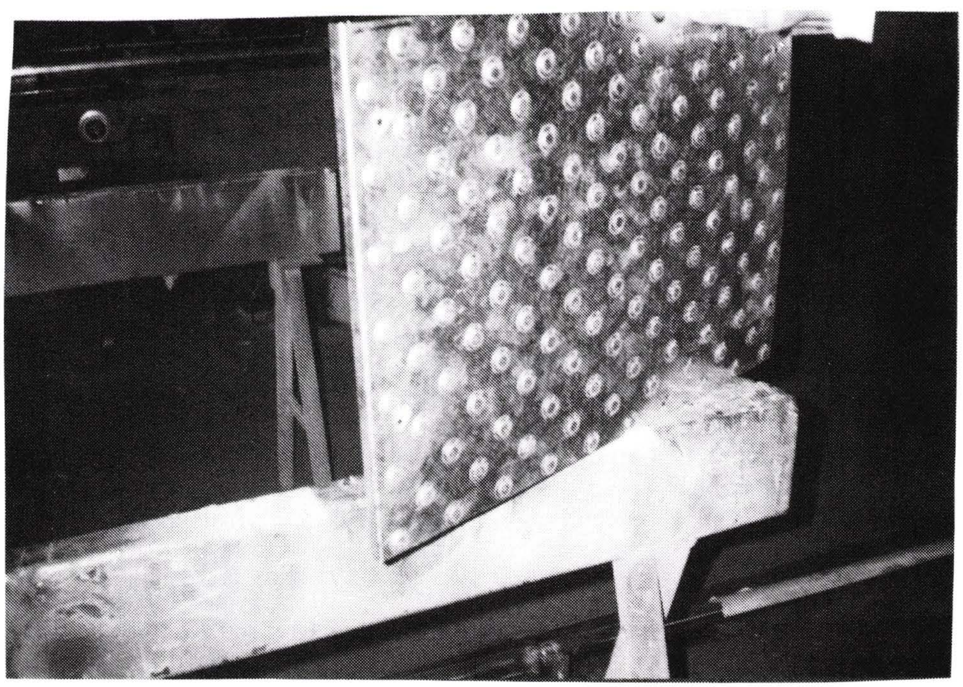


FIGURE 3-11. STAMPED SHEET METAL WITH EDGE BENT OVER

metal itself is simply fastened to the concrete Mishawum Station platform using concrete nails (Figure 3-12). At Yawkey Station, where the platforms are wood, the sheet metal is fastened using stainless steel wood screws. The tactile strip can be cleaned using standard industrial cleaning solution. Gum can be removed using xylene with a rubber brush or scraper.

Because of the ease of installation and relative low cost this material is a candidate for retrofitting of existing stations. Wear data is not yet available for the non-slip coating in this application. A similar non-slip floor and deck coating (NS-550) has been used to resurface platforms of the New York City Transit Authority. The material has also been widely used in other industrial applications and has been successfully used on stair treads in stations of the MBTA. For this application, there is some concern the paint will wear off the top of the impressed domes. Boston is considering fairly widespread use for commuter rail stations. In addition, the MBTA has installed this material on the inbound platform of the State Street Station on the Blue Line to see whether it will hold up to heavier rapid transit usage (Figure 3-13).

Gene Lozano of the American Council of the Blind examined a sample and found the lower height and smaller size of the bumps made the surface difficult to detect. (As stated, AMS will correct this deficiency.) He also did not observe a noticeable difference in resiliency or sound-on- cane contact. Underneath the tactile strip, AMS now plans to add a 1/16 inch synthetic rubber membrane to improve installation over uneven platform surfaces and provide a more distinctive sound-on-cane. The backing is being tested at State Street Station.

AMS is also planning to apply a urethane sealant over the safety yellow paint to make it easier to clean. The tactile strip can also be provided in stainless steel at a somewhat higher cost.

3.1.5 American Olean Tile

American Olean has been marketing ceramic platform edge tile for a number of years. The Jacksonville Automated Skyway Express, an automated people mover system

FIGURE 3-12. AMS SHEET METAL STRIP NAILED IN PLACE ON MISHAWUM STATION PLATFORM

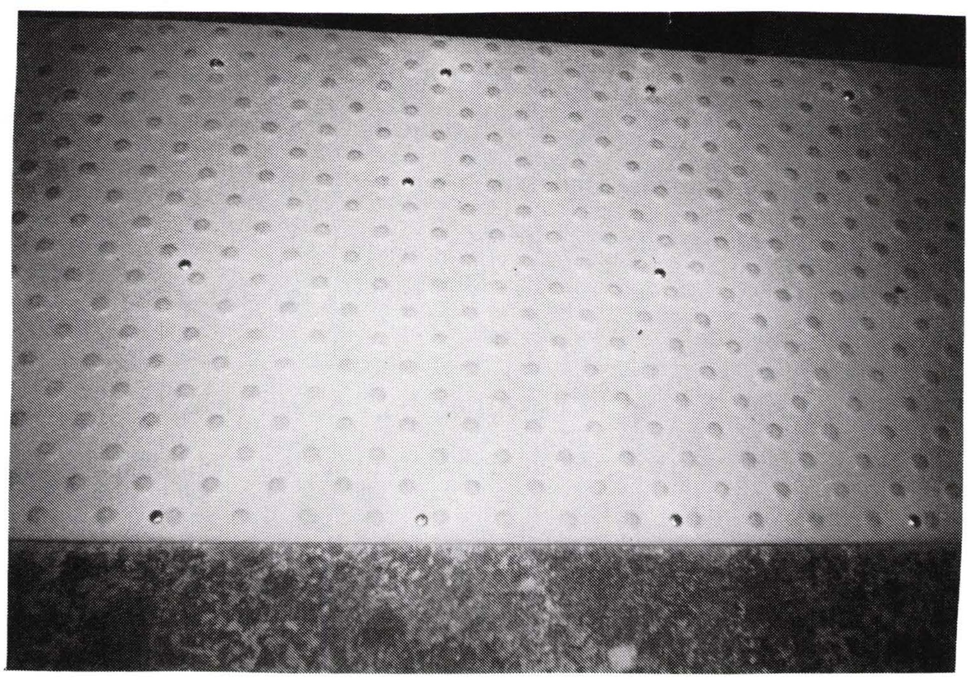


FIGURE 3-13. AMS SHEET METAL STRIP NAILED IN PLACE AT MBTA STATE STREET STATION

which opened for service in 1989, uses American Olean "Transit-Tile 191" at all platform edges. The ceramic tiles are six inch x six inch x 0.5 inch thick. Each tile has sixteen discs, 0.875 inch in diameter and 0.09 inches high. It can be installed using conventional mortar or epoxy mortar. A two foot wide strip of "Canyon Red" tiles is laid along the entire platform edge which is also protected by a railing (Figure 3-14). At the openings in the railing an additional six inch strip of warning tile finished "Safety Yellow" is added. In addition to Jacksonville, American Olean has also installed a similar tile at four stations on the Southeastern Pennsylvania Transportation Authority (SEPTA) Market-Frankford Line (the 19th, 30th, 34th and 38th Street Stations).

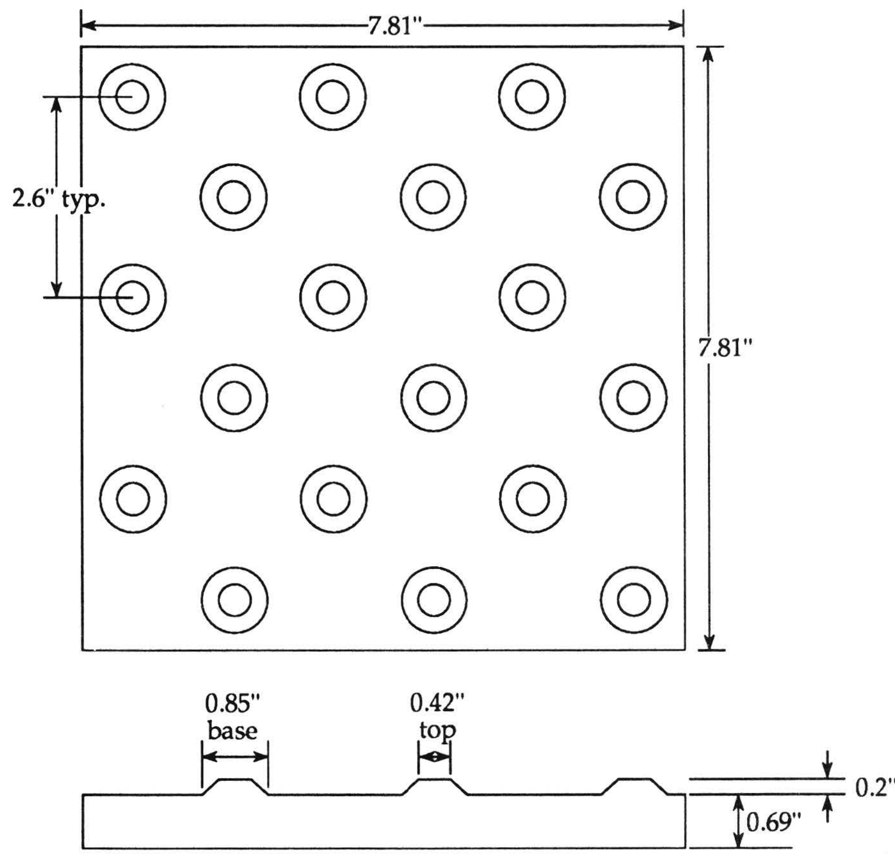
The supplier no longer makes the tile in Safety Yellow although we were able to get an unglazed sample in canyon red. No formal tests of detectability were located for this tile. However, Gene Lozano of the American Council of the Blind examined a sample tile and advised that the bumps are not high enough and are too close together to be useful for cane detection. (These bumps would not meet Department of Transportation regulations.)

American Olean has been closely following regulatory developments and has recently fabricated a 6 inch x 6 inch prototype ceramic tile to meet the dimensional requirements of Department of Transportation regulations. While the sample is gray, American Olean will offer the material in a buff color, similar to the Kowa ceramic tile and is also working on a new safety yellow prototype in their laboratory.

3.1.6 Terra Clay Tile

Terra Clay of Roanoke, Alabama is developing a tile it refers to as "Braille Tile" which addresses the need for a bright color and also concerns about ceramic tile being slippery when wet. Tile dimensions are shown in Figure 3-15. Prototype tiles are 7.81 inch x 7.81 inch x 0.69 inch thick. The tile is finished with a safety yellow or yellow-orange glaze. Abrasive grains are added to the glaze to provide slip resistance. The body of the tile is a typical porcelain composition which is very dense and strong as compared with tiles fired at lower temperatures. Terra Clay has also made sample tiles in an unglazed yellow porcelain which has a buff color. In all cases, the pattern consists of bumps with a 0.85 inch

FIGURE 3-14. AMERICAN OLEAN WARNING TILE IN JACKSONVILLE, FLORIDA



Dimensions in Inches

FIGURE 3-15. NOMINAL DIMENSIONS FOR TERRA CLAY TILE

base diameter, a 0.42 inch top diameter and a height of 0.2 inches. Bumps are spaced 2.6 inches apart. [18]

3.1.7 Other Warning Strip Materials

Another ceramic tile, this one made in Germany, was originally purchased for use at platforms of the Sacramento Regional Transit light rail system. This tile, made by Agrob, is finished in a buff yellow and has raised ovals in an "x" pattern. It was rejected by the Sacramento blind community because the "bumps" are not high enough and are too close together. In addition to Kowa, American Olean and Terra Clay, the MBTA has also obtained sample ceramic tiles from Summitville Tiles and Crossville Ceramics.

The San Francisco Municipal Railway (MUNI) has been doing research into some other alternative edge warning systems. [19] Testing has been conducted upon non-skid material made by Norcal Molecular Inc. and rubber tiles manufactured by R.C. Musson, Co.

The non-skid material consists of an aluminum oxide aggregate embedded in a long chain organic polymerizing fluid. [20] The material was initially tested in both striped and solid patterns, but subsequent testing has been limited to the solid pattern. As for the rubber tiles, several different styles of flame retardant rubber flooring were initially tested, all meeting the ASTM-E-84 Steiner Tunnel test with a flame spread rating of 25 or less. [21] The version selected for additional testing is an oatmeal colored rubber flooring tile designated 550SL, which is available in 24 inch x 24 inch tiles, 7/32 inch thick with a waffle iron grid pattern. It is applied using a two part epoxy adhesive.

Tests are now underway with 20 foot long by two foot wide warning strips of the non-skid aluminum oxide and waffle pattern rubber tile in the Van Ness Station of Muni (Figure 3-16). In addition, MUNI has arranged for the Department of Health to conduct flammability and toxicity tests on both of these materials as well as "Pathfinder" tile; results are not yet available. Neither of the two materials being considered by MUNI would meet Federal regulations for a detectable warning surface because they do not have the "bump" pattern.

FIGURE 3-16. SERVICE TEST OF WAFFLE PATTERN RUBBER TILE (LEFT SIDE) AND NON-SKID ALUMINUM OXIDE (RIGHT SIDE) AT MUNI VAN NESS STATION

3.1.8 Capital Costs of Warning Edge Protection

Capital costs of warning edge protection systems installed range from $10 to $30 per square foot. One of the least expensive approaches is the use of stamped galvanized sheet metal with sprayed abrasive coating. This method costs $14-17 per square foot installed. [22] "Pathfinder" tiles were installed at 27 stations and two pedestrian malls in 1987 for a total contract price including installation of $650,000. The order involved approximately 32,000 one foot square tiles. This is equivalent to $20/square foot. [23] Engineered Plastics provided a budget estimate price of $20/square foot (U.S. currency) installed for their "Armour-Tile". [24] Kowa ceramic tile costs $23/square foot for material only. [25] Terra Clay "Braille Tile" is expected to cost about $15 a square foot for material only. Using a typical price of $4/square foot for installation [26] would make the total price $27/square foot for Kowa and $19/square foot for Terra Clay. The Munson rubber tile being used in MUNI tests is estimated by the supplier at $24.23/tile or $6/square foot for materials only [27]

The above costs are supplier's estimates and do not include any allowance for engineering the job or for a contingency.

3.1.9 Maintenance Required for Warning Edge Protection

The Sacramento Regional Transit District does a careful job of maintaining their "Pathfinder" tiles. The maintenance effort required is estimated by their Operations Support Manager at 8 personhours every 1 1/2 to 2 months or 48 to 64 personhours per year. [28] This effort maintains all tiles in 27 stations, each with 320 foot long single sided platforms with one foot wide warning strips. It does not include maintenance of tiles in two pedestrian malls which are the responsibility of the city. This amounts to six to seven personhours per year per 1000 square feet of tile. There is insufficient experience with the other approaches to provide a solid estimate of maintenance requirements. However, because of the problems with liftoff experienced with these early "Pathfinder" tiles, it is expected this figure should be a conservative number for planning purposes, regardless of the surface material selected.

3.1.10 Detectability of Warning Tiles

In terms of detectability, independent tests at transit systems in San Francisco, Toronto and Miami have tended to confirm the effectiveness of the raised dot pattern specified in Department of Transportation regulations.

1) Dr. Alec Peck and Billie Louise Bentzen of Boston College under terms of an independent contract with the Urban Mass Transportation Administration conducted formal tests of the platform edge material installed at BART's Rockridge, Berkeley, Montgomery and Lake Merritt Stations. Detectability of "Pathfinder" tile was 100% for long cane users with a two foot wide warning strip. The platform floor approaching the warning strip was terrazzo. [29]

2) The Toronto TTC tested 17 edge warning materials, all two feet in width, at the Bay Lower subway station. 97 persons participated of whom 14 used a tipping cane, 38 a sweeping cane, 13 guide dogs, and the remainder partial vision. 100% detectability was achieved by the "Pathfinder" tile and "Armour-Tile", both of which use a raised dot pattern and bright yellow color. In the same tests, flamed granite achieved a detectability of 91%. [30]

3) The Metro-Dade Transit Agency compared "Pathfinder" tile with a granite edge in tests at the Civic Center Metrorail station. 19 cane users were able to detect a 24 inch wide "Pathfinder" warning strip 99% of the time compared with 89% detectability for the existing flame cut granite edge. The approach platform material in Miami is red paver tile. [31]

A possible deficiency in these tests and the Architectural and Transportation Barriers Compliance Board guidelines incorporated in Federal regulations is in the relative inattention given to the approach material. Since cane users rely heavily on the change in texture, an effective warning strip may depend upon the texture of the approach material.

Earlier detectability studies stressed this factor which has tended to be minimized in more recent work.

The above cited studies all demonstrate the effectiveness of a two foot wide warning strip. The Toronto study states that "...based on the previous experiments a 24 inch width of warning strip appears to be most effective. Anything narrower adversely affects detection while anything wider interferes with traffic flow, reduces the effect of the strip as a warning device, and doesn't appear to significantly increase detectability." [32]

During study for the present report, passenger activities in the BART Embarcedero station during rush hour were videotaped. This station is equipped with a two foot wide warning strip using "Pathfinder" tile whose pattern and color meet Section 4.29.2. of the Architectural and Transportation Barriers Compliance Board guidelines. Inspection of the videotape showed this warning edge to be remarkably effective at keeping all patrons away from the platform edge; the vast majority of passengers stand away from the warning strip. However, even with the present two foot warning strip, occasional aggressive patrons can be seen using the two foot warning strip as a walkway to avoid the crowded platform (Figure 3-17). Two feet is generally considered inadequate for a walkway. If a three foot wide strip were used, as has been suggested at various times, the temptation for aggressive passengers to make use of the strip as a walkway could be expected to increase, with a possible adverse impact upon the success this warning edge has in reducing platform edge accidents, not only for the disabled, but for all passengers. In addition, center platform widths can be as narrow as 11 feet. With two detectable warning edges each three feet wide, over half the available platform area becomes prohibited to passengers. This would be expected to cause excessive crowding as all passengers would be restricted to only five feet of the eleven foot platform width. By comparison, a two foot wide warning strip is more realistic. In designing station platforms, it is standard to assume 18 inches of unused space at walls or platform edges. Thus use of a two foot wide warning strip on each side of a center platform will only reduce the effective width of the platform in terms of passenger staging capacity by one foot. For these reasons it appears that the present Federal requirement for a two foot wide warning strip is appropriate.

