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A STUDY OF WHEELCHAIR ACCESS TO THE CURRENT TRANSIT BUS DESIGN

APRIL, 1977

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16. Abstract

THIS REPORT DESCRIBES THE BACKGROUND AND CONCEPTUAL DESIGN OF INCORPORATING INTO THE CURRENT 40 FOOT BUS A LEVEL CHANGE DEVICE TO BOARD WHEELCHAIR PERSONS. IN ADDITION IT ALSO COVERS SEATING, WHEELCHAIR POSITIONING AND SECURING THE WHEELCHAIR ONCE ON BOARD.

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PREFACE

A great deal of public debate currently exists on the best way to improve and increase use of public transit equipment by the elderly and handicapped. One aspect of the debate deals with the transport of wheelchair-bound passengers on current design, high floor, urban transit buses. This possibility has interested a growing number of manufacturers in the development of platform lift devices especially designed for use on transit buses. Consequently, several devices are now in the early stages of production and others in various phases of development.

This report is the result of a study conducted by AM General under a contract with the Department of Transportation, Urban Mass Transportation Administration (UMTA), to investigate the feasibility and practicality of wheelchair lift platforms for current design 40-foot transit buses.

The authors of this report wish to express their appreciation to the many wheelchair and lift device manufacturers, transit operators and handicapped organizations that contributed valuable assistance and data for this study. Special recognition is due to the personnel of Everest and Jennings, Los Angeles, California, for their assistance in analyzing wheelchair dimensions and populations by size and type.

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1.0 INTRODUCTION

Public and legislative pressure has been increasing in recent years for improved accessibility for the elderly and handicapped to all modes of public transportation. Not a small measure of this pressure has come from various public and private organizations representing the interests of disabled, elderly and other transportation handicapped citizens. These organizations, as a whole, have become skillful in lobbying for favorable legislation and increasing public awareness of inadequacies in existing public transit for serving the disabled patron. Perhaps equally important, they have served as a collective voice for the elderly and handicapped in asserting their rights as taxpayers and citizens for equal public transportation.

Organizations for the handicapped have successfully intervened through the courts recently to influence or halt the purchase of urban transit buses that did not provide improved accessibility to disabled passengers in accordance with existing federal regulations.

The transportation handicapped are also well represented today at all levels of government as members of agencies, departments and committees that deal with public transportation regulation, coordination and funding.

It appears to be a foregone conclusion that our public transit industry in the United States faces a severe re-evaluation in the near future of its obligations and abilities to better serve the transportation handicapped patron. Federal agencies dealing with transportation needs are tending more and more to formulate rules and regulations that would make improvements in transit equipment and operations for the handicapped a condition of federal grant aid.

This report addresses itself to one element of public transportation – the standard 40-foot urban transit bus – and the feasibility of incorporating a wheelchair lift platform (level change) device that could provide safe ingress and egress of wheelchair-bound passengers. The transit bus industry is currently limited in its ability to accommodate severely handicapped patrons because there is no currently developed lift device for use on standard 40-foot buses with a demonstrated record of performance and reliability.

Lift devices have been designed and are currently on the market for use with a variety of small buses and van-type vehicles. These devices, however, have not been manufactured in any great quantity for use on standard transit buses.

Another aspect of existing devices is that they are used on vans and small buses especially equippea for providing services to the elderly and handicapped on a call or demand basis. Under these conditions, cycling time required to load and unload a wheelchair-bound passenger is not a primary consideration as it is on a scheduled route where schedules and dwell times are critical.

One can recognize that conditions occur when it would be practical to use a full size 40-foot bus rather than a small bus or van to transport larger numbers of handicapped passengers. There are also conditions where buses equipped to safely and efficiently transport a mixed population of handicapped and non-handicapped patrons would offer distinct advantages to both the system operators and passengers. This report will evaluate both the feasibility and practicality of satisfying these conditions with current standard design 40-foot transit buses.

2.0 STUDY OBJECTIVES

Only three companies manufacture standard 40-foot urban transit buses in the United States today. There is a high degree of commonality in the design of all three manufacturers due, most probably, to the competitive nature of the business, the low bid procurement system, and the fact that procuring transit properties greatly influence design features through their specifications.

Two of the common design characteristics that most impact assessibility of wheelchair-bound transit passengers are the floor height of approximately 33 to 35 inches and the standard entry door width of approximately 30 inches. With these constraints in mind, it was the objective of this study to determine the feasibility of incorporating into the design of current standard 40-foot transit buses a wheelchair lift platform (level change) device, and to determine whether or not it would be practical to offer such a device as an option in the manufacture of new buses.