FIGURE 3-17. PERSON USING BART WARNING STRIP AS WALKWAY

3.1.11 Platform Edge Safety Data

BART has done a study of the impact of the "Pathfinder" tiles upon platform accident rates. [33] Figure 3-18 shows track fall incident rates for the period 1977 through 1990. Track fall incidents are defined as "those occurrences in which a patron accidentally falls from a station platform onto the trackway" and exclude deliberate suicides. Data for blind patrons has been broken out and shown separately. "Pathfinder" tile installation began in July, 1987, and was completed December, 1987. Despite large statistical vagaries, there does appear to have been a fairly substantial reduction in track fall incidents since the "Pathfinder" tile was installed with the total incident rate dropping from a trend line of 0.25-0.3 incidents per million patrons down to below 0.15 incidents per million patrons. Videotape observations of the effectiveness of the warning strip in keeping all passengers two feet away from the platform edge may explain this reduction. There also appears to be a substantial reduction in incidents involving blind persons with the rate dropping from 0.07 blind incidents per million total passengers (blind and nonblind) to between 0.02-0.03. after installation of the tile.

BART safety analysts have concluded that "...Accident-Injury Report data, gathered by the Safety Department, indicate that this detection system may be effective in reducing the incident rate of visually impaired and non-handicapped patrons falling onto the trackway...Platform edge-related incidents are not very frequent occurrences and their numbers vary greatly from year to year. It is thus necessary to track the incident rates for at least another two years before establishing the effectiveness of the tile system in reducing the platform edge incident rates." [34] This report was written in May 1989 documenting one year of experience with the new tile. Two additional years of data are now available and have been added in Figure 3-18. This data continues the encouraging trend observed in 1988.

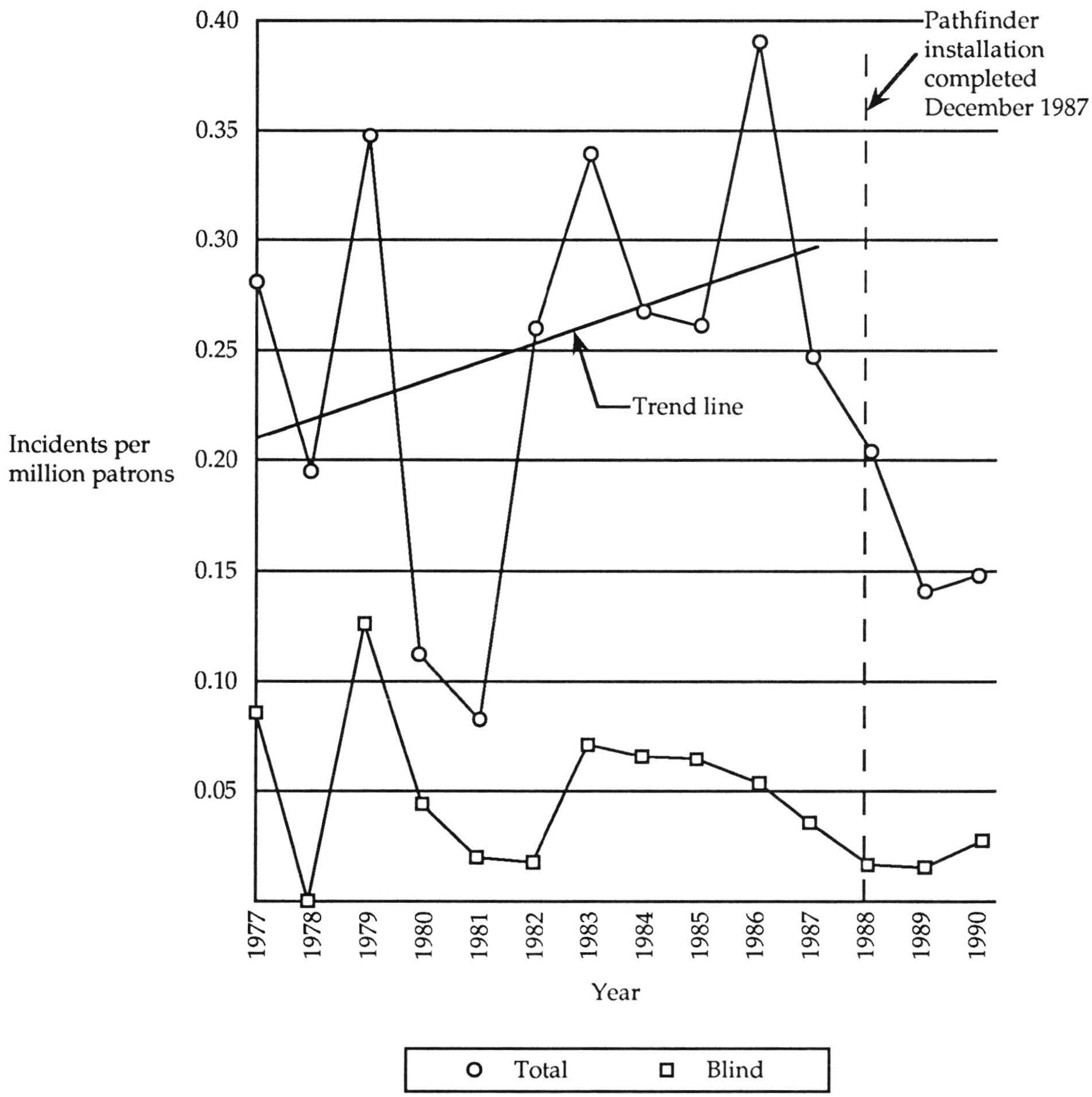


FIGURE 3-18. BART TRACK FALL INCIDENT RATE

3.2 ACTIVE INTRUSION DETECTION SYSTEMS

An alternative or adjunct to passive platform edge protection using tiles to provide a warning is the use of electronic surveillance techniques to detect intrusion of persons onto the guideway and stop approaching trains. It is common practice for automated transit systems as well as modern rapid transit systems to provide closed circuit television (CCTV) surveillance of the track area. Cameras, either fixed or panning in predetermined patterns are located on the station platforms. The image is transmitted to a central control area where it is displayed on a CRT (Figure 3-19). Small systems may provide a separate CRT for each camera. For larger systems it is more usual to sequence the images with one screen serving multiple stations. The images are monitored by central control personnel, who are able to hold the image in a particular station if a problem is observed. Videotape recording is available to provide a record. CCTV surveillance is well known in the industry and therefore will not be treated at length in this report.

Of more interest are intrusion detection systems which have been installed on automated transit systems to provide an electronic alarm to central in the event of pedestrian intrusion onto the track. One of these systems, installed at the SkyTrain in Vancouver, Canada and for the Harbourlink Monorail in Sydney, Australia, operates with standard open platforms. The other for the Jacksonville Automated Skyway Express is used in conjunction with platform barriers which limit passenger access to the guideway to gates aligned with the position of vehicle doors when a train is stopped in the station.

3.2.1 Vancouver/Sydney System

In 1985, the Platform Intrusion Emergency Stop (P.I.E.S.) system was developed and built for the Vancouver SkyTrain by I.P.T. Structures, Inc. The P.I.E.S. system uses a series of sensor panels that are placed in transit system passenger stations along the rail tracks, between the platform and the first rail and between the rails for the entire length of the station platform (Figure 3-20). These panels are connected into an alarm system to automatically stop the train if anyone intrudes onto the track.

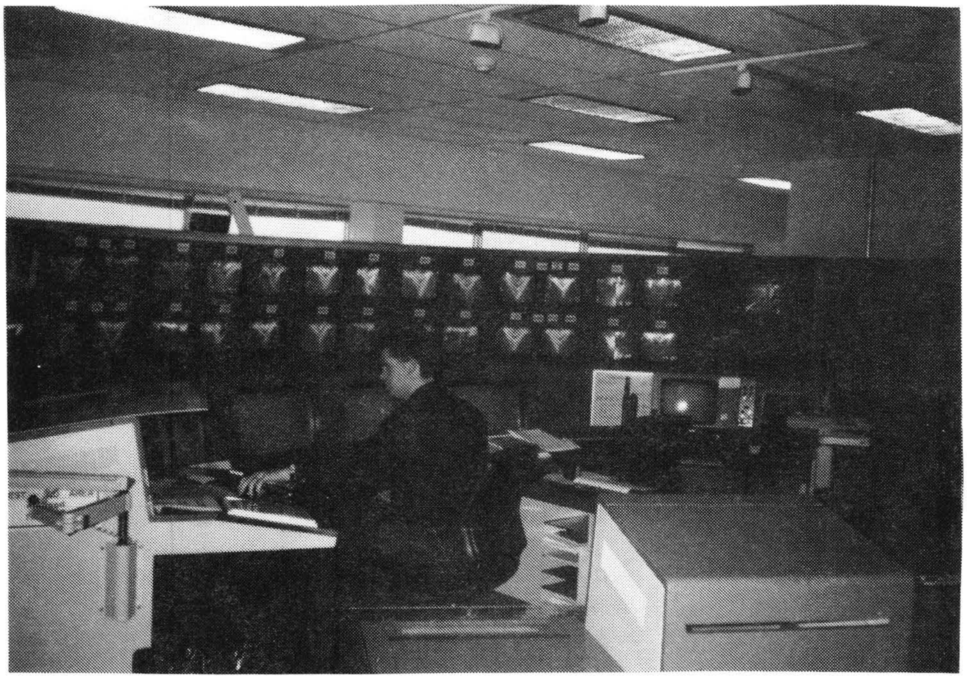


FIGURE 3-19. CLOSED CIRCUIT TV SURVEILLANCE (VANCOUVER SKYTRAIN)

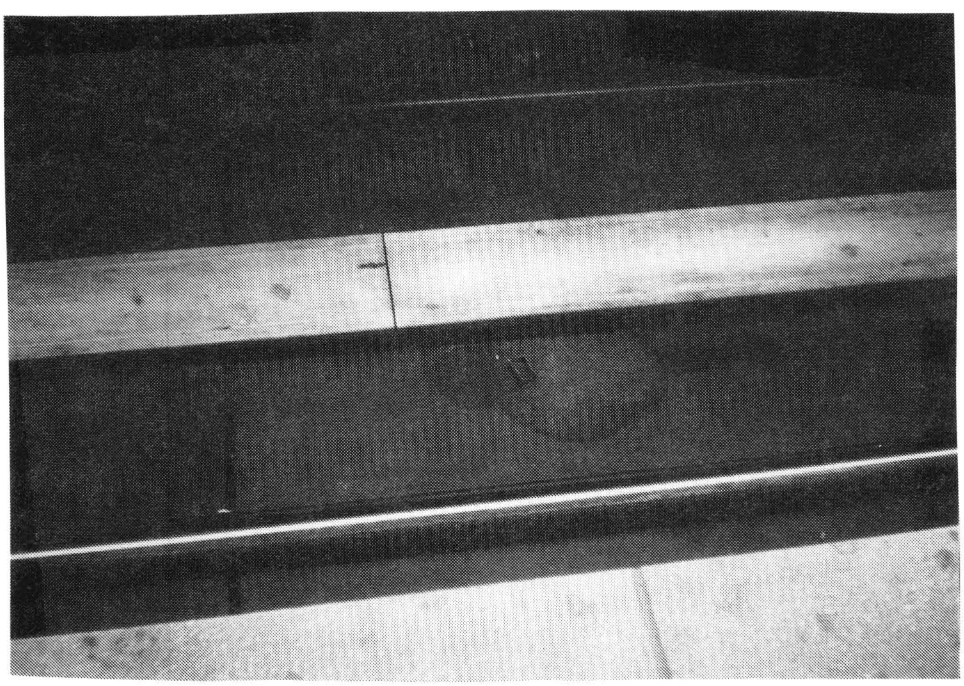


FIGURE 3-20. P.I.E.S. INSTALLED IN VANCOUVER SKYTRAIN STATION

The original Vancouver contract provided for installation at 31 platforms in 15 stations. There are normally three rows of plates per platform with six rows for a two track station. Two additional stations have since been provided with P.I.E.S. as Vancouver has extended the SkyTrain. In 1988, a refined version of the system was installed on the Harbourlink Monorail which connects downtown Sydney with Darling Harbour, the largest urban renewal project in Australia's history. The P.I.E.S. system has been installed at eight single sided stations on this monorail.

The P.I.E.S. concept uses a series of plates. In the Vancouver system these plates are eight feet long by 1.5 feet wide and made of 3/4 inch thick fire-treated fir plywood, a material selected to comply with fire regulations established by the city fire marshall. (Flame spread of less than 25 and smoke development less than 450.) For the Sydney installation the plates are four feet long by two feet wide and made of a fire retardant urethane foam, bonded to an aluminum outer covering. The plates are mounted in the guideway suspended on spring/damper supports located at each corner (Figure 3-21). A continuous 3/16 inch outer diameter coaxial cable is fastened periodically to built-in clips along the top of one edge of the rectangular panels, in this manner connecting all panels and running the length of the platform (Figure 3-22). The coaxial is a microphonic or "strain sensitive" cable, specially developed for this purpose with the trade name "Blucor". It is made so that bending or flexing tends to generate electronic noise. If an object strikes a panel, the mechanical movement of this panel relative to adjacent panels bends the coaxial, inducing electrical noise into the cable. The frequency, amplitude and duration of the electrical noise is compared with reference values to determine whether the "signature" is representative of human intrusion. The Vancouver system is set so that a thirty pound object is necessary to set off the alarm and activate a relay to initiate safety measures designed into the system.

The signal selection electronics consist of a signal pre- amplifier and bandpass filters tuned to the frequencies generated by an intruding object. The bandpass filters remove signal components outside of the frequencies of interest, including electrical noise created by the SkyTrain linear induction motors. These motors are a problem for P.I.E.S. because they operate in a range of zero to sixty cycles, which spans the range of interest for intrusion