No consideration has been given in this study to level change designs for the purpose of retrofitting existing buses.

3.0 TASKS

The specific tasks undertaken to meet the objectives set forth in Part 2.0 of this report are delineated in the contract statement of work and restated here to provide a frame of reference. In accordance with the contract, AM General's standard 40-foot Metro Series Bus was used as the design baseline for determining the feasibility and practicality of incorporating a level change device.

3.1 TASK 1

Based on the current manufacturing design of the AM General 40-foot transit bus, develop several tentative design approaches for incorporating a wheelchair lift device; associated hardware; internal arrangements for maneuvering, positioning and securing; and resulting seating arrangements for non-handicapped passengers. The lift device and, in so far as possible, other portions of the system when not in use, shall not prevent the normal mode of operation for the bus.

At least two interior arrangements shall be investigated; one which will accommodate two wheelchair passengers and another which will accommodate an approximate equal number of wheelchair-bound and non-handicapped bus passengers.

3.2 TASK 2

Evaluate the tentative design approaches developed under Task 1 to determine the most practical devices and conditions which could be offered as an option in new bus production. Consideration need not be given to designs most suited for retrofit to existing buses under this project.

In establishing the relative merits of the several tentative designs, the evaluations shall include, but not be necessarily limited to, the following:

a. Lift location in the bus; order of preference being front door, rear door, near front in driver's view, other.
b. Safety
c. Reliability and complexity

d. Time required to deploy lift, secure, release and maneuver in bus.

e. Cost.

f. Interference with normal bus operations.

3.3 TASK 3

Based on the best design approach determined under Task 2, develop a complete conceptual design. The design shall be sufficiently delineated to permit reasonable judgement of its acceptability by non-technical persons.

3.4 TASK APPROACH

A task approach was defined based on the following basic assumptions and conditions:

- There is no existing lift design available specifically for large transit bus applications and, therefore, no documented experience on performance, reliability or cost.

- No data has been gathered on wheelchair designs, specifically on wheelchair sizes, nor any correlation of wheelchair user population to wheelchair size.

- A lift device could be designed with existing technology and a major development program was not required.

From these assumptions and an understanding of the contract tasks, a logical sequence of steps and events required to achieve the study objectives are established as follows:

- Survey wheelchair designs and correlate population usage to wheelchair sizes to establish the maximum size and spacial envelope required to accommodate all, or an acceptable majority, of wheelchair-bound transit patrons.

- Determine the design and hardware impact, if any, on existing 40-foot transit buses to accommodate the wheelchair parameter established above.

- Survey currently available wheelchair lifts and new designs in various stages of development, and evaluate the merits of these designs in relationship to the criteria defined in Task 2, Part 3.2 above.

- With the data and background developed above, develop tentative design concepts for wheelchair lifts.

- Evaluate tentative design concepts and from the candidate designs develop a complete wheelchair lift conceptual design that best meets the overall design goals.

- Evaluate and determine the requirements for optimum maneuvering, positioning and securing of wheelchair patrons; and investigate arrangements for integrated loads of wheelchair and non-handicapped passengers.

The data and conclusions derived from the above events form the basis of this final report on wheelchair access to the current design transit bus.

4.0 WHEELCHAIR SURVEY

A survey of four (4) wheelchair manufacturing companies was made to establish wheelchair sizes and types commonly available.

Commercial literature was received from all the manufacturers describing their standard wheelchair designs. The catalogs show that wheelchairs of practically any size and type are readily available as standard production items. In addition, numerous options and accessories are available that can modify overall size, such as headrests, extended footrests, roller bumpers, special handrims and handrim covers, reclining backs, etc.

Some common wheelchair types can be illustrated as follows from the Everest and Jennings catalog:

- Adult
- Narrow adult and junior
- Amputee
- Heavy-duty
- Lightweight
- Active duty lightweight
- Sportsman
- Pediatric
- Indoor
- Power drive

All manufacturers also provide custom design wheelchairs to meet special requirements.

Everest and Jennings is a large manufacturer of wheelchairs and their catalog of standard models lists twenty-five (25) overall (extended) widths ranging from 18.63 to 31.86 inches, and twenty-two (22) lengths (less footrests and front rigging) from 26.63 to 37.00 inches.

Meetings were held with the Everest and Jennings Company Sales Marketing Department to arrive at a correlation between the wheelchair sizes available and the user population. Sales and marketing data from the Everest and Jennings files was used to make the required correlation. Based on these records, a wheelchair dimensional model was developed that would accommodate approximately 85% of the wheelchair user population. See Figure 1.

For the purposes of this study, the most important dimension from the model is the 26.00-inch overall width. The 42.00-inch overall length dimension is important when considering maneuverability and positioning within the bus, but is more easily accommodated by modification of interior arrangements whereas the width can impact bus structure, underbody and design.

Wheelchair sizes vary considerably, as noted above, with the extreme dimensions and customized designs required by approximately 15% of the user population. With the data available from Everest and Jennings on percentage of sales by size, a determination was made that wheelchairs and wheelchair lift platforms that could accommodate 85% of the user population would offer an acceptable and significant improvement over existing equipment. Additional data used to make this determination was taken from *Designing For The Disabled, Second Edition.*[1]

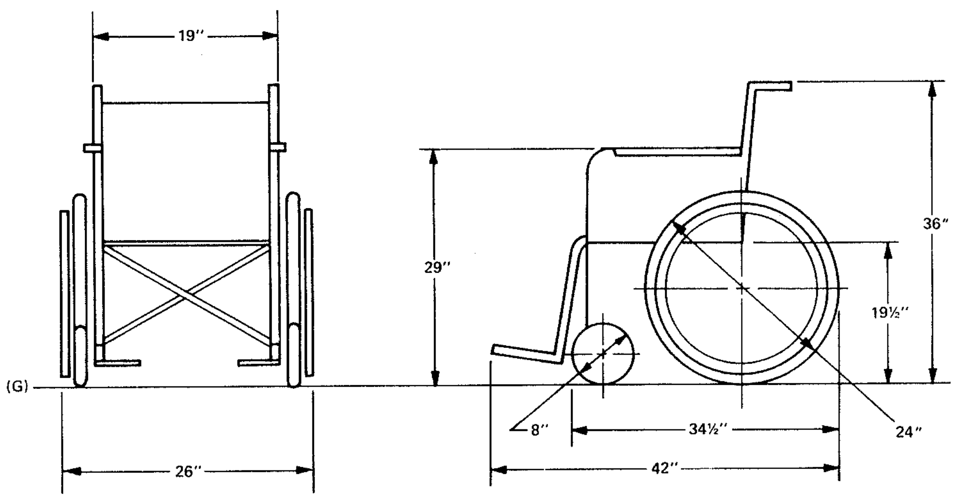

FIGURE 1. WHEELCHAIR PARAMETERS

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(1) Selwyn Goldsmith, *Designing For The Disabled,* McGraw-Hill, Second Edition.

5.0 BUS DOOR REQUIREMENTS

With some exceptions, transit operators use the bus front door for passenger ingress. The AM General standard 40-foot transit bus has a front entry door clear dimension of 30.0 inches. The clear dimension represents the maximum opening width attainable between the door leaves with the door in the fully opened position. (It is assumed at this point that no door grab bars are installed that would intrude into the 30.0-inch clear opening space.)

When the 30.0-inch door opening is compared to a 26.0-inch wheelchair width from the wheelchair model, it is clear that a 30.0-inch door is inadequate. These conditions provide a clearance of only 2.0 inches on each side of the wheelchair. Wheelchair widths are typically measured from the outside surface of each handrim and additional space outside the rims is required for the hands, heavy clothing and varying degrees of dexterity by the users.

Another important factor here is that wheelchair users need to feel confident they can safely and comfortably negotiate the wheelchair through the door opening. Literature on this subject suggests that one of the principal apprehensions of the handicapped is the possibility of attracting undue attention or of becoming a spectacle.(1) The handicapped generally tends to avoid situations perceived as potentially embarrassing or likely to cause any emotional stress.

In *Designing For The Disabled,*(2) Selwyn Goldsmith notes that no special empirical study has been made to determine space requirements for wheelchair users and that data derived for design standards was obtained by simply plotting diagramatically the movement of standard size wheelchairs. In discussing special tolerances for maneuvering, Goldsmith states that a minimum of 2.0 inches is required between the face of any obstruction and any protruding part of the wheelchair, but to permit comfortable maneuvering of wheelchairs an additional 4.0 inches should be allowed in all critical directions.

If 6.0 inches of clearance on each side is added to the 26.0-inch wheelchair width from the model, one is led to a recommended bus clear door opening width of 38.0 inches.

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(1) *Travel Barriers: Transportation Needs of the Handicapped,* Abt Associates, Cambridge, Mass., 1969.

(2) Selwyn Goldsmith, *Designing For The Disabled,* McGraw-Hill, Second Edition.