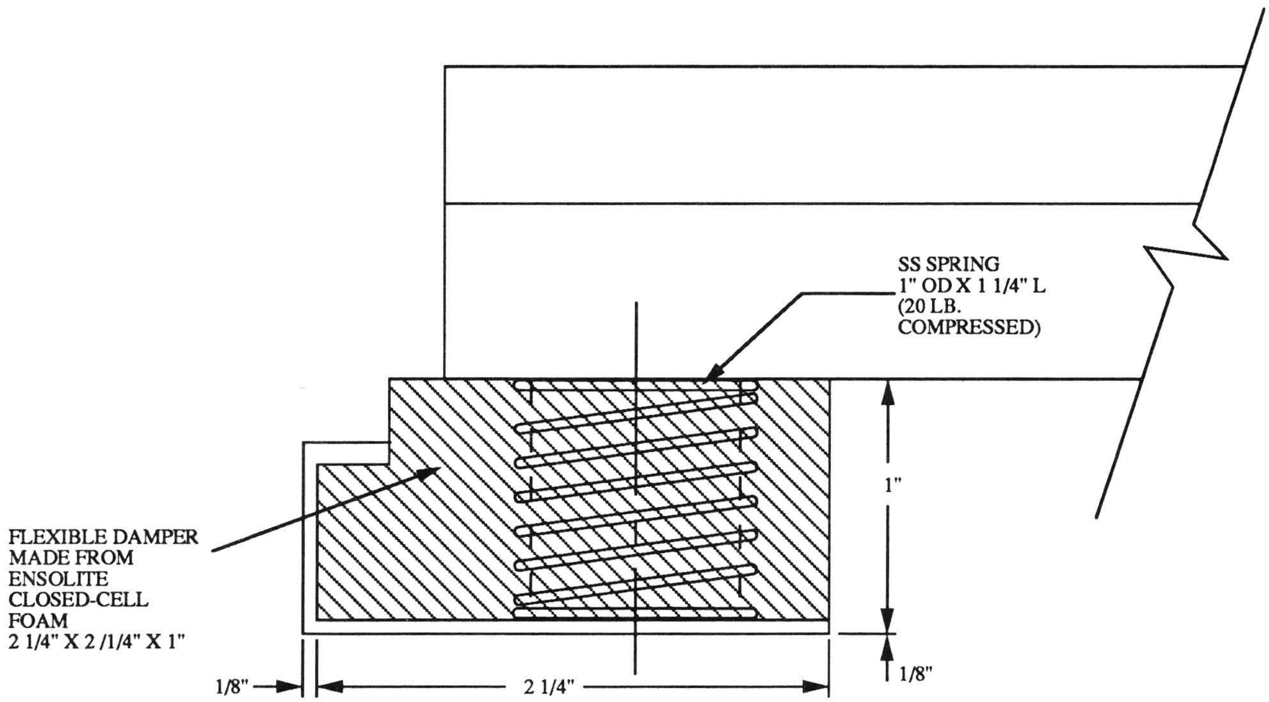


FIGURE 3-21. P.I.E.S. SPRING DAMPER SUPPORTS

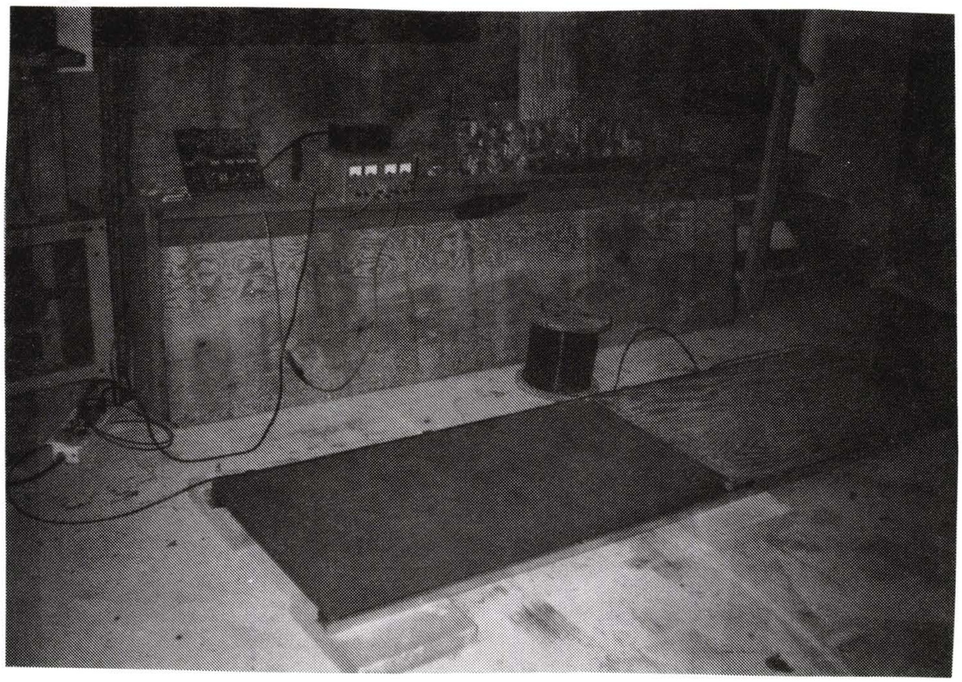


FIGURE 3-22. LABORATORY DEMONSTRATION OF P.I.E.S. SHOWING COAXIAL CABLE RUNNING ALONG TOP EDGE IN REAR

detection. Other spurious signals are generated by vibration produced by the wheels of an approaching train and other environmental sounds. The filtered signal is next amplified and passed through a latching circuit which prevents the alarm from being actuated by spurious short duration "spikes". The values for amplitude and duration of signals may be adjusted by means of potentiometers, rotary switches and dip switches. LED displays of circuit status and signal strength are provided to assist in diagnostics and field set-up of the system. The system requires a 24 volt DC power supply. [35]

The maximum length of coaxial cable permitted per controller is 1000 feet in order to assure adequate signal strength.* This length includes both the strain sensitive "Blucor" coaxial attached to the panels, plus standard RG-58A/U coaxial leads connecting the signal to the electronic units.

Intrusion alarms generated by the P.I.E.S. system are transmitted to vehicle emergency stop electronics located in central control which automatically stop the train and sound an alarm in the central control room (Figure 2-23). Central control operators may also stop the system using red alarm buttons if a problem is seen on the CCTV system (Figure 3-24). Any time there is a P.I.E.S. alarm, it is necessary to send a person to the site to check the system and determine the cause.

3.2.1.1 Reliability of the P.I.E.S. System

B.C. Transit, operator of the SkyTrain, has maintained excellent records on operation of the P.I.E.S. system in Vancouver. [36] Figure 3-25 is a summary of data collected for all stations from November 1, 1986 through January 30, 1991. "Nuisance trips" are an inevitable problem with an electronic detection system. These are occurrences when P.I.E.S. was actuated and the maintenance person sent to investigate could not confirm any intrusion. Subsequent tests of P.I.E.S. found it operating properly. The Vancouver system, which carries 80,000 riders/day, averages 18 nuisance trips a month, a little over

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* I.P.T. states they have now developed a refined P.I.E.S. controller which can utilize up to 5000 feet of coaxial cable.

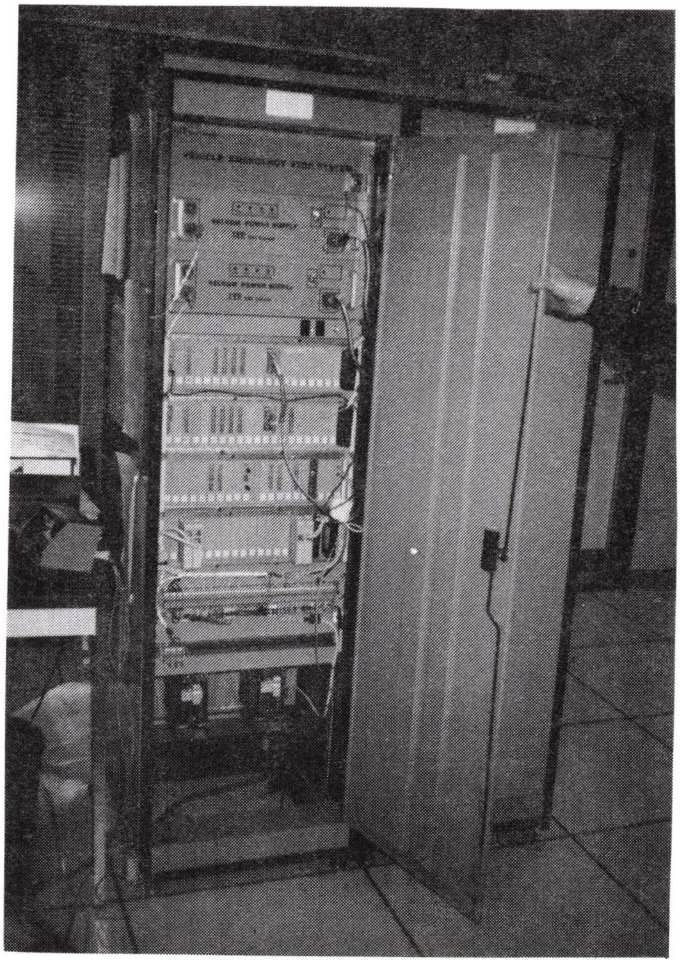
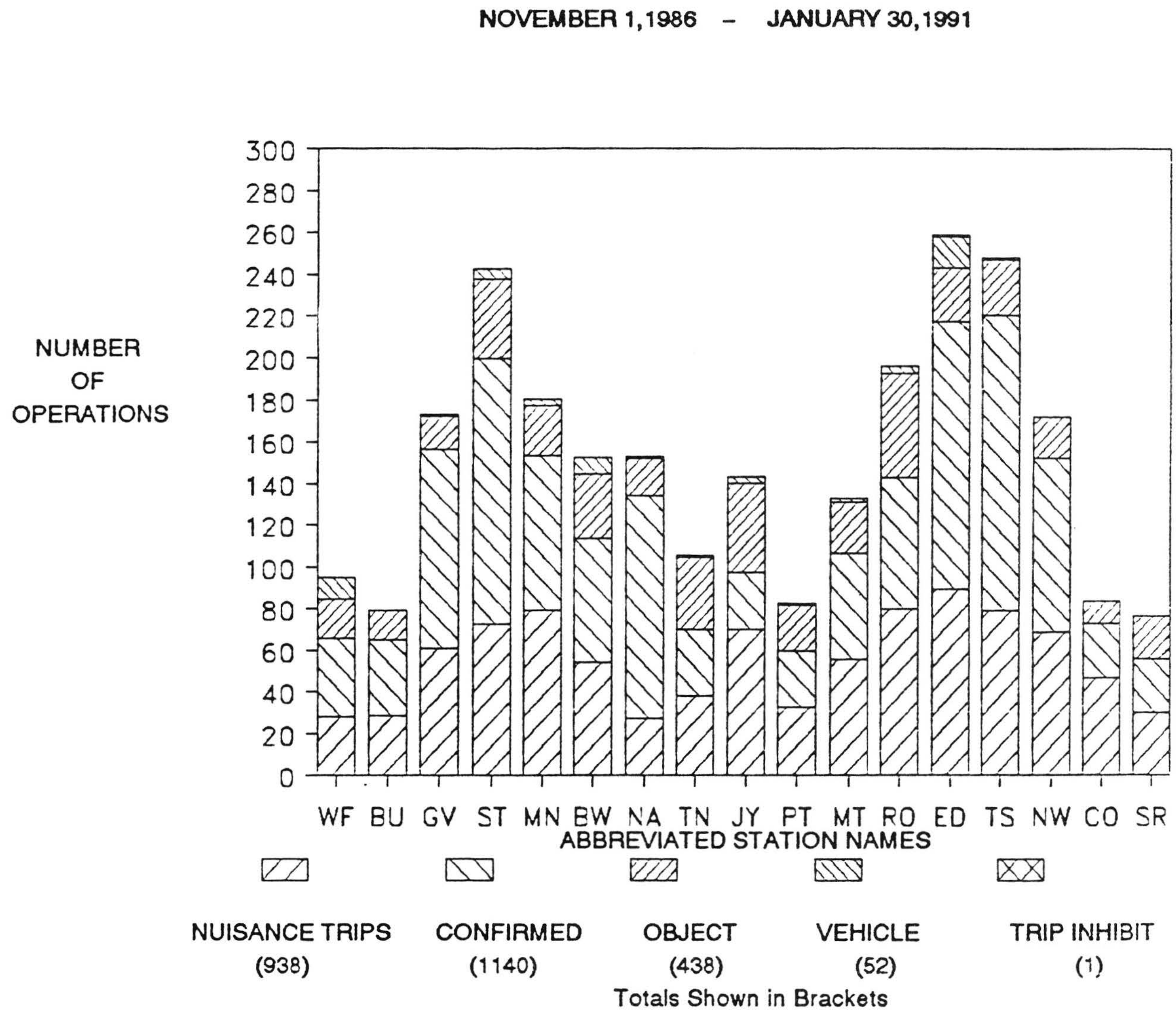


FIGURE 3-23
← **P.I.E.S. EMERGENCY STOP ELECTRONICS FOR SKYTRAIN**

FIGURE 3-24 EMERGENCY STOP BUTTONS AT SKYTRAIN CENTRAL CONTROL →



DEFINITION:

NUISANCE TRIP	PIES operated but reason unknown. Subsequent test of PIES system okay. No intrusion can be confirmed.
CONFIRMED	Intruders were captured on platform camera, witnessed by passengers or held for questioning by SkyTrain Staff.
OBJECT	PIES operated due to obstruction found (typically pop cans, umbrellas or large balls on guideway).
VEHICLE	Train induced PIES operations due to misaligned plates or displaced sensing cable.
TRIP INHIBIT	Intrusion confirmed but PIES malfunctioned and failed to operate.

FIGURE 3-25. P.I.E.S. OPERATING STATISTICS IN VANCOUVER

one per station. SkyTrain engineers advised that water in cable splices can be one cause of these false alarms. "Vehicle trips" are another class of spurious alarm, where the alarm was tripped by approach of a train due to misaligned plates or improperly positioned coaxial cable. Such "vehicle trips" occurred on the average once a month on a system-wide basis. "Object trips" occur when the P.I.E.S. system is tripped by soft drink cans, umbrellas or similar objects on the guideway struck by the train. "Object trips" occurred on the average eight to nine times a month on a system-wide basis. The total of spurious trips from these three categories over the 51 months for which data is available was 1428 incidents, equivalent to 28 incidents per month on a system-wide basis. During the same period P.I.E.S. detected 1140 confirmed intrusions, an average of 22 per month. Intrusions were confirmed by video monitors, reports from passengers or interdiction and questioning by SkyTrain staff. During the entire 51 month period there was only one instance when an intrusion was confirmed, which had not been detected and alarmed by the P.I.E.S. system.

This data indicates the P.I.E.S. system to be dependable in almost always reporting instances of guideway intrusions, at the price of a combined false alarm rate from all causes of 127%. (The manufacturer has advised us that new digital control circuits and software have increased the stability and reliability of the system since its original installation in 1986.)

3.2.1.2 Maintenance Requirements for P.I.E.S

At Vancouver each station is tested weekly. The maintenance person steps on one plate in the station to confirm that the alarm is properly actuated. The check takes about a half personhour per station. Once a month a more thorough electronic check is performed which takes about 2-3 personhours per station. Repairs to the system are required 2-3 times a week and are usually caused by passenger induced problems. The typical field repair takes two personhours. [37]

3.2.1.3 Capital Costs

The Vancouver system was installed in 1985-86 for $1,000,000 Canadian. This covers 31 platforms each 262 feet long for a cost of approximately $123 U.S. per platform-foot at current exchange rates and in 1991 dollars. The Sydney installation cost $149,000 U.S. in 1988 for eight platforms, 89 feet long for a cost of $222 per platform-foot in 1991 dollars. [38]

3.2.1.4 Safety

In discussions with Gene Lozano of the American Council for the Blind we were told intrusion systems such as P.I.E.S. were of limited value to the blind since they do not warn the blind person of the platform edge, but only protect a person from the train after falling off the edge. None-the-less these systems are a useful adjunct to a platform warning system. Vancouver engineers noted a number of instances where wheelchair users and blind travellers have been successfully detected by P.I.E.S.

Since June 1988, the Vancouver Safety and Training Manager reports the SkyTrain has had six fatalities all of which are considered to have been suicides. In addition, eight persons have sustained injuries. One of the eight persons was visually impaired and one was in a wheelchair. One of the eight injuries was the result of a suicide attempt and alcohol was a factor in the other case. [39] A total of 27 other persons were either pushed or fell into the guideway sustaining either minor injury or no injury at all. In eight of these incidents alcohol was contributory, four involved visually impaired individuals, two were pushed, one fainted and one was an attempted suicide.

Since SkyTrain carries about 23 million riders a year [40] the platform incident fatality rate over this three year period is 0.09 per million passengers carried and the platform incident injury rate (both fatalities and injuries) is 0.2 per million passengers carried. If suicides are excluded, the injury rate would be cut in half to 0.1 per million passengers carried. The BART system with "Pathfinder" warning tile is averaging about 0.15 injuries per million passengers carried excluding suicides, but the differences in population characteristics and system operating characteristics (BART has operators) make it difficult to suggest any meaningful comparisons.

3.2.2 Jacksonville Automated Skyway Express System

The Jacksonville Automated Skyway Express (ASE) is planned as a 2.5 mile double guideway people mover system with nine stations in downtown Jacksonville, Florida. The first phase of this system consists of a 0.7 mile, three station people mover operating two single car trains as a shuttle. The first phase opened for revenue service June 5, 1989. The design developed in concert with the Citizens Advisory Committee called for open platforms [41] so the Jacksonville Transportation Authority (JTA) elected to use intrusion detection to prevent unauthorized passenger access to the guideway. Two intrusion systems work together in Jacksonville; an early warning alarm system designed by the JTA staff, and a separate system which automatically initiates vehicle emergency braking if a potential intruder is detected. The latter system was supplied by Matra Transport, the people mover supplier.

The platform area of the Automated Skyway Express system is protected by railings set two feet back from the edge of the platform. At loading areas, the railings are directed toward the edge of the platform at a forty-five degree angle, (Figure 3-26) so that an open gate area for passenger boarding is provided. The alarm warning system designed by JTA staff consists of two infrared beams across each loading gate area two feet back from the platform edge. In the event a potential guideway intruder interrupts the beams, a loud horn alarm is sounded at the loading gate area along with a flashing light. In addition, a buzzer and flashing light are activated in the central control room above the appropriate CCTV monitor.

The early warning alarm system is backed up by an intrusion detection system supplied by Matra Transport. It consists of rows of four infrared beams recessed in a 3 1/2 foot high pillar installed to the side of the loading gate opening at the platform edge (Figure 3-27). [42] Instead of being located two feet away, these beams are only four inches from the edge of the platform. Each side of the platform has two sets of detectors, one for each

FIGURE 3-26. JACKSONVILLE STATION
WITH RAILING SET BACK TWO FEET
FROM PLATFORM EDGE

FIGURE 3-27. PILLAR WITH ROW OF FOUR INFRARED DETECTORS

of the two sets of vehicle doors. A separate Electronic Barrier Control Unit (EBCU) controls each side of the platform. The EBCU is enclosed in a box with a key operated door and installed on the platform wall. Each EBCU processes signals from the infrared detectors. If any two of the four beams from a row of detectors are interrupted, the safety frequency (safe to proceed signal transmitted to the people mover) is removed causing initiation of emergency braking of an approaching train or preventing its departure from the station if it is already stopped. An alarm is also sent to the central control operator who can then take action as necessary including pressing a large mushroom button to remove guideway power. Each EBCU includes, on its front panel, an emergency push-button to stop the vehicle in a station, a switch to override the electronic barrier function and a reset button. A similar intrusion detection system has also been installed on Line D of the fully automated Lyon Metro in France. [43]

There are thus two intrusion systems in Jacksonville. The first, two feet from the platform edge, discourages passengers from moving closer by sounding a loud warning horn. The second system, located four inches from the platform edge, actually stops the people mover if it is tripped. The presence of the warning system helps to reduce the number of times the system must be shut down because of trespassers.

3.2.2.1 Reliability

Formal data is not available on system reliability. JTA staff advise that since the systems were fully tested and accepted, maintenance requirements and cost have been negligible. The warning system is actuated quite often by waiting passengers not familiar with it. However, actuation does not affect system operation because people intentionally activating the alarm can be warned using the station PA system. There has been no problem with false actuation of the backup system which actually stops the people mover. JTA staff are completely satisfied with their intrusion system. [44]

3.2.2.2 Capital Costs

The warning system was designed by JTA staff and installed in 1988-1989. Protection for a total of 12 gates in three stations cost $36,000. [45] A single car platform is about 44 feet long, and each station has four gates, two for each direction of travel. The system thus has about 264 feet of platform, making the cost $136 per linear platform foot in 1988 dollars. The cost of the Matra designed intrusion system was born equally by the JTA and Matra. The city's share was $118,000 in 1988 dollars to protect 12 gates, making a total cost of $236,000. [46] Again assuming 264 feet of platform, this is a cost of $894 per linear platform foot in 1988 dollars. The combined cost of the alarm and shutdown systems together would be $272,000 in 1988 dollars or about $1000 per linear platform foot in 1988 dollars ($1100 per linear platform foot in 1991 dollars). The railing would add another $30 per platform foot installed.

3.2.2.3 Safety

There have been no reported platform accidents since the system opened for revenue service June 5, 1989. The system has carried 821,869 passengers as of August 31, 1991. [47]

3.3 FULL PLATFORM BARRIERS - THE PEOPLE MOVER SOLUTION

It is axiomatic that the ultimate in passenger platform protection is a barrier separating the passengers from the track. As far back as 1970 the National Transportation Safety Board reviewed safety procedures proposed for the Washington Metro and pointed out that the relatively precise stopping capability of modern automated transit vehicles would make it possible to develop an arrangement for separating waiting passengers from incoming trains by a barrier wall. [48] In another study of rail transit safety in 1971 the Board stated that "...The highest incidence of fatality has resulted from persons on the roadway (track) who have been struck by a train. This incidence may be minimized by the separation of passengers from the track in stations..." [49]

Rapid transit systems did not implement such barrier concepts, claiming that stopping accuracy with steel wheel on rail was not reliable, especially with wet rails. However the concept did meet with acceptance by the automated people mover (APM) industry where many vehicles have the higher traction provided by rubber tires. APM's have pioneered in the use of platform barriers since the first systems began operating in the 1970's. Complete separation of station platform areas from the guideway has been accomplished by floor to ceiling walls provided with elevator type doors which automatically open only when a vehicle is berthed in the station. Station and vehicle doors are coordinated so that passenger access to the guideway is precluded. The first three major APM systems, built at Tampa, Seattle-Tacoma and Dallas Fort Worth airports, were all provided with this complete protection which virtually eliminates train/person collisions. Figure 3-28 shows a typical platform barrier/door arrangement for the people mover at Atlanta Airport.

As people movers have moved from activity centers such as airports into urban environments, the tendency has been to adopt rapid transit type stations without platform barriers. Thus the Miami Metromover and Detroit People Mover have open platforms. [50] Key objections to the use of coordinated vehicle and station doors are the additional cost and the loss of reliability caused by doubling the number of doors in the system. Doors are one of the major reliability problems for automated systems. Since automated people movers do not have a driver on board, a door failure inevitably causes a passenger delay. It is possible to eliminate the station doors and simply provide a barrier with openings which align with the stopped vehicle doors. This retains much of the safety of the platform barrier concept, while eliminating the cost and loss of reliability inherent in coordinated station doors. Such an approach is used by the people mover at West Virginia University. By equipping the openings in the barrier with intrusion detection sensors it is possible to even more closely approximate the protection provided by coordinated doors. An example is the approach taken by the Automated Skyway Express people mover in Jacksonville which was described in the preceding section of this report on active intrusion detection systems.

FIGURE 3-28. FULL PLATFORM DOORS AT ATLANTA AIRPORT PEOPLE MOVER

The following sections discuss in further detail the Morgantown solution as well as the ultimate solution using coordinated station doors.

3.3.1 West Virginia University Personal Rapid Transit System

The West Virginia University Personal Rapid Transit (PRT) System was built as a demonstration of automated people mover technology with funding from the Urban Mass Transportation Administration. The system, which connects the University with downtown Morgantown, West Virginia, has five stations, 73 vehicles each holding up to 21 passengers, and 8.7 miles of single-lane guideway. [51] It is the only automated guideway transit system in regular passenger service which provides origin-destination service.

Another unique feature of the Morgantown people mover is its use of platform barriers to separate the passenger platform area from the guideway. Morgantown uses two distinct types of platform barriers. Beechurst and Walnut stations have simple 3 1/2 foot high aluminum railings with openings aligned with the stopped vehicle doors (Figure 3-29). The other three stations at Medical Center, Towers and Engineering have seven foot high window walls of tempered glass with tubular aluminum framing (Figure 3-30). Closed circuit video cameras monitor the openings but no other intrusion detection is provided. It should be noted that PRT cars are normally kept parked at the boarding gate in the offline stations so that access to the guideway is not possible most of the time. Unloading areas are less frequently occupied by vehicles, but are not areas where passengers normally congregate. Transit systems with online stations would not have cars parked in the stations so that passenger intrusion onto the guideway could be a greater problem than at Morgantown.

3.3.1.1 Capital Costs

Cost data for the Morgantown partitions is not readily available and would be needlessly out of date since costs for such simple construction items are readily available from standard cost estimating manuals. Based on Means national average construction costs

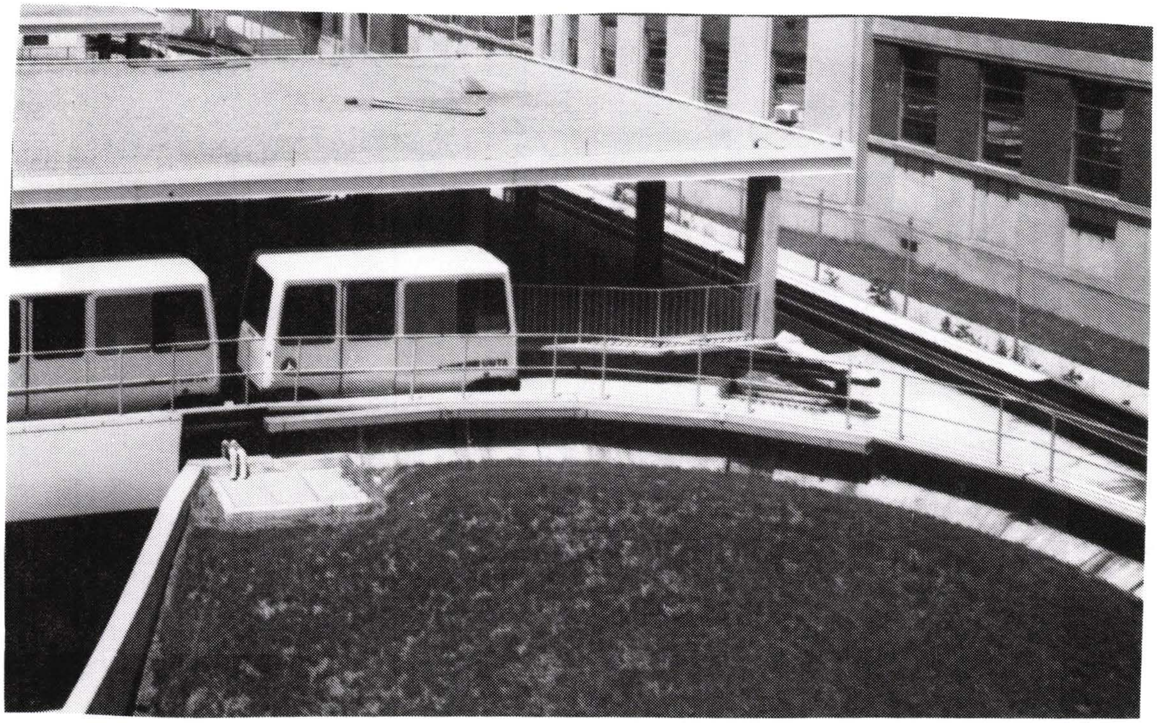


FIGURE 3-29. PLATFORM RAILINGS AT BEECHURST STATION - MORGANTOWN

FIGURE 3-30. WINDOW WALL PARTITIONS FOR NEW MORGANTOWN PRT STATION

and adding a 15% contingency plus 25% for professional services, the cost for a 3 1/2 foot high railing would run approximately $30 per linear foot installed [52]. A seven foot high window wall, using the same assumptions, would cost about $220 per linear foot installed. [53] Operating and maintenance costs are limited to painting the railing and costs for cleaning and replacing the glass. By using a vandal-proof finish in place of glass, partition maintenance costs could be made negligible. A major advantage of this approach is that it adds no moving parts or electronics, so there is no impact on system reliability or maintenance costs.

3.3.1.2 Regulatory Impacts

Department of Transportation regulations incorporating ADA Accessibility Guidelines for Buildings and Facilities (Section 10.3.1) do not require detectable warning surfaces if there is a platform screen or guardrail. [54] Since a 3 1/2 foot railing costs $30 a platform foot compared with costs of $29 to $86 per platform foot for a two foot wide warning strip, the use of railing may well be a cost-effective solution and should be given careful consideration by transit agencies concerned with complying with these new regulations. If a railing is provided, special warning tile would only be needed at the openings.

3.3.1.3 Safety

The Morgantown barriers are a reasonably effective means of platform protection. Since the full five station Morgantown PRT opened in July 1979, PRT operations staff report less than ten instances of unauthorized persons on the guideway, none of which has resulted in passenger injury or fatality. [55] The system has carried approximately 30 million persons over this twelve year period, for an incident rate of 0.3 persons per million passengers carried. By comparison, the P.I.E.S. system in Vancouver is detecting 22 intrusions a month on a system which carries about 2.4 million riders a month, a rate of 9 intrusions per million passengers carried. It is possible that the less sophisticated detection system in

Morgantown is the reason that fewer unauthorized intrusions are detected. However, the lack of any injuries or fatalities indicates the combination of CCTV observation with platform barriers is working well. PRT operations staff advise that trespassers usually do not climb over the railing, but rather enter the guideway at the openings. [56] As a result, the 3 1/2 foot high railing is an effective barrier although the higher glass wall is certainly preferred.

Railings have also been used to protect passengers at APM's operating in amusement and theme parks. In these applications additional protection is provided by a station attendant who assists passengers boarding. The AEG Westinghouse people mover at Busch Gardens in Williamsburg, Virginia is an example. [57]

3.3.2 Coordinated Station/Vehicle Doors

Automated people movers (APM's) are the sole transit mode which has utilized full platform barriers equipped with coordinated station doors which only open when a train is stopped and properly aligned in the station. This method of platform protection essentially eliminates the possibility of passenger intrusion onto the guideway and the possibility of train/person collisions. Among the many APM systems using platform barriers with doors, along with the date they began operating, are the following: [58]

Tampa Airport, 1971
Seattle-Tacoma Airport, 1973
Dallas Fort Worth Airport, 1974
Duke University, 1980
Atlanta Airport, 1980
Miami Airport, 1980
Orlando Airport, 1981
Houston Airport, 1981
Lille People Mover (France), 1983
Gatwick Airport, 1983

Birmingham Airport (England), 1984

Las Colinas (Texas), 1989

3.3.2.1 Reliability of Coordinated Station Doors

Published data on station door reliability is somewhat limited. Airtrans data taken over a six month period (182 days) in 1975 indicated 134 unscheduled maintenance actions. There were 16,300 station stops per day. [59] If it is assumed that 80% of the stops were passenger vehicles (employee stations do not have coordinated doors) and that half of the trains were two car trains there would be roughly 20,000 door cycles a day. This leads to a failure rate of 37 unscheduled maintenance activities per million station door cycles. The average time to repair was two personhours.

Booz Allen did a comprehensive study of rail vehicle door reliability and found failure rates ranging from about 15 to 40 unscheduled maintenance actions per million cycles. [60]

An assessment of the Atlanta people mover gave an average of 304 vehicle operating hours between failures for both vehicle and station doors. [61] Since it takes 12 minutes to make a single round trip and each round trip involves 12 stops, there are 60 stops per vehicle operating hour. Since each vehicle opens two doors every time it stops there are 120 vehicle door cycles per vehicle operating hour. Adding an equal number of station door openings gives 240 total door cycles per vehicle operating hour. With 304 vehicle hours per failure, this is equivalent to 14 unscheduled maintenance activities per million cycles.

A range of 15 to 40 unscheduled maintenance activities per million station door cycles, each involving about 2 personhours would thus seem a reasonable estimate of unscheduled maintenance activities for station doors.

3.3.2.2 Maintenance Requirements

From the above reliability data, it is possible to estimate unscheduled maintenance requirements. Assume a typical single car train station with two doors cycling every two minutes during peak hours and every five minutes during non peak hours. The system operates 5000 hours a year with an equal number of peak and non peak hours. The station will experience 210,000 door cycles a year or 3 to 8 failures per year. At two personhours each, door unscheduled maintenance would run 6-16 personhours per year per station. With a typical 40 foot people mover car length, this is equivalent to 0.2-0.4 personhours/year per platform foot.

Preventative maintenance (PM) required for the Atlanta people mover is as follows: [62]

Door daily PM - one personhour per station
Door monthly PM - 3.7 personhours per station
Door semiannual PM - 24 personhours per station
Door annual PM - 14.4 personhours per station

This leads to a total annual preventative maintenance activity of 472 personhours per year per station. Atlanta stations operate typically with three car trains. Thus, this is equivalent to 157 personhours per year per single car station or, for a forty foot car, about 4 personhours year per platform foot.

On this basis, total scheduled and unscheduled maintenance can be anticipated to run about 4-5 personhours per year per platform foot. By way of comparison, Airtrans total scheduled and unscheduled maintenance in 1975 ran 126 personhours per year per two door station, equivalent to 3 personhours per year per platform foot for these 42 foot long two-car trains. [63]

3.3.2.3 Capital Cost

Station doors for the Airtrans people mover cost $316,000 for 28 sets or $11,300 each in 1972-1973 ($30,000 in $1991). [64] Station doors for the Atlanta Airport system were bid at $754,000 for 72 sets or $10,500 in 1977 ($20,000 in $1991). [65] In 1986, the Jacksonville ASE system received an estimate of $458,769 for 12 door sets or $38,000 per set ($43,000 in $1991). [66] (Jacksonville did not install the doors, opting instead for the electronic system described in Section 3.2.2.) Las Colinas door sets were estimated to cost $29,500 each in 1986 ($33,500 in $1991). [67] Costs in 1991 dollars were obtained by escalating using the Means historical cost index [68] and do not include contingency or professional services allowances, except for the Jacksonville ASE costs which do include professional services. A reasonable estimate for station doors exclusive of partitions would be $30,000 per set in current dollars. Allowing 25% for professional services and 15% contingency, the cost would be $43,000. Assuming two door sets for a forty foot car, this would be a cost per platform foot of $2150 exclusive of partitions. Adding $220 per platform foot for partitions, the total cost would run about $2400 per platform foot in 1991 dollars.

3.3.2.4 Regulatory Impacts and Safety

As has been stated, use of platform barriers with coordinated station doors will effectively eliminate the train/person collision as a platform accident risk. As an example, during the period 1973-1977, the Sea-Tac system had no reported injury accidents. Patronage for 1976 was estimated at 10.1 million by SRI International, suggesting a total patronage of 40 to 50 million riders during the period 1973-1977. [69] While safety records for most other systems are not readily available, there is consensus among professionals that the record has been quite good.

A key concern with regard to station platform barriers is related to Section 2-2.4.3 of the National Fire Protection Association Fixed Guideway Transit Systems regulations (NFPA 130) [70] which requires all station public areas to have a fire separation of at least three hours from all nontransit occupancies. This may pose problems when stations are integrated into airport terminals or building lobbies. Elevator doors typically have only a 1 1/2 hour fire rating [71] and glass curtain walls also will not meet a three hour separation. [72] Generally speaking a three hour rating requires a masonry or composite wall structure. [73] The provisions regarding stations will be modified to acknowledge that "...where the station is integrated into a building nontransit occupancy, special considerations will be necessary beyond this standard." [74] Use of the words "beyond this standard" implies that the existing fire separation requirement remains intact. Section 2-2.4.3 does allow modification of the fire separation requirements based upon an engineering analysis provided the station is above ground. However, experience with the Detroit people mover indicates that obtaining exceptions can be a very expensive and time consuming process. [75]

To conclude, the use of platform barriers and doors on platforms dedicated solely for use by transit passengers should meet Americans with Disabilities requirements and NFPA codes. However, if the platform area is shared with non- transit uses it may be necessary for the barrier and door to meet a three hour fire separation.

3.4 COST COMPARISON OF PLATFORM PROTECTION OPTIONS

The following platform protection options have been discussed in this chapter:

1) Platform warning tile
2) P.I.E.S. intrusion detection
3) Railing with openings at train door locations
4) Window wall with openings at train door locations
5) Window wall with openings equipped with infrared detectors
6) Platform barriers with coordinated station doors

This section compares the capital cost and annual personhours of added maintenance cost incurred by each option. In order to meet ADA regulations, it should be noted that option 2 would require platform warning tile the full length of the platform. This cost has been included in our estimates. Platform warning tile will also be required at openings for options 3, 4 and probably also 5. The added cost of warning tile for these options is negligible and has not been included in the estimates. ADA regulations require a two foot wide warning strip. The basic installed cost of platform tile is $10 to $30 per square foot. A 25% allowance for engineering and a 15% contingency have been added to this amount in making the price comparisons.