5.1 DOOR LOCATION

The front entry door was chosen as the optimum location for possible installation of a lift device on the standard 40-foot transit bus. This conclusion was based on a careful consideration of the following major factors:

- Anticipated problems arising from the normal bus operating mode.
- Safety aspects directly related to operation and use of a lift device.
- Psychological factors as they relate to the wheelchair user.

The three (3) major factors leading to a front entry door location are reviewed in the following sections.

5.2 NORMAL BUS OPERATING MODE

It is necessary for a bus to stand as parallel as possible to the curb line to ensure safe and proper deployment of a lift device. This statement holds true whether the device is located to the front, rear or mid-center of the bus.

In practice it was noted that, as often as not, the bus did not stand parallel to the curb for many reasons, such as:

- Approach to the loading zone obstructed (or partially obstructed) by illegally parked automobiles, standing commercial vehicles such as delivery vans, utility vehicles and work crews, other transit buses, and accumulations of ice and snow.
- Loss of sufficient maneuvering space during peak traffic hours.
- Deficient maneuvering tactics by the driver, such as overshooting or undershooting the loading point.

Under any of the above conditions the driver has a better opportunity to position the front door in relation to the curb line than either the rear door or a mid-center door. He is aided by both the ability to view the curb, or some portion of the loading point, through the lower glazing in the front door and by the close proximity of the front door to the driver and steering controls.

The factor leading to the front door choice is the angle of divergence created between the curb line and bus when the bus is standing in a non-parallel position. Any angle resulting from a non-parallel condition causes the bus side to curb distance to increase as one moves along the bus toward the rear.

The best set of conditions for deployment of a lift platform, then, is with the bus parallel to the curb line and standing within a prescribed distance from the curb.

Most lift platforms presently available are designed to lower the platform to either the curb height or to ground level. Some incorporate sensitive edges to stop operation if objects or obstructions are encountered.

If a platform is lowered to ground level, and if there is adequate unobstructed space, no problem would be expected. If, however, the platform is to be lowered atop a 6.0 or 8.0-inch curb, both bus to curb alignment and bus to curb distance become factors. To illustrate, assume a bus is standing so that the door to curb distance is 48.0 inches, and further assume a fully extended platform length of 48.0 inches. This condition does not ensure firm support of the leading edge of the platform. If we also consider the possibility of the bus not standing in a parallel position, the forward corner of the platform could be firmly supported while the rearward has little or no support.

Either condition would cause the platform to wobble or twist to some degree when a wheelchair is rolled on, leading to a feeling of instability by the wheelchair passenger. Although there is no way to measure the long term impact on the equipment, one could logically conclude that repeated use of the platform in this manner could adversely affect life cycle durability due to the torsional stresses applied.

It becomes clear, then, that both parallelism and door to curb distance can be best controlled and optimized if the lift is located at the front door position.

Another consideration, often encountered, is the instance where the driver positions the bus with good curb alignment and unobstructed clearance at the front door, but finds the rear door partially obstructed by utility poles, benches, shelters, refuse containers, trees or shrubs, etc. This condition normally would not negate use of the rear exit door by non-handicapped persons that have the ability to maneuver around the obstruction. However, deployment of a lift platform and assurance of required maneuvering space for a wheelchair passenger could be difficult or even impossible to accomplish.

The same problem would exist, at least to some degree, with a mid-center door location.

5.3 SAFETY ASPECTS

Consideration of problems related to operational safety also support a front entry door selection as the best platform lift location.

Setting aside for the moment any questions concerning safety inherent in the basic platform lift design, it seems apparent that safety to the wheelchair user can be optimized if the bus driver is in a position to visually monitor the lift operation throughout the operating cycle.

The driver has complete control of the lift through the various switches at his command and is in a position to observe the loading passenger and the various stages of lift deployment and retraction. The capability of a bus driver to visually monitor the lift and passenger, to stop and restart the lift cycle, to react instantly and override the cycling sequence, all add significantly to overall operational safety.

Figure 2 illustrates the ease with which a driver can monitor and control the complete lift operation with the front door lift installation.