Figure 3-31 compares cost per linear platform foot for the six alternatives. All figures are in 1991 dollars. The least expensive solution is the use of a 3 1/2 foot steel or aluminum railing with a cost installed of $30 per platform foot. The next least expensive is platform warning tile at $29 to $86 per platform foot. The main disadvantage of the railing is that trains must be able to align with the openings. If this can be assured, railings could prove a simpler alternative for some systems, especially newer automatic controlled systems which because of automation may be able to stop with adequate accuracy.

The P.I.E.S. intrusion detection system is the next most expensive alternative at $152-308 per platform foot. As stated this cost includes a two foot wide strip of warning tile. An inexpensive combination which could be considered would be a simple railing with P.I.E.S. detection only in the area of the openings. This has not been costed but should be quite inexpensive. A tempered glass window wall would run about $220 per platform foot installed. If vandalism dictates a non-glass partition, solutions would be available using more vandal proof materials within the cost limitation.

The infrared detection system as used in Jacksonville is fairly expensive at $1100 per platform foot installed with a 3 1/2 foot railing. If a glass window wall were used instead of a steel railing, the cost would increase to $1300 per platform foot. As might be expected, the most expensive alternative is full platform barriers with coordinated, elevator type, station doors. The cost per platform foot is estimated at $2400 installed.

Added annual maintenance effort has also been estimated for the various alternatives and is summarized in Figure 3-32. Annual maintenance for tiles is estimated at 6-7 personhours per year per 1000 square feet of tile or, for a two foot wide strip, 12-14 personhours per year per 1000 platform feet. Maintenance for platform barriers such as railings or glass window walls is assumed negligible. While window wall maintenance has not been significant in Morgantown, it is possible that vandalism would be prohibitive in many urban locations. In that case, use of a more vandal resistant material at the same basic cost should be possible.

Maintenance for the Jacksonville infrared detection system is estimated to be negligible by the JTA staff. The P.I.E.S. system has a fairly significant maintenance requirement. Fifty times a month personnel must check when P.I.E.S. is activated. The

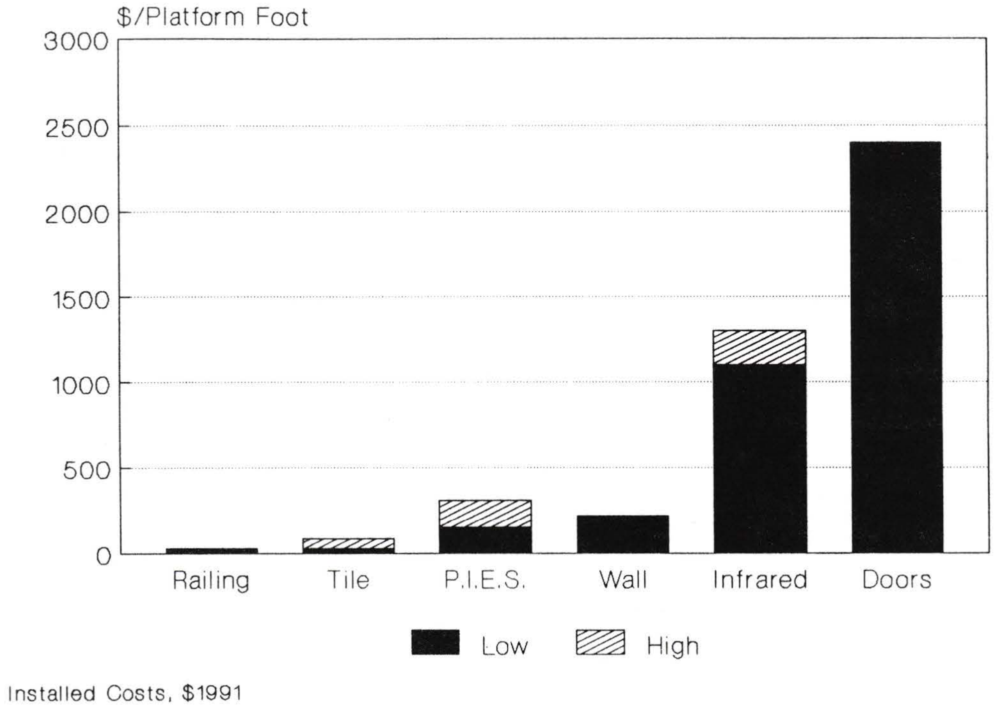


FIGURE 3-31. CAPITAL COST PER PLATFORM FOOT OF PLATFORM PROTECTION ALTERNATIVES

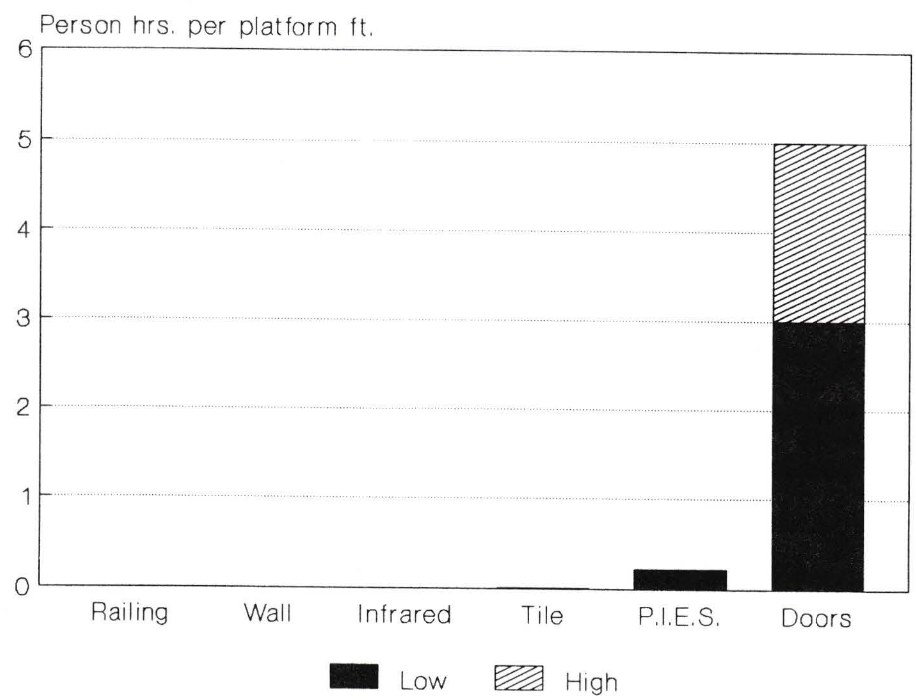


FIGURE 3-32. ANNUAL MAINTENANCE EFFORT FOR PLATFORM PROTECTION ALTERNATIVES

check averages one hour. Inspections are required weekly at a half hour per station and monthly at 2 1/2 hours per station. Unscheduled repairs are required on the average 2 1/2 times a week and require about two hours each. This is a total annual maintenance effort of 1700 personhours. Spread over 31 platforms each 262 feet (80 meters) long, this is equivalent to an annual maintenance effort of 209 personhours per 1000 platform feet. Adding maintenance of the warning tiles, the total annual maintenance effort is 222 personhours per 1000 platform feet. As was stated in a previous section, annual maintenance required for full coordinated station doors is 3000 to 5000 hours per year per 1000 platform feet.

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CHAPTER FOUR
INNOVATIVE SOLUTIONS FOR COMMUTER RAIL BOARDING

Commuter rail operations have been using a number of creative approaches to providing disabled accessibility. These include simple mobile wayside lifts, low floor cars with ramps, mini-platforms and full high level platforms. Even the vehicle borne lift can be looked at as an innovative solution because of the ingenuity required to adapt these lifts, originally developed for bus and light rail use, to a commuter rail car. The following sections describe the various alternatives being used on various commuter rail systems and discuss their cost and schedule impacts.

Table 4-1 summarizes accessibility options presently in use by American commuter rail systems. Alternatives include full high level platforms, mini-platforms, onboard vehicle lifts, portable wayside lifts and low floor cars with ramps.

4.1 HIGH LEVEL PLATFORMS

Approximately a quarter of the national commuter rail car fleet consists of cars designed to operate with full high level platforms. Much of the high level operation is in areas supplied by third rail power, where low level loading would be dangerous. In some cases, full high level platform access is provided with gaps of two to five inches, similar to that for conventional rapid rail. [1] However, on commuter rail systems where equipment shares the track with freight operations, larger gaps are required because station platforms must be kept outside of the clearance envelope for the freight cars. The maximum width envelope for freight cars is 10'8". Allowing for tolerances, this results in a minimum distance of 5'6" from the track centerline to the edge of the platform. Since commuter rail cars are typically ten feet maximum width over thresholds, this means that the minimum possible nominal gap is six inches. [2] Many systems will require an even wider gap. For example, Illinois Commerce Commission regulations require a clearance for freight traffic of eight feet from track centerline, resulting in a gap of over three feet. [3] Even a six inch gap

TABLE 4-1. COMMUTER RAIL ACCESSIBILITY OPTIONS

Accessibility Method	Used By
High Level Platforms	MBTA* (Boston Commuter) N SEPTA* (Philadelphia Commuter) E Long Island Rail Road E Metro-North Commuter (New York) E New Jersey Transit* E Amtrak (Northeast Corridor) E Maryland State Railroad (MARC) E METRA* (Chicago) E
Miniplatforms	MBTA* (Boston Commuter) N SEPTA* (Philadelphia Commuter) E New Jersey Transit* (planned) E Caltrain* (planned) N
Onboard Vehicle Lifts	METRA (Chicago - planned) N
Portable Wayside Lifts	MBTA (Boston Commuter - Back Bay Station) N Amtrak (Amfleet and Heritage) N VIA Rail (Canada) N
Low Level Car with Ramp	Amtrak Superliners N San Diego Oceanside N Tri County Commuter (South Florida) N

KEY
* operation requires a bridgeplate
E electrified line
N nonelectrified line

is not safely negotiable by a wheelchair so that a bridge plate is normally required for systems which share right-of-way with freight usage.

The Illinois Central Gulf (ICG) commuter rail line operated by the Chicago Regional Transportation Authority (METRA) is a fully electrified system running 78 miles and providing service between downtown Chicago and large suburbanized areas to the south. ICG operates 165 bi-level self propelled Highliner cars serving 57 stations. [4] All stations provide high level platform boarding. The gap is 12 inches horizontal and minus six inches plus four inches vertical, requiring a bridgeplate for wheelchair access. [5] Metra has designed a short, hinged bridgeplate which is permanently mounted near the door and manually operated and deployed. It mounts on the side of the door and is hinged to unfold in front of the door and then hinged again to swing out over the gap opening. Metra is modifying 140 Highliners for accessibility. In addition to providing bridgeplates, Metra is replacing four seats with flip seats which can be retracted to make room for a wheelchair and is also making other minor modifications.

The Long Island Rail Road also has high level platforms at most stations on its electrified routes. Bridgeplates are not being used. Instead crews assist in getting wheelchair users across the gap. A training program has been established which includes disabled persons. [6] The Metro-North Commuter Railroad Company operates commuter lines formerly run by the New York Central and New Haven Railroads. Most platforms are high level. Horizontal gaps range from 4 to 6 inches and according to company officials normally cause "no real problem." However, the more modern M-3 and M-4 cars are equipped to carry bridgeplates. [7] Amtrak operations in the northeast corridor (Washington-New Haven) have high level platforms for boarding (Figure 4-1). Bridgeplates are not used in high platform territory.

4.2 MINI-PLATFORMS

To reduce the cost of full high level platform operation, a number of systems have elected to use mini-platforms, which provide access only to one car of a train. Mini-platforms can be constructed for one-tenth the cost of full length platforms, thereby making it

FIGURE 4-1. AMTRAK HIGH PLATFORM AT NEW CARROLTON STATION

possible to provide ten times as many accessible stations for a given expenditure. A further advantage is that mini-platforms can be designed as a standard component to be inserted at each station, and do not have to be individually designed as is necessary for full length high-level platforms.

In May 1988, New Jersey Transit (NJT) commenced design of a mini-platform for its commuter rail operations. In 1989, a prototype installation was tested in a non-public area. The first public installation is scheduled for 1991. The NJT mini-platform is a prefabricated structure which bolts to a foundation constructed flush with the low level main platform. A sixty foot ramp provides access to the mini-platform. NJT uses a simple unpowered bridgeplate which swings up out of the way when not in use to provide side clearance. [9]

The Massachusetts Bay Transportation Authority has made a policy decision to use either high platforms or mini-platforms to make all "key" commuter rail stations accessible. All rehabilitated stations will have 45 foot long mini-platforms. New stations will have full 730 foot long platforms. The design target for horizontal gap on MBTA commuter lines is five inches but freight clearances on some lines require a greater amount. [10] To handle these situations, the MBTA has developed a unique frangible platform edge shown installed at the Mishawum station. Figure 4-2 shows the edge in the deployed position, while Figure 4-3 shows it retracted. The outer edge consists of a two foot wide hinged aluminum structure which can be rotated to a vertical (retracted) position to provide increased clearance. The normal or deployed position permits high level boarding of passenger cars. Because relatively few special "wide" freight loads are carried, the MBTA has arranged that it receive prior notification from the carrier. Maintenance staff then go out and retract the platform edge. To protect against failure to retract the edge, the outer nine inches of the edge consists of polyurethane foam supported by individual hinged aluminum channels on 12 inch centers. If the edge is struck, the channels swing out of the way and the frangible foam is harmlessly scattered upon impact. [11]

Project ACTION (Accessible Community Transportation in our Nation) is presently sponsoring a project at the Southeastern Pennsylvania Transportation Authority (SEPTA) to develop a low cost mini-platform. [12] Project ACTION is administered by the National

FIGURE 4-2
FRANGIBLE
← PLATFORM EDGE
AT MBTA
MISHAWUM STATION
(DEPLOYED)

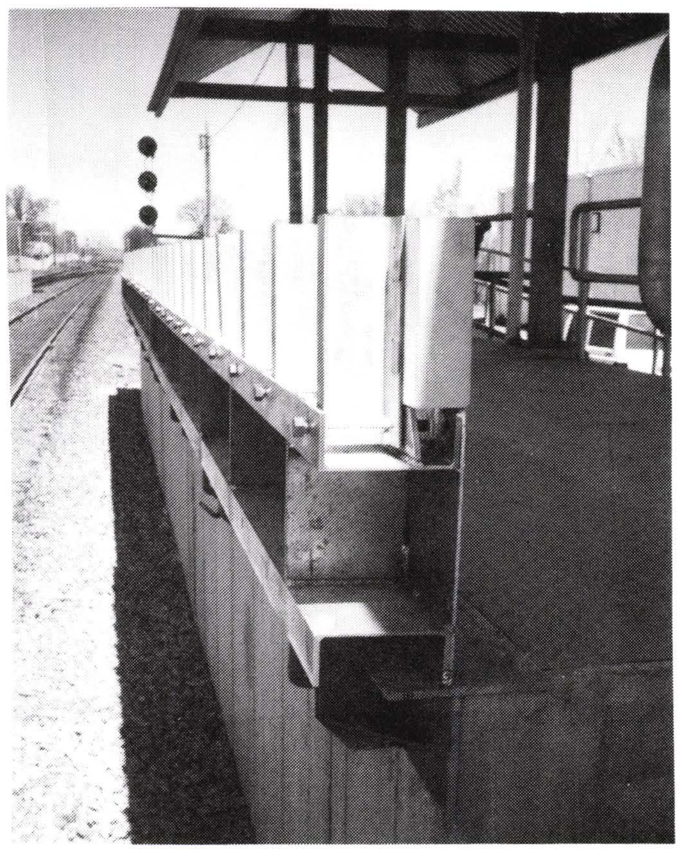

FIGURE 4-3. FRANGIBLE
PLATFORM EDGE →
AT MBTA MISHAWUM STATION
(RETRACTED)

Easter Seal Society under a cooperative agreement with the Urban Mass Transportation Administration. The mini-platform concept consists of a simple wood platform using a modular, low cost approach. The goal is to achieve a unit cost less than $10,000 per platform. SEPTA commuter rail passenger cars will have a 19 inch setback from the mini-platforms so a bridgeplate will be necessary. The Project ACTION project is also developing a light bridgeplate for use with the mini-platforms. The bridgeplate is 32 inches wide, 36 inches long and weighs only 14 pounds. These bridge-plates will cost about $100 apiece. [13]

Caltrain serves the San Francisco Peninsula, an urbanized corridor stretching about 50 miles from San Francisco south and east to San Jose. Caltrain is operated by the Southern Pacific Transportation Company under a contract with Caltrans. The system operates 71 bi-level coaches hauled by push-pull diesel locomotives. A recent study evaluated scissors lift, sidewalk elevator, wayside lift, mini-platform, onboard lift and mobile lift accessibility solutions and recommended the use of mini-platforms with a car-mounted bridgeplate as the preferred solution for most stations. [14]

4.3 ONBOARD VEHICLE LIFTS

Onboard vehicle lifts may be considered innovative for commuter rail, since rather extensive modifications are required to accommodate the lifts to commuter rail cars. Chicago Metra operates an extensive commuter rail network including the Rock Island, Burlington Northern, Chicago & Northwestern, Illinois Central Gulf, Norfolk and Western and Milwaukee Road commuter rail systems serving 246 stations. [15] Only the Illinois Central Gulf line is electrified. The other nonelectrified lines operate 682 bi-level gallery coaches in push-pull locomotive service. All are presently low platform boarding. Floor level is 44 inches above top of rail and access is by means of four steps in the car vestibule. Plans are to provide accessibility by purchasing 172 fully accessible cab cars equipped with onboard wheelchair lifts. [16] This will make one car of each four car train accessible. Metra considered putting a bus lift on the car stairs but concluded it would block too much of the stairs. It has developed a bid spec calling for a special on-board lift which folds into the steps to form a normal stairway when not in use. There will be three wheelchair positions on each accessible car.

While this approach has not yet been used on commuter rail in the United States, the Swedish carbuilder Kalmar Verkstad has used a lift which retracts into the car vestibule on high speed trains used by the Swedish State Railways. [17]

4.4 PORTABLE WAYSIDE LIFTS

Amtrak and VIA Rail Canada both use a mechanically assisted (crank and gear) mobile lift inside a portable framework (Figure 4-4). The mobile lift is a moveable device, normally stored out of the way in a locked shed or room. It is moved into position in front of the door after the train has stopped. The wheelchair passenger maneuvers onto the lift which is then hand cranked up to the floor level of the car. A bridge plate on the wheelchair lift platform is then manually folded down to traverse the stairwell and provide access to the train. A lift of this type, the "AMPLE" lift, is manufactured by Adaptive Engineering, Ltd. of Calgary, Alberta. [18] The lift includes a braking and stabilizing system; the brakes are locked by default unless released to roll the lift around the station. Amtrak uses this lift for access to Amfleet and Heritage equipment operating from low level platforms. Mobile lifts provide a simple solution. However a manual operator is required. If job descriptions and union agreements do not permit station agents or train crew members to operate the mobile lift, then an additional class of station agent would be required, making the mobile lift extremely expensive. The other key concern with mobile lifts is the time required to access the lift, move it into position, and hand crank it up and down. The mobile lift is the most time consuming solution and therefore only suitable where the demand for wheelchair service is not very high.

4.5 LOW LEVEL CAR WITH RAMP

Amtrak Superliners have a low level floor, only 18 inches above the top of rail. These cars have been equipped with a portable ramp, stored on the cars, which can be used

FIGURE 4-4. OPERATION OF PORTABLE LIFT

to access the low level portion of these bi-level cars. [19] In a demonstration conducted by Amtrak for Chicago Metra, many handicapped persons had difficulty getting up the ramp and required assistance. [20] The Amtrak ramps have a metal, nonskid surface.

UTDC has built 18 bi-level commuter rail cars for the Tri-County Commuter Rail Authority of South Florida for use between West Palm Beach and Miami. [21] The cars entered service on the 60 mile route in 1989. The car, a derivative of the GO Transit cars used in Toronto, utilizes short manual ramps similar to those on Amtrak Superliners to permit access from a slightly raised platform (Figure 4-5).

4.6 COST, PERFORMANCE AND DEMAND

Table 4-2 summarizes cost and performance attributes of various commuter rail accessibility alternatives. Capital costs estimates are just for the accessibility equipment itself. Special car characteristics or modifications and their expected costs are separately estimated. Annual maintenance costs are also provided from available studies in the literature. It is clear that, relative to car costs of over $1.5 million each, the actual costs for ramps, lifts or mini-platforms are not all that significant. Rather, the decision will normally depend upon other considerations. For example, a key concern is the cost of modifications to existing rolling stock to accommodate ramps or lifts. Where full high platforms or mini-platforms are being considered, important factors will be wayside space constraints and impact upon railroad freight operations.

Another consideration is the time required for each alternative, as excessive time can impact on train schedules. Estimates from the literature for boarding or disembarking of one wheelchair rider and three wheelchair riders are also provided in Table 4-2. These estimates provide a comparison of the time required by various options and a preliminary estimate of their likelihood of causing train delays. With the exception of the manually operated mobile lift, delays are limited to a few minutes which would normally not seriously impact commuter train schedules. Mobile lift delays can run as high as fifteen minutes, and represent a serious consideration if their use is envisioned.

FIGURE 4-5. RAMP BOARDING OF TRI-COUNTY BI-LEVEL CARS IN SOUTH FLORIDA

TABLE 4-2. COST & PERFORMANCE OF COMMUTER RAIL ACCESSIBILITY OPTIONS

Option	Modifications etc.	Capital Cost (Excludes Mods.)	Annual Maintenance Cost	Dwell Time Seconds	
				1 Wheelchair	3 Wheelchairs
Ramp	Depressed Floor Car - added cost $150,000[a]	$2,000 - $4,000[a]		33-58[h]	49-78[h]
Vehicle Lift	Car Modification to accept lift - added cost $20,000[a]	$20,000 - $30,000[a,b]	$1,000-$1,5000[b]	75-81[h] 78-141[j]	169-191[h]
Miniplatform	Bridgeplate - added cost $100 - $300[b,e] (annual maintenance $81[d])	$10,000 - $30,000[b,c,d,f,g]	$67-$100[b,d]	62 1 stop[i] 102-142 2 stop[i] 41-99[j]	108-246[j]
Mobile Lift	No changes	$1,250 - $4,000[b,c,d]		260-348[j]	744-978[j]

[a] "Metra Accessible Bi-level Car Design Project", Metra Contract K8868, January 1989 Passenger Transportation Specialists page 146.

[b] "Summary Report: 321(b) Rail Retrofit Evaluation - Light and Commuter Rail Systems" Volume I, Crain & Associates, February 1990 page 4-17.

[c] Op cit reference b page 6-9.

[d] "Peninsula Commute Rail Service Accessibility Study", Final Report, Crain & Associates, February 1987 page 49 Table 5-1.

[e] Conversation with Carol Lavoritano, Assistant General Manager, SEPTA

[f] Conversation with Bob Corresell, SEPTA

[g] Project ACTION goal

[h] Op cit reference a, page 92

[i] Op cit reference b, page 4-9

[j] Op cit reference d, page 85

Table 4-3 summarizes estimates of disabled usage of commuter rail systems obtained from a survey of commuter rail operators performed by Passenger Transportation Specialists for the Chicago Metra in 1988. [22] At the time Chicago Metra itself was not accessible, and the figure on usage for Metra was estimated by Crain Associates by extrapolation from the experience of other systems. Usage is modest, emphasizing the need for cost effective solutions which, if possible, extend benefits to not only wheelchair passengers but others such as the ambulatory elderly, those with walkers, persons with baby strollers etc.

TABLE 4-3. DISABLED USAGE OF COMMUTER RAIL

System	No. Stations	Accessibility: Stations	Accessibility: Trains	Usage by Disabled
MBTA	91	Key stations	All	75-100 users a day (updated 1991 figure)
SEPTA	172	19 - 2 inbound only	All	"Some but not many"
LIRR	141	74	All electric trains	4-5 users a month
Metro-North	109	"most"	All except 100 series MU cars	12 daily disabled commuters not all wheelchairs
NJ Transit	150	8	All with crew help	"Some regular daily users"
Amtrak	500	Key stations	All	20,000 users with orthopedic aids per year (updated 1991 figure)
MARC	32	Key stations	All NE Cor. None CSX	2 regular users
Caltrain	26	None	None	None
METRA	246	All by 1995	All by 1995	69/day 1992 estimate

Source: Data extracted from "Metra Accessible Bi-level Car Design Project", Metra Contract K8868, Passenger Transportation Specialists, January 1989

CHAPTER FOUR REFERENCES

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[2] Ibid. page 28.

[3] "Metra Accessible Bi-level Car Design Project", Metra Contract K8868, Passenger Transportation Specialists, January 1989, page 10.

[4] "Rail Modernization Study - Rail System Description Summaries", Gannett Fleming Transportation Engineers, UMTA-PA-06-0099-86-1, (pages not numbered).

[5] "Accessibility of Metra Coaches", Richard Vadnal, paper delivered at American Passenger Transit Association Annual Rapid Rail Conference, Philadelphia PA, June 9-12, 1991.

[6] See Reference 3, Survey of Commuter Rail Properties, Appendix I, (Updated by Michael Charles of Long Island Rail Road, July 1991).

[7] See Reference 3, Survey of Commuter Rail Properties, Appendix I.

[8] Ibid.

[9] Letter to Dennis Cannon, Architectural and Transportation Barriers Compliance Board from Shirley DeLibero, Executive Director, New Jersey Transit, December 4, 1990.

[10] See Reference 3, Survey of Commuter Rail Properties, Appendix I.

[11] Visit with Robert Adduci, Massachusetts Bay Transportation Authority Supervisor of Facilities, Structures and Right-of-Way, April 1991.

[12] "Combined Research Results", Project ACTION, report not dated.

[13] Carol Lavoritano, SEPTA, Panelist "Implementation of the Americans with Disabilities Act", American Public Transit Association Annual Rapid Rail Conference, Philadelphia, PA, June 9-12, 1991.

[14] "Peninsula Commuter Rail Service Accessibility Study", Final Report, Crain and Associates, February 12, 1987, page 18.

[15] <u>Jane's Urban Transportation Systems, 1991,</u> Edited by Chris Bushell, page 78.

[16] See Reference 5.

[17] See Reference 3, Minutes of Carbuilder's Meeting, June 23, 1988, page 8.

[18] See Reference 14, page 36.

[19] See Reference 3, page 2.

[20] See Reference 3, Minutes of Project Review Committee, January 25, 1988, Appendix B, page 7.

[21] "The Bi-Level Edge - Access, Comfort, Capacity", UTDC Lavalin Product Brochure.

[22] See Reference 3, Survey of Commuter Rail Properties, Appendix I.

CHAPTER FIVE
INNOVATIVE SOLUTIONS FOR ROADWAY TRANSIT BOARDING

This section discusses innovative solutions being used to provide for disabled access to roadway transit vehicles. The conventional solution for wheelchair access to buses has been the use of lift mechanisms. This solution has several drawbacks. The delay caused by deploying the lift mechanism disrupts bus schedules and subjects the disabled user to perhaps unwanted attention. In addition the lift adds weight and complex electrical and mechanical systems to the bus, adding to maintenance and increasing fuel consumption.

In Europe and Canada, the trend is clearly towards eliminating the need for steps to access the bus, thereby benefitting not only the wheelchair user, but the elderly, persons with baby strollers, and all the many categories of passengers who find steps an encumbrance. At the same time, elimination of steps speeds the boarding process, providing better service to all passengers and savings to the bus operator. Two approaches have been taken towards elimination of steps. One is to lower the bus floor to the extent that a small ramp will suffice for boarding. The other approach is to raise the curb level to that of the bus floor. It is ironic that the low floor solution was first suggested in the United States by the National Academy of Engineering in 1968. Both private and public efforts to implement a low floor bus in the United States were aborted, but the cause has now been taken up by other nations.

This chapter summarizes worldwide developments in the area of low floor buses as well as efforts to operate buses with high platforms.

5.1 LOW FLOOR BUSES

One solution to simplify disabled accessibility while at the same time speeding normal bus operations is the use of low floor bus technology. As far back as May, 1968, the National Academy of Engineering (NAE) studied the characteristics needed for improved buses of the future. [1] A major conclusion was that buses should have low floors which would both improve productivity by speeding the on-off flow of passengers and reduce physical barriers to the elderly and infirm. The "win win" nature of low floor technology which benefits not only the disabled but all transit users makes it an especially attractive solution.

During the 1970's, the UMTA sponsored Transbus program to develop an improved bus design drew heavily from the NAE study, accepting its recommendation to develop a low floor bus. During testing of Transbus prototypes in four U.S. cities reactions from 11,000 bus riders were documented. Of the thirty major bus features investigated, the greatest positive response was in favor of the low floor. [2]

In addition to the UMTA Transbus program, General Motors independently initiated a massive vehicle research and development effort called the RTX or Rapid Transit Experimental. GMC officials made a key feature convenience to the elderly and the handicapped. The result was the design of what was probably the first low floor bus, with a 14 inch floor height plus a "kneeling" concept to lower the front door, obviating the need for wheelchair lifts. [3] As an added comfort for the mobility impaired, a fold-out ramp was installed in the front door enabling wheelchair-bound passengers to roll into the low floored bus.

The history of both the RTX and Transbus program is a case study of the difficulties with innovation in a large bureaucratic environment. In response to objections from bus operators, General Motors gradually eliminated most of the innovative features of the RTX including the low floor, and when it finally went to market as the RTS it was a fine, modern bus, but hardly the technology breakthrough originally envisioned. The Transbus story is similar. Although GM participated in the program along with AM General and Flxible, it had already completed development of the RTS which was due to go into production. As a result of its large private investment, GM was less than enthusiastic about a Federal bus R&D program at this time and went on record with then DOT secretary John Volpe as "opposed to the concept of the federal government mandating a 'one only' design." [4] Having abandoned the low floor concept for the RTS, General Motors took vigorous exception to Transbus specifications calling for a 22 inch floor height. Transit operators also rejected the Transbus concept which, after an expenditure of over $28 million, was never brought to the marketplace.

Transbus and RTX are just one of many cases where the need for new technology and its early development were pioneered in the United States, but the product was finally developed and brought to the market by foreign companies. Today, leadership in low floor bus technology has passed to the Canadians and Europeans, who are marketing buses with floor heights between 12 and 22 inches. Several hundred low floor buses have been operating in Germany in regular service for a number of years. [5] There are also a number of low floor buses operating in the Netherlands. Table 5-1 provides a summary of buses now available with a floor height of 15 inches or less. ADA regulations require a 6 foot long wheelchair ramp for a 15 inch floor height in conjunction with a six inch curb. Thus ramps become impractical if the floor height is much greater than 15 inches. Meeting in Stockholm in the summer of 1990, the Transport Ministers of the 19 countries which make up the European Conference of Ministers of Transport adopted a resolution calling for the introduction of Europe-wide legislation to require future buses to be of low floor construction. [6] In Canada, the Toronto Transit Commission has recently completed a definitive policy study concerning transit services for disabled and elderly persons. [7] A key conclusion is that lift equipped buses are not an effective solution because of low utilization by the disabled community. This conclusion has caused considerable interest in low floor and kneeling buses which can serve not only wheelchair users but the broader community of the elderly. Thus policy decisions in both Europe and Canada are encouraging development of low floor bus technology. The following sections discuss the characteristics of modern low floor bus designs now available on the market.

5.1.1 Orion II

The Orion II (Figure 5-1), built in Canada by Ontario Bus Industries and in the United States by Bus Industries of America, is offered in two models. The 22 foot model has seats for 18 persons while the 25 foot model seats 25 persons. The diesel powered buses have a stainless steel structure with removable aluminum, fiberglass and stainless steel

TABLE 5-1. LOW FLOOR BUSES
FLOOR HEIGHT LESS THAN 15 INCHES

Manufacturer	Model	Length Feet	Floor Height Inches	Boarding Height Inches (Kneeled)	Kneeling Provided	Capacity (w/o Wheelchairs) Seated	Capacity (w/o Wheelchairs) Total	Where on Order or Operating
ORION II (Canada)	21 foot	22.3	12	4-8	Yes	18	18	Toronto
	25 foot	26.3	12	4-8	Yes	25	25	Syracuse
NEW FLYER (Canada)	D40LF "TUF"	40.3	14	11	Yes	30	80	JFK Airport LaGuardia Airport Victoria BC
Neoplan (USA)	AN440L	40.0	14	10	Yes	37	82	Demonstrator
NEOPLAN (Germany)	N4021NF	57.2	13	10	Optional	58	161	
	N4009L	30.8	13	10	Optional	31	69	
	N4014	38.1	13	10	Optional	30	90	Munich, Bremen, Cologne
	N4016	37.6	13	10	Optional	35	90	Wilhelmshaven, Ludenschied, Bielefeld, Freising,
	MIC4008 (Available in 34.8 and 38.6 lengths)	25.7	13	10	Optional	22	45	Karlsruhe, Thalwiel, Frauenfeld Berlin, Erlangen Gutersloh Berlin, Stuttgart, Herten
MAN (Germany)	NL202	38.3	13	10	Optional	42	98	Cologne, Bochum
Mercedes (Germany)	O-405N	38.3	13	10	Optional	43	99	

FIGURE 5-1. ORION II BUS

panels. An unusual feature which facilitates the low floor height is front wheel drive. This feature also makes it possible to pull the whole power train out of the bus to permit servicing. Floor height is 12 inches throughout with no steps or ramps inside the vehicle. The buses have air bag suspension and a kneeling feature which can drop the floor to 8 inches from the ground in the front and only 3.6 inches from the ground in the rear, so that a simple ramp suffices for wheelchair boarding. [8]

Orion II buses have been tested by the Michigan Department of Transportation, and Central New York Regional Transportation Authority. [9,10] The New York study evaluated five Orion II vehicles over an 18 month period in Fulton and Syracuse, New York. The study found that passengers preferred the ease of boarding of the low floor Orion II's. Drivers found the vehicles acceptable. Problems with the low floor seem to have occurred primarily on demand responsive routes in Syracuse, where the vehicles were operated over speed bumps in parking lots and on unplowed side streets and unpaved country roads. Under these conditions the low profile resulted in frequent damage to the bottom of the bus. [11] Battelle evaluated ten Orion II's for the Michigan Department of Transportation operating in Bay City, Lansing, Holt, East Lansing, Detroit, Mount Pleasant and surrounding areas. Testing began in November 1985 and a total of over 180,000 miles was accumulated on the ten vehicles altogether. The buses averaged 4211 miles between road calls and required 6.1 personhours per 1000 miles for maintenance. [12] These measures are said to compare well with similar high floor vehicles in the same type of service. Fuel consumption at 6.8 miles per gallon was also comparable to that achieved by similar size high floor buses under the same type operating conditions. Again passengers liked the ease of boarding and the bus was acceptable to drivers. No problems are reported associated with inadequate ground clearance. As of mid 1990 over 500 Orion II buses were in service at over 30 locations throughout North America. [13]

5.1.2 New Flyer

In 1986 Flyer Industries of Winnipeg, Manitoba, was acquired by the Dutch bus builder Den Oudsten. A prime objective of the acquisition was to market Den Oudsten's low floor forty foot bus in North America. [14] The original low floor Dutch model had a floor height of 21 inches above street level. This design has been refined and a new bus, "The User Friendly (TUF)" transit coach (Model D40LF), with a floor height of 14 inches from front to rear doors is now being offered for sale (Figure 5-2). This full size forty foot bus is powered by a Detroit Diesel 6V92 TA 220 horsepower engine with a ZF transmission. Full airbag suspension is provided with optional kneeling capability which can reduce boarding height to only 11 inches. The 80 passenger bus has a turning radius of 39 feet, 10 inches. The body is an integrally welded frame of tubular steel and all outer panelling is of fiberglass. [15]

Forty "TUF" low floor buses have been purchased by the New York Port Authority for service at JFK and La Guardia airports. [16] In addition, the Victoria Regional Transit System in British Columbia has ordered nine "TUF" buses for delivery in November of 1991. Capital cost of the Victoria low floor buses is about five percent higher than a standard bus while operating and maintenance costs are expected to be about the same. [17]

5.1.3 Neoplan

Germany is probably the country most active in low floor bus development, and in Germany the leader is Neoplan. Neoplan has built over 1650 low floor vehicles of varying sizes and designs beginning in 1959 when a bus was designed for Frankfurt Airport with a floor height of 14 inches and no steps. [18] In 1964, a doubledecker city transit bus was designed with a floor height of 13 inches and also no steps. To make a low floor in the area near the front axle possible, this bus had a new independent suspension using bonded rubber in place of the traditional rigid axle and leaf springs.