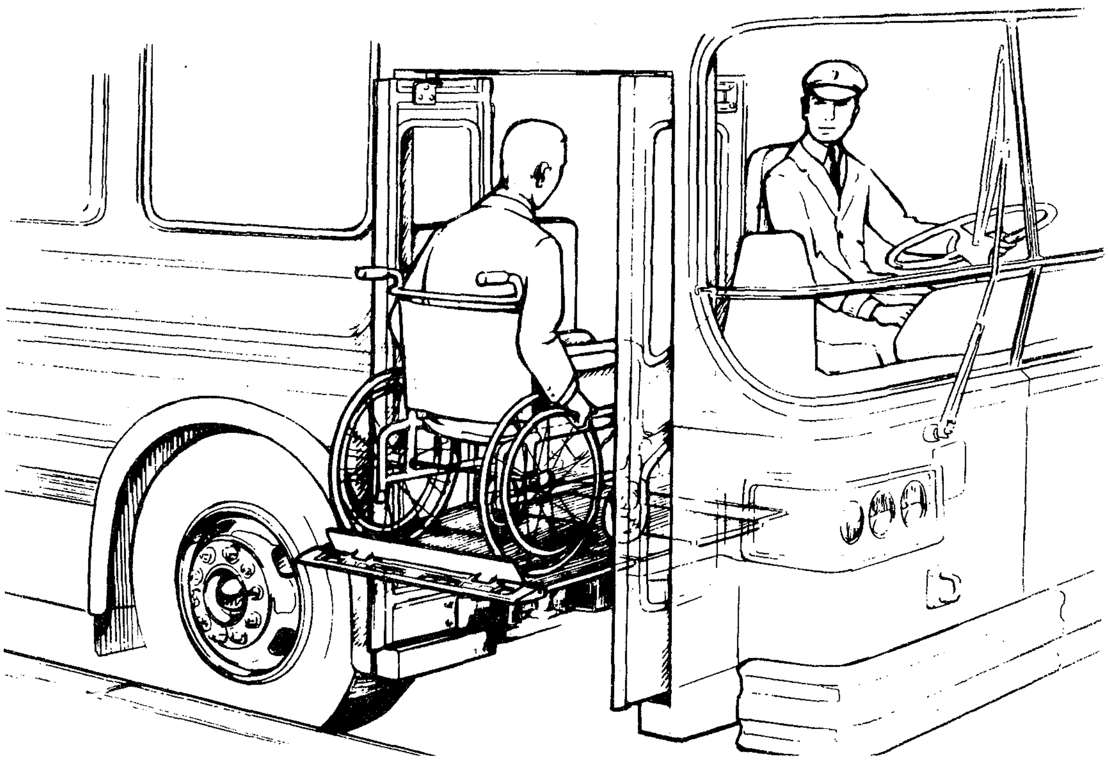

FIGURE 2. DRIVER'S VISIBILITY OF LIFT OPERATION.

5.4 PSYCHOLOGICAL FACTORS

Any detailed discussion of all the complex psychological factors at work when considering public transportation of the transportation handicapped is obviously beyond the scope of this study. In any event, numerous studies and papers exist on the subject as indicated by the bibliography included at the end of this report.

Some psychological factors, however, have a bearing on the selection of an optimum platform lift location on the bus. For example, numerous public pronouncements attributed to spokesmen for organizations representing handicapped and elderly persons have expressed annoyance at being considered and/or treated in a manner different from the non-handicapped. Their feelings can be summarized as a desire to "use the same entry door as everyone else."

This attitude was demonstrated quite dramatically at the Annual Conference on Transportation for the Elderly and Handicapped held at Michigan State University in July of 1976. During a presentation by a bus manufacturer to an audience of approximately thirty (30) handicapped attendees, several features of their new advance design bus were mentioned as improvements to handicapped ridership, among them the availability of a wheelchair platform lift at the rear door.

Strong objections were raised by the audience to the rear door location. Members of the audience pointed out the difficulties encountered when the bus is not standing parallel to the curb and problems related to ineffective surveillance by the driver of a rearward located lift device.

The strongest objections, however, were directed toward any suggestion of second class status or uniqueness associated with being compelled to use other than the normal entrance door. One member commented heatedly,

> "Our black brothers started in the rear – but we don't plan to start any place other than in the front, and we want the same service you would give to anyone else".

This statement, expressed with some emotion, appears to represent the general attitude of the handicapped attending the conference. It may be inappropriate to examine such an attitude as a psychological factor, for an argument could be made that it is more social in nature than psychological. It is also possible that it is political, to some degree, in that it may actually be more a demonstration of unity among the handicapped in their effort to arouse attention to their demands for improved access to public transit.

It is interesting to note that some handicapped spokesmen see no contradiction between their aim for equal and non-discriminatory access to public transportation, and the fact that impaired mobility necessitates the use of a wheelchair.