In 1979 the Neoplan Telebus was demonstrated at the International Transport Exhibition in Hamburg. The floor of this small bus was only nine inches high and could be further dropped to only six inches during boarding. In 1987, Neoplan developed the N 4021 NF, the first low-floor articulated vehicle, for the Munich Transport Corporation (Figure 5-3). Six of these buses are now operating in Munich, another 35 in Bremen and five in Cologne. Neoplan now offers a complete line of low floor vehicles with a floor height of 13

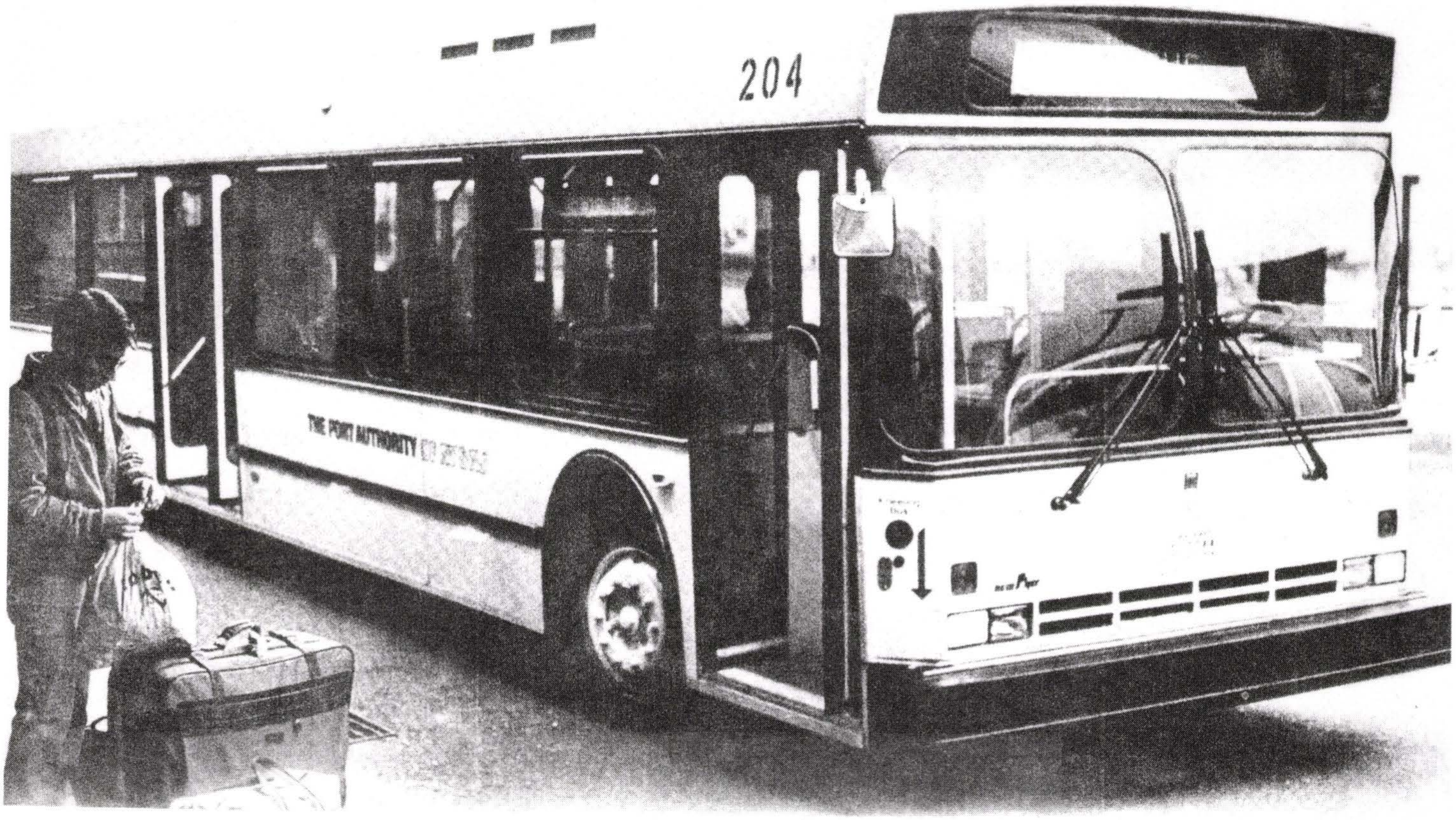


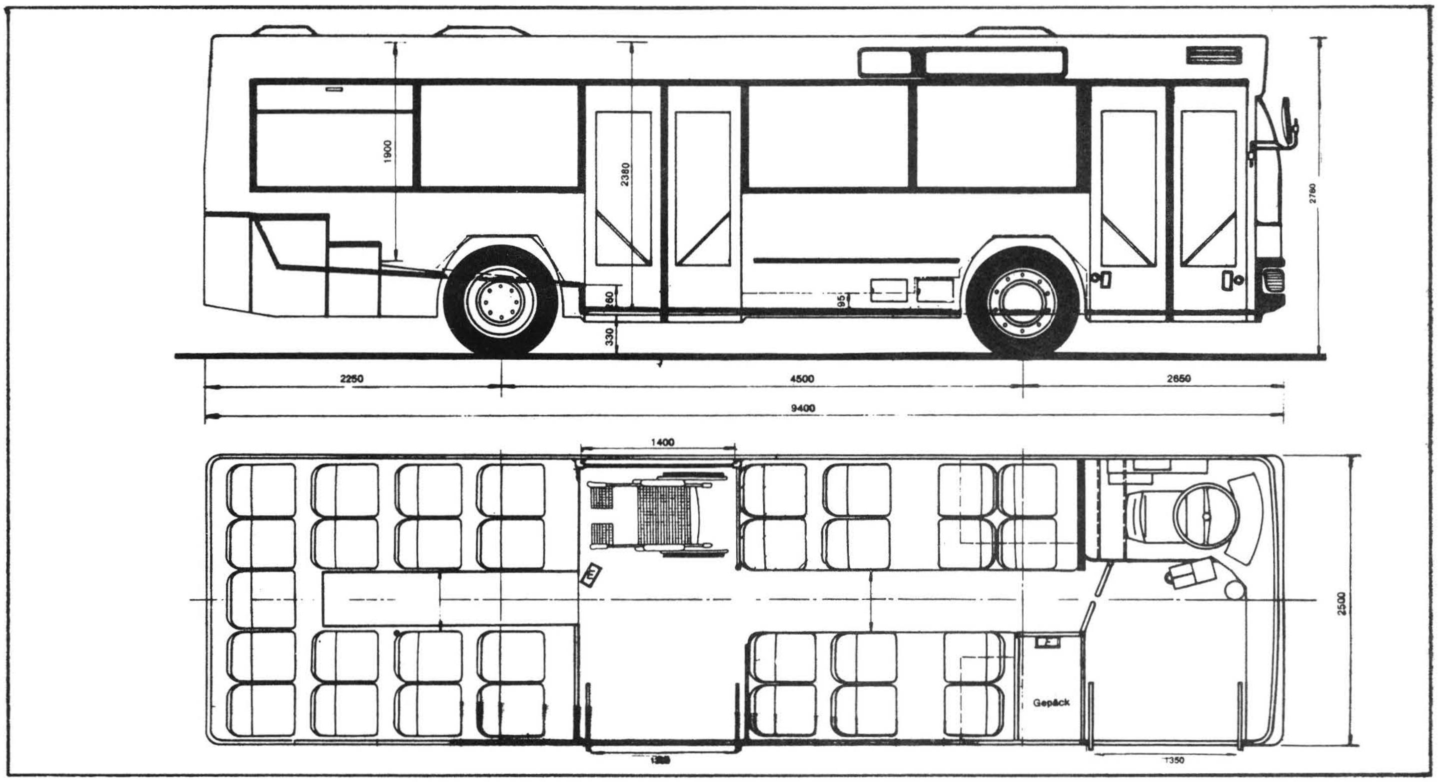
FIGURE 5-2. NEW FLYER "TUF" BUS

FIGURE 5-3. NEOPLAN LOW FLOOR ARTICULATED BUS

inches which can be dropped by kneeling to ten inches. These include the Model N 4009 L which is a small bus seating 31 passengers. Three of these buses are operating in Wilhelmshaven (Figure 5-4). Small buses of this type are also used in Ludenschied, Bielefeld, Freising, Karlsruhe, Thalwiel and Frauenfeld and at various different airports. The low floor extends to just in front of the rear axle where a step and slight ramp provide room for the rear axle and overhang clearance. In the standard forty foot bus size, two low floored N 4014 buses are operating in Munich. These have three doors, and ramp both up and down to provide clearance for the rear axle. Another standard sized model, the N 4016, is also available. Eight of these N 4016 low floor buses are now operating in Berlin, 16 in Erlangen and four in Gutersloh. The N 4016 has only two doors, both in front of the rear axle. The low floor extends to just in front of the rear axle where a single 9 percent continuous ramp provides clearance for the rear axle (Figure 5-5).

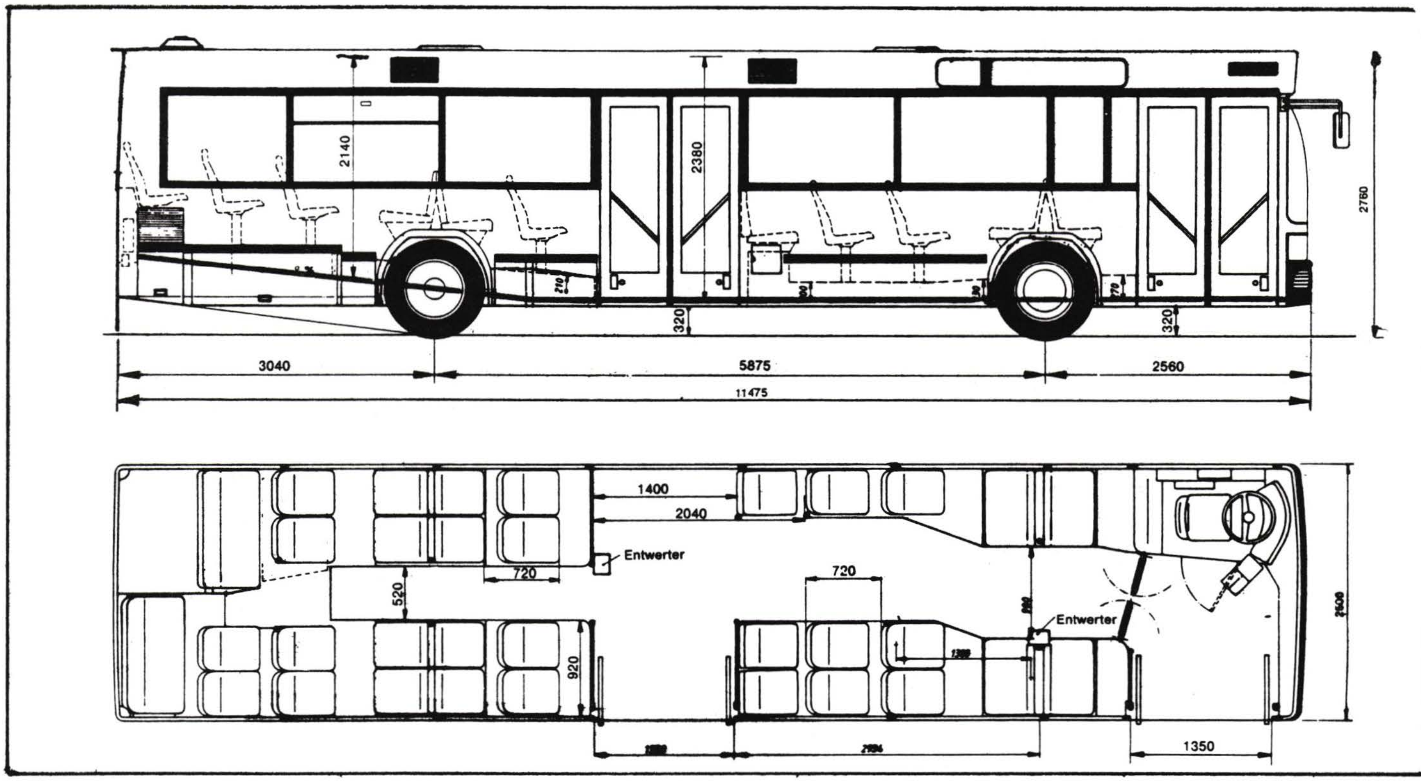
Neoplan has an even more modern set of low floor buses under development and testing. These vehicles, known as "Metroliners", are composed of lightweight carbon fiber shells joined vertically without metal reinforcement (Figure 5-6). Weight is a third less than comparable models in use today. [19] The first Metroliner in regularly scheduled service began operating in Berlin in 1988. Metroliners are also in service in Stuttgart where Neoplan world headquarters are located and also in Herten, Cologne and Bochum. Neoplan is offering the Metroliner in a 26 foot model seating 22 passengers with 23 standees, a 35 foot model seating 43 passengers with 36 standees and a forty foot model with a total capacity of 106 passengers. [20] The Metroliner low floor extends to just in front of the rear axle where it ramps up to provide needed clearance.

In the United States, the Denver Regional Transportation District has ordered a prototype Metroliner vehicle to operate on the mile long Denver downtown mall. [21] The prototype will be a 44 foot long bus, with seats for 23 passengers and a 14 inch floor height which rises to 20.8 inches above the rear drive axle. A one piece, electric operated 40 inch wide ramp, remotely operated by the driver, will permit wheelchair boarding from street level. The bus will be powered by a Detroit Diesel 6-71 Turbocharged DDEC engine with ZF automatic transmission. Cost for the prototype is $360,000. [22]



N 4009 L

FIGURE 5-4. NEOPLAN SMALL LOW FLOOR BUS



N 4016

FIGURE 5-5. NEOPLAN STANDARD SIZE LOW FLOC S

FIGURE 5-6. NEOPLAN "METROLINER"

5.1.4 MAN Model NL202

MAN of Munich, Germany offers the model NL202, a standard size transit bus with a boarding height of 12 inches at the forward door. [23] It is powered by a turbocharged D 08 engine mounted on the off-side to make room for a third door. From the front door, the floor is ramped to the center platform where there is space for a wheelchair. An optional kneeling capability is provided. MAN has delivered 105 of these low floor buses to Munich. The same bus is also being offered by Graf & Stift, MAN's subsidiary in Vienna, Austria.

5.1.5 Mercedez Benz Models

Mercedes Benz is one of the largest bus manufacturers in the world with annual sales of 27,000 units worldwide. The company currently offers a 38 foot low floor bus, the model O405N, with a floor height of 15 inches. [24] Two engine power outputs are available, 157 kW and 184 kW. A larger low floor articulated bus, the O405GN, is currently under development.

5.1.6 Other Low Floor Bus Designs

Most other low floor bus designs have floor heights significantly greater than 15 inches. [25]

The Belgian firm Van Hool produces the A500, a 38 foot bus with the entire length of the floor 20 inches above street level. [26] The entrance height at the three doors is only 13 inches and a height adjustment device can drop the floor another three inches. Vehicle capacity is 100 with 23 seats. The A600 is a similar low floor design with only two doors. A500 buses are now in operation in Belgium, France and Switzerland. In February 1991, 120 A500 vehicles were delivered to MIVB, the city transit authority in Brussels. As to the A600, 383 have been delivered in Belgium, 90 of which are now operating in Liege. Jonckheere, another Belgian firm, offers the "Tricity" a three door, 100 passenger bus, with a floor height of twenty inches. And the Dutch firm Den Oudsten, in collaboration with DAF, is said to be developing a low floor standard size city bus (model B88) aimed at the American market. (Den Oudsten also owns New Flyer Industries in Canada, whose low floor bus was described in Section 5.1.2.)