6.0 WHEELCHAIR RETENTION

It is generally assumed that some type of wheelchair retention device, or system, will be necessary if wheelchair-bound passengers are transported on urban transit buses. The purpose is to ensure the safety of the wheelchair passenger and to prevent a loose wheelchair from becoming a projectile inside the bus in the event of a sudden deceleration or an accident.

Proposals to add wheelchair lifts and transport wheelchair passengers on standard 40-foot buses operating on regular schedules and routes are a relatively recent development. As a result, there is a minimum of design and production hardware for retention devices currently on the market. Those that are available usually are comprised of some type of wheelchair restraint device plus a combination of belts and straps.

Several very difficult, and as yet unresolved, questions arise in any discussion of this subject. A typical one is how to accommodate a wheelchair passenger that does not have the manual dexterity required to manipulate the various devices. Another complex issue is what means can or should be taken to ensure use of the devices by wheelchair passengers. Many persons in wheelchairs are very capable of holding on to vertical stanchions or other passenger assists, and with the wheelchair brakes set, are at least as restrained as non-handicapped standees to sudden vehicle movement.(1)

Determination of whether or not a wheelchair retention system is adequate is impossible without establishing certain ground rules. For example, if wheelchair ridership is limited to those who are completely mobile under their own power and have full use of arms and hands for manipulation of the devices, it appears probable that devices to effectively secure the chair and passenger in a fixed position can be readily available. If the degree of disability is broadened to include upper extremity amputations or lack of upper body motor control, such as congenital muscular disfunction or partial paralysis, a new and extremely complex set of problems is introduced.

A detailed description of difficulties encountered by the more severely handicapped is not necessary here, but it is important to note that proper and prescribed positioning of the wheelchair, plus virtually unimpaired use of the upper body extremities, would be required to effectively and safely operate wheelchair retention systems known today.

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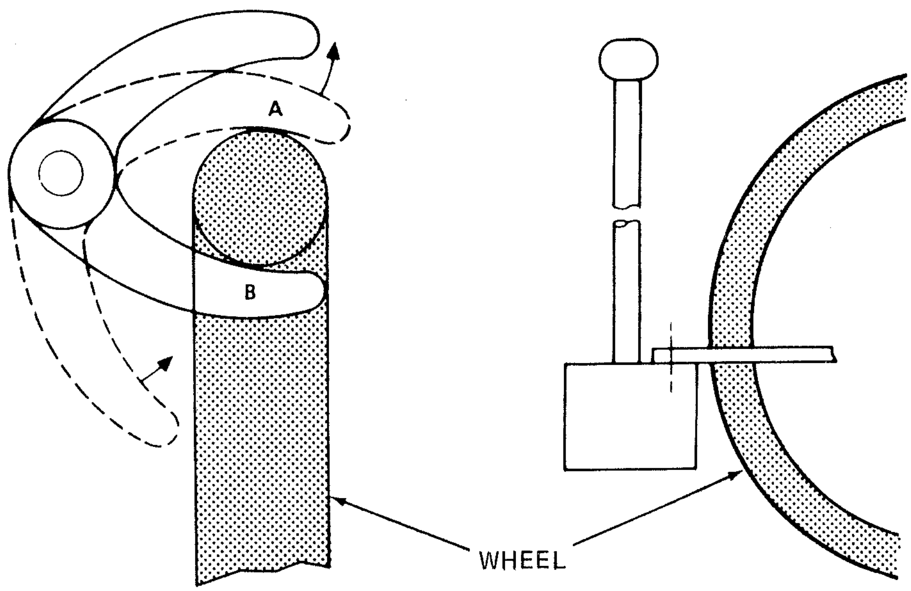
(1) U.S. Department of Commerce, *Transportation Problems of the Transportation Handicapped,* Vol. 4, (1976).

6.1 Wheelchair Retention Systems

Three different transit operating authorities are currently purchasing 40-foot transit buses from AM General with a lift platform. The retention devices being provided vary in detail design and application to some degree, but all will require either considerable upper body dexterity by the wheelchair passenger or the presence of an attendant to ensure proper use of the systems.

The systems incorporate both a mechanical wheel lock device and a set of retractable lap and shoulder belts. A typical mechanical wheel lock is shown in Figure 3.



POSITION A – OPEN
POSITION B – CLOSED

FIGURE 3. TYPICAL WHEEL LOCK.

The lock is a spring-loaded jaw arrangement designed to close around one wheel of the chair at approximately axle height. With the jaws open, a wheel is aligned with the jaw and backed into place. Pressure from the back edge of the wheel pushes a trigger causing the jaws to snap shut around the wheel. Some devices have only a single movable jaw and others use two movable jaws that close together. In either case, it is necessary for the locking jaw(s) to extend around the wheel and through the spokes to fully close.