Renault offers the R312, the French standard bus design with a continuous floor height of 22 inches. Access to the bus is via two steps. The 39 foot bus carries a total of between 92 and 120 persons with seating arrangements varying from 23 to 45 persons. The R212 is a smaller 29 foot version with the same 22 inch floor height and a capacity of 65 persons including 13 seated.

The Volvo N10R is a standard size forty foot bus with a floor height of 21 inches which, like the Renault models, is accessed by steps. The Model CN113, offered by the Swedish firm, Scania is a standard city transit bus with three doors and seating fifty persons. It is said to be available in a low floor version. Iveco-Fiat of Italy offers two models with 22 inch floor height, the TurboCity-UR 490 Green and TurboCity-UR 590 Green. Access is via two steps.

In the United States, the new Goshen Coach Corporation is reported to have introduced a low floor semi-monocoque small size bus. Don Manning & Associates of Troy, Michigan has designed a new bus called the "World Bus". Manning was formerly the chief bus designer for General Motors. [27] A 30 foot bus, with seats for 35 persons, a floor height of 21 inches and a kneeling height of 18 inches was exhibited at the Houston APTA Exposition in 1990. An electric powered ramp extends from above the single, six inch high step at the front door to provide wheelchair access (Figure 5-7). The bus is not in production at the present time.

There is also some low floor bus activity in Japan. In recognition of Japan's rapidly aging society, the Tokyo Metropolitan Government has decided to gradually replace all of its conventional buses with low floor types. The first group of ramp equipped new buses has been phased in. The buses are equipped with a recessed sliding panel under the first step which forms a ramp for wheelchair users. The bus floor has been lowered to 22 inches above street level. [28]

FIGURE 5-7. RAMP ACCESS TO DON MANNING BUS

5.2 LOW FLOOR TROLLEYBUS DEVELOPMENTS

Switzerland has recently announced developments in the area of low floor trolleybuses. [29] The Geneva Public Transit Authority has received a prototype low floor trolleybus from NAW/Hess and another dozen units are on order. The lowest interior floor segment is 13 inches above the pavement. In Lausanne, Saint Gal and the Vevey-Montreux area, the Swiss are operating electric trolleybuses with low floor trailers which have door openings only about a foot above pavement level. The trailer units can accommodate 26 seated passengers with standing room for 32 more.

5.3 HIGH PLATFORM BUS OPERATIONS

Another innovative alternative to wheelchair lifts to improve disabled access to buses is the use of high level platforms, similar to those in general use for rapid rail. It is also possible to use mini-platforms as have been used for light rail and commuter rail systems.

There are two obstacles to the use of high platforms for bus boarding. One is the cost and right-of-way constraints which can be expected to severely limit any widespread installation of high platforms. This limitation is sufficiently serious that high platform loading will at best be restricted to high volume busway operations. The other obstacle is technical and relates to the difficulty of accurately aligning a bus with the platform.

Experiments with high platform bus operations have been conducted in Germany, Sweden and Holland. Mechanical bus guidance has been used in the German experiments to assure proper alignment with the boarding platform. Electronic guidance was used initially in the Swedish experiments. The Dutch work relied upon the driver to accomplish proper bus alignment. In addition to these efforts with full high platform boarding, guided bus projects in Germany and Britain have also used platforms which are level with the first step of the bus. While these platforms do not permit wheelchair access, the technical problem of aligning with the platform is relevant. The following sections discuss briefly experiences with high platform bus operations.

5.3.1 Mechanically Guided Buses

Mechanical guidance has been tested using both conventional buses and dual propulsion trolleybuses on routes in Essen Germany (Figure 5-8). German work on guided buses began at test tracks in the early seventies under the auspices of the Federal Ministry for Research & Technology. Both the MAN guided bus test track in Munich and the Daimler Benz test track near Stuttgart were provided with station platforms of various heights including full high level platform boarding (Figure 5-9). Development was moved to Essen in 1980. Mechanically guided equipment now operating in Essen includes 29 articulated Mercedes buses, 18 standard two-axle Mercedes buses, and 18 articulated "dual propulsion" Mercedes buses which have both diesel and electric trolley propulsion. [30] In addition, a single dual propulsion prototype built by MAN was also operated in Essen. The mechanical track guidance equipment allows the vehicle to be steered without any action being taken by the driver. Automatic steering is effected by rubber guide rollers mounted on arms rigidly bolted to the steering knuckle on each side of the bus. These guidewheels run against guiderails installed on either side of the guideway and are directly connected to the stub axles of the front wheels (Figures 5-10 and 5-11). If the bus moves away from the nominal track determined by the guiderails, the deviation is immediately corrected via the guide roller, guide arm and stub axle. Small rollers are also attached to the rear axles of the bus to act as safety rollers to prevent the shoulders of the rear tires from contacting the guiderails in sharp curves. The existing steering system of the bus remains unchanged and normal manual steering is still possible when operating on the street network. The two guiderails are 7 inches in height and spaced 8 1/2 feet apart (Bus width is four inches less). In Essen more than 1.5 million miles have been traversed on the guided busway. [31]

At the Essen demonstration, bus stop platforms are normally 12 inches above the running surface which puts them in line with the first step of the bus (Figure 5-12). However, there is a half mile tunnel section with high level island platforms where passengers load directly into the dual propulsion buses at floor level through doors on the left hand side. [33]

FIGURE 5-8. GUIDED BUS IN ESSEN, GERMANY

FIGURE 5-9. HIGH LEVEL PLATFORM BOARDING OF MECHANICALLY GUIDED BUS

FIGURE 5-10
← GUIDEWHEEL ON
DAIMLER BENZ
GUIDED BUS

Daimler Benz

FIGURE 5-11
GUIDEWHEEL ON →
MAN GUIDED BUS

MAN

FIGURE 5-12. ESSEN PLATFORM IS LEVEL WITH FIRST STEP OF GUIDED BUS

High level platform bus loading using mechanical guidance was studied for Logan Airport in Boston in 1985-86. The plan envisaged guided buses running on the freeway system between the airport and outlying Boston area communities. Buses would receive priority treatment in the Harbor Tunnel. At airport terminals the buses would transfer to the guided mode. This would permit high level platform loading and unloading directly into the terminal building through coordinated doors, as is now done by automated people movers. MAN submitted an informal proposal to Logan Airport for their guided bus system. [34]

Mechanically guided buses have also been operated in Adelaide Australia, and Birmingham, England. In Birmingham, double decker guided buses were operated beginning in 1984. Service was terminated with deregulation of transport in Britain. Stations had raised platforms level with the entrance step to the bus. [35]

The Japanese have been experimenting with mechanically guided buses at the Public Works Research Institute test track 40 miles northwest of Tokyo since the early 1980's. In 1986, a mechanically guided bus system began testing in Nagoya Japan. [36] The guidance system is reported to cost $20,000 per bus. The Japanese system was chosen as an actual transport mode for the Asian-Pacific Exposition at Fukuoka Japan in 1989. [37]

Guided bus studies have been reported to be underway in Jakarta, Indonesia; Auckland, New Zealand; and Bangkok, Thailand. [38]

5.3.2 Electronic Bus Guidance

In electronic bus guidance systems the steering effort is generated by a vehicle mounted power unit driven by a closed-loop control system. The reference signal generated by the wayside, (typically by a buried cable), is picked up by vehicle mounted antennas and fed to the control system. The error signal obtained by comparing the actual vehicle position with the reference signal is used to control a servo motor or hydraulic actuator linked to the steering system. In the case of electronic guidance, the absence of elements to physically contain the vehicle in case of failure requires that special attention be given to safety.

German electronic guidance systems developed by MAN and Daimler-Benz provide total steering control. When the guidance system is active, the driver does not need to keep his hands on the steering wheel. The MAN version was demonstrated in Furth, Germany beginning in 1984. [39]

Volvo's Guided City Bus System, operated in Halmstad Sweden since 1979 is more directly applicable to high level platform boarding. The system consists of special bus stops with high level platforms. It initially employed an electronic inductive loop control system by which the buses could be docked entirely automatically, thereby providing level platform boarding. The electronic guidance technology has since been eliminated. The guidance system was designed to maintain a distance of 16 inches between the platform and the vehicle and it was found that the drivers could achieve comparable accuracy under manual control. High platform operation under manual control has been continued and in 1984 consisted of 21 buses operating at 53 specially equipped stops. A special bridge plate is used to surmount the gap between the platform and the bus. [40]

5.3.3 Manually Guided Operation

The Swedish decision to use manual guidance in place of electronic guidance in Halmstad has already been mentioned. The Dutch have also experimented with high platform bus operation under manual control. In 1986, four prototype buses were tested in the Dutch city of Niewusjen. The buses used were the Den Oudsten forty foot city bus which has a 21 inch floor height. The curb was raised to within one inch of the vehicle floor, making arrangements such as lifts for the mobility impaired unnecessary. [41]

The very rapid recent progress towards low floor buses may have overtaken this earlier work with high platforms. For example New Flyer, which is owned by Den Oudsten, now offers a 14 inch floor height bus which can provide street level accessibility in conjunction with a ramp.

CHAPTER FIVE REFERENCES

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[29] "Trolleybus Innovations", Public Innovations Abroad, June 1991, page 5.

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[32] "Spurbus Essen Information on the Research and Development Project Guided Bus Essen", Federal Ministry of Research and Technology, Federal Republic of Germany, page 25.

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[35] "The Guided Bus - West Midlands Passenger Transport Executive", page 3.

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[37] See Reference 31, page 3.

[38] See Reference 31, page 8.

[39] "Advanced Bus Technology Study", T.J. McGean et al, Orange County Transit District, August 1985, page 33.

[40] See Reference 16, pages 547-548.

[41] "What's New", Mass Transit, September 1986, page 34.

APPENDIX A

COST ESTIMATE FOR LIGHT RAIL MINI-PLATFORM

COST ESTIMATE FOR LIGHT RAIL MINI-PLATFORM

HANDICAPPED RAMP COST ESTIMATE

This cost estimate if based upon the standard Handicapped/Elderly Ramp and Platform, Type 1 as designed by the California Department of Transportation. The cost per ramp is estimated to be approximately $15,000 (fifteen thousand dollars) in 1991 dollars. This includes all labor and materials and contractor's overhead and profit.

The estimate assumes the cost for construction of a single ramp, independent of other items. Such would be the case to retrofit a single station to comply with accessibility requirements. If more than one ramp were to be constructed or a single ramp were built as part of new construction, the cost could be expected to decrease by two to three thousand dollars per ramp.

The prices used in the estimate are national average as compiled in the 1991 issue of "MEANS BUILDING CONSTRUCTION COST DATA." Actual prices will vary depending on project location. Ramps constructed in "Closed Shop" states will tend to cost more than those built in states with Right-to-Work laws. In addition, projects constructed with Federal funds must conform with the Davis-Bacon act which sets minimum wages for construction trades. This also tends to increase costs.

The estimate is broken down into five packages; Foundation, Blockwork, Fill, Concrete, and handrail.

FOUNDATION: The estimate for this item assumes a standard strip footer in suitable soil. While not shown on the drawings provided, installation of #5 reinforcing steel is included in the cost. The footing is assumed to be 3 feet wide and 8 inches in depth as shown on the drawing. An additional half cubic yard of concrete is included to account for waste.

MASONRY WORK: The estimate for this item assumes all block is scored, split face block with all cores filled with grout and horizontal ladder type reinforcing. #5 vertical dowels which would tie the block into the footing and the slab have been included in the reinforcing cost of those items. This would be required for seismic design. Fifteen percent (15%) wastage was included in the estimate of masonry. This is because the design requires extensive block cutting.

INTERIOR FILL: The estimate for this item assumes select fill is used to support the slab and that the fill must be hauled a distance of at least 5 miles. If material were available on site, then the cost of this package would be labor and equipment only.

CONCRETE:

Formwork - Because the curbs are elevated on top of the block work, the cost for a conventional at grade curb cannot be used. For the purpose of this estimate, the forming costs for these curbs was considered to be equivalent to a standard interior beam. This was confirmed with an alternate estimate assuming 2x6 and 2x12 wood forms held with metal snap ties and braced to grade with 8 foot 2x4s and stakes. The cost differential was $31.

Reinforcing Steel - While none was shown on the drawings provided, the cost of installing 6"x6", #10 wire mesh in the supported slab and #4 bars each way in the overhang was added in this estimate. Because steel fabricators usually have a $500 minimum order which was included in the foundation package, and the total amount of re-bar estimated for the foundation and slab falls well below this amount, no material cost was included for this item.

Placement and Finishing - Five Percent (5%) wastage of concrete was included in this amount. The additional amount for sandblasting the curbs is accounted for by extending the amount of time required for finishing.

HANDRAIL: The price for a standard 3 rail steel handrail with 1 1/2" tubing was adjusted up from $23/LF shown in MEANS to $35/LF to account for the 2" tubing and the extra rail required on the upper platform.

A 15% contingency factor is included in the total cost. This is standard practice for a preliminary estimate.

BY: TJM
DATE: JUNE 4, 1991

COST ESTIMATE
STANDARD HANDICAPPED PLATFORM

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
PACKAGE 1 - FOUNDATION				
EXCAVATION				
LABOR (1 OPERATOR, 2 LAB.)	2	HOUR	$58.95	$118
BACKHOE	1	DAY	$190.00	$190
REINFORCING STEEL				
MATERIAL (MIN. ORDER)	1	LS	$500.00	$500
LABOR (2 RODMEN)	2	HOUR	$80.00	$160
CONCRETE				
MATERIAL	7	CY	$51.00	$357
LABOR (1 FORMAN, 4 LAB.)	2	HOUR	$143.00	$286
PACKAGE 2 - MASONRY WORK				
BLOCK WORK				
SCORED, SPLIT FACE CMU	262	SF	$2.41	$631
LABOR (CREW D-8)	8	HOUR	$155.70	$1,246
GROUT LABOR & MAT.	262	SF	$2.20	$576
PACKAGE 3 - INTERIOR FILL				
MATERIAL				
SELECT FILL	22	CY	$7.35	$162
HAUL >5 MILES	22	CY	$3.11	$68
LABOR				
1 OPERATOR, 2 LABORER	4	HOUR	$58.95	$236
EQUIPMENT				
BACKHOE	1	DAY	$190.00	$190
TAMPER	1	DAY	$35.00	$35
PACKAGE 4 - CONCRETE WORK				
FORM				
CURBS (MEANS 031-138-2050)	182	SFCA	$5.95	$1,083
OVERHANG (031-150-1000)	13.3	SFCA	$5.20	$69
REINFORCING STEEL				
MATERIAL PAID FOUND. MIN	200	LB	$0.00	$0
LABOR (2 RODMEN)	8	HOUR	$80.00	$640
PLACE CONCRETE				
MATERIAL	9	CY	$51.00	$459
LABOR (CREW C-6)	4	HOUR	$177.48	$710
FINISH CONCRETE				
LABOR (CREW C-10)	4	HOUR	$99.72	$399
HANDRAIL (MEANS 055-203-0600)	132	LF	$35.00	$4,620
TILE (MEANS 093-102-4300)	14	SF	$8.50	$119
SUB-TOTAL				$12,854
CONTINGENCY (15%)				$1,928
TOTAL				$14,782

THIS ESTIMATE IS BASED ON OUR FIRMS EXPERIENCE AS PROFESSIONALS FAMILIAR WITH THE CONSTRUCTION INDUSTRY. WE CAN NOT AND DO NOT GAURANTEE THAT ACTUAL BIDS WILL NOT VARY FROM THIS ESTIMATE.

ALL PRICES IN 1991 DOLLARS

ESTIMATE BASED ON COST TO CONSTRUCT A SINGLE RAMP. CONSTRUCTION OF MORE THAN ONE RAMP ON A PROJECT WILL REDUCE UNIT PRICE AS QUANTITES INCREASE.

ALL COSTS ARE NATIONAL AVERAGE. ACTUAL COSTS WILL VARY DEPENDING ON PROJECT LOCATION, OPEN SHOP VS. UNION CONSTRUCTION AND DAVIS BACON WAGE RATE REQUIREMENTS.

PACKAGE 1
FOUNDATION

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
EXCAVATION				
LABOR (1 OPERATOR, 2 LAB.)	2	HOUR	$58.95	$118
BACKHOE	1	DAY	$190.00	$190
REINFORCING STEEL				
MATERIAL (MIN. ORDER)	1	LS	$500.00	$500
LABOR (2 RODMEN)	2	HOUR	$80.00	$160
CONCRETE				
MATERIAL	7	CY	$51.00	$357
LABOR (1 FORMAN, 4 LAB.)	2	HOUR	$143.00	$286
TOTAL PACKAGE COST				$1,611

PACKAGE 2
C.M.U.

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
BLOCK WORK				
SCORED, SPLIT FACE CMU	262	SF	$2.41	$631
LABOR (CREW D-8)	8	HOUR	$155.70	$1,246
GROUT LABOR & MAT.	262	SF	$2.20	$576
TOTAL PACKAGE COST				

PACKAGE 3
INTERIOR FILL

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
MATERIAL				
SELECT FILL	22	CY	$7.35	$162
HAUL >5 MILES	22	CY	$3.11	$68
LABOR				
1 OPERATOR, 2 LABORER	4	HOUR	$58.95	$236
				$0
EQUIPMENT				
BACKHOE	1	DAY	$190.00	$190
TAMPER	1	DAY	$35.00	$35
TOTAL PACKAGE COST				$691