The devices are opened, or unlocked, by manually exerting a force of approximately 5 to 10 pounds on a release handle. The jaws then remain in a cocked open position until a wheel is again inserted against the trigger mechanism. Release handles can be positioned at almost any angle from vertical to horizontal.

Wheel retention devices of the locking jaw type are designed to be mounted on a vertical plane, usually the bus sidewall or on the bottom of a fold-up seat. Only one device for each wheelchair is used due to variable wheelchair widths and axle lengths.

There are several functional problems with this type of device that would appear to outweigh the positive factors of design simplicity, low cost and versatility of installation. The most obvious are:

- Necessity to align one wheel with the device and maneuver backward into the jaws.
- Necessity to reach toward the rear to grasp the release handle and unlock the device.
- Possibility of damage to wheel spokes and rims, and high probability that decorative metal finishes will be scratched and marred by the metal jaws.
- Necessity to exert sufficient force on the release handle to unlock the device.
- No capability to restrain both wheels due to variations in wheel width.
- When the device is mounted to the bottom of a fold-up seat, it becomes a hazard to the feet and ankles of passengers sitting in the adjacent rear seat.

Another, but more complex, approach to wheelchair retention that has been studied uses a system of underfloor cylinders to raise wheel chocks into position when a push-button signal or switch is activated. A conceptual system is illustrated in Figure 5.

This concept would require a lesser degree of dexterity from the user in that only an ability to activate a push-button switch and properly position the wheelchair is necessary.

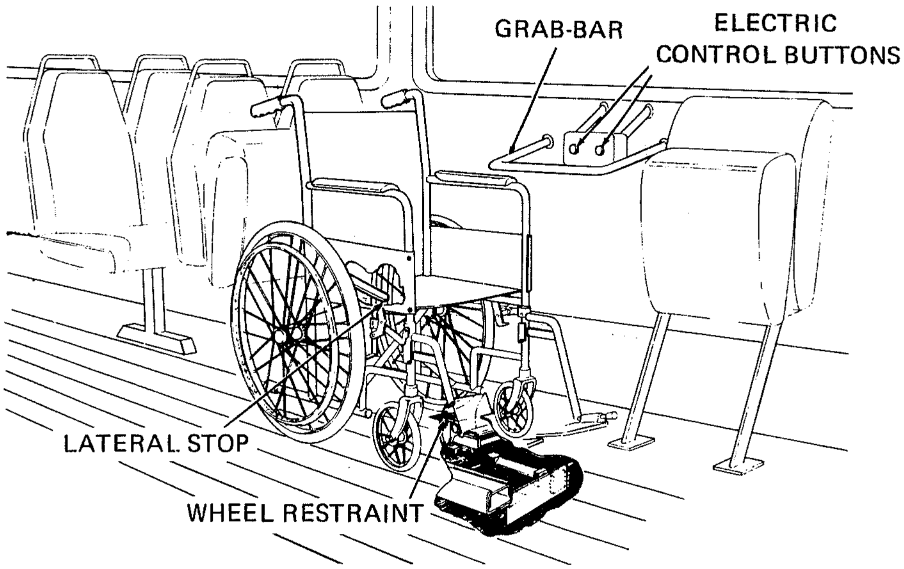


FIGURE 4. WHEELCHAIR RESTRAINT CONCEPT.

Lateral movement of the chair is controlled, to some extent, by a lateral stop mounted to the bottom frame of a fold-up seat. The stop is intended to extend along the inboard side of a wheel and is covered by the fold-up seat bottom when not in use.

The wheel restraint (or chock) can be semicylindrical in shape or a flat plate, either of which would retract into the floor when not in use. A system of cylinders and linkages raises or retracts the wheel restraint when the on-off switch is activated. The cylinder(s) could theoretically be powered by hydraulics, air or from the bus electrical system.

An advantage of such a system over the mechanical wheel lock discussed earlier is that less dexterity and ability to reach is required. Disadvantages appear to be:

- Modification of bus floor and underbody structure required to mount and house the mechanism.
- High cost for components and connections to power source.
- Added maintenance tasks and costs for the transit operator, including adjustments and adjustment checks of the cylinder(s) and linkage(s).
- Necessity to protect underfloor mechanism from contamination and still provide water drainage when bus interiors are hosed down during cleaning operations.

6.2 Passenger Restraints

For optimum safety to both the wheelchair and other passengers, consideration must also be given to methods and devices designed to secure an occupant in the wheelchair. Such devices currently available and being offered to transit operators consist of a combination lap and shoulder belt as shown in Figure 5.

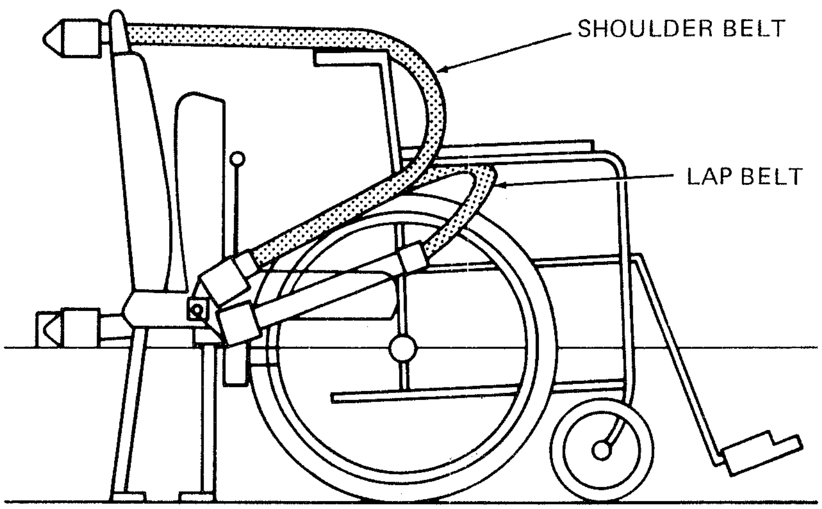


FIGURE 5. PASSIVE BELT RESTRAINT.

Wheelchair lap belts are available as an option from all wheelchair manufacturers. While they are helpful to the occupant during normal maneuvering in the chair, they must be considered inadequate as the only available restraint for bus travel since they would provide no restraint of the upper body.

The passive belt system, however, appears to provide the best all-around protection. The lap belt secures both the wheelchair and occupant while the shoulder belt provides necessary stability for the upper body. Both belts are retractable and thus become only a minimum obstruction to passengers when not in use.

Advantages are low cost, versatility and simple installation. The major disadvantage is the high degree of occupant dexterity and mobility required to reach, adjust and lock the belts.

6.3 Application

It is obvious that neither wheelchair retentions or occupant belts alone offer the degree of protection desired. Without the belts, and in an emergency stop or front end impact, there is a possibility that the wheelchair, its occupant, or both, could be catapulated forward if only the wheels are held in place. On the other hand, a possibility exists that a chair, its occupant, or both, could be pulled under and thrown forward if only the belts are used. It must also be remembered that a loose wheelchair, whether occupied or not, becomes a hazard to all passengers in an accident or sudden stop.

The best protection is provided when the lap and shoulder belt is used in combination with a wheel lock. Buses currently in production that will be delivered with wheelchair lift platforms incorporate the combination belt and wheel lock system.

7.0 INTERIOR ARRANGEMENTS AND MANEUVERING

The requirements of the contract are for at least two interior seating arrangements. The first would have facilities for two (2) wheelchairs, while the second would have a near equal number of wheelchairs and seated passengers. Inherent in the investigation of interior arrangement, besides the in-transit position of the wheelchairs, are several other factors including:

- Space requirements for wheelchair entry and accessibility to fare box.
- Maneuvering of the wheelchair passengers to specified locations.
- Additional traffic flow, both of wheelchairs and non-handicapped passengers, during ingress and egress.

These problems must be addressed and resolved regardless of interior arrangement. The specific problems related to each of the required plans are discussed individually later in this section.

Layouts and floor plan studies show that problems encountered in a 96.0-inch wide coach are significant. Maneuvering during entry is restrictive at best. Cross vehicle dimensions with passengers seated on front longitudinal seats is insufficient for wheelchair passage, and two wheelchairs opposite each other in travel position results in unsatisfactory aisle clearances. Figures 6 and 7 showing views of entry area support these conclusions. With the input from these studies it was determined that the interior conditions of a 96.0-inch bus makes the wheelchair lift installation impractical. Therefore, all additional data, dimensions, and conclusions in this section refer to interior arrangements of a 102.0-inch bus.

7.1 Entry

After the wheelchair passenger has been lifted to the bus floor level, entry to the vehicle proper must be negotiated. Factors considered and studied in this area were (1) floor space between lift platform and driver's platform, (2) convenience to fare box, and (3) passage past longitudinal front seats mounted atop the wheelhousings.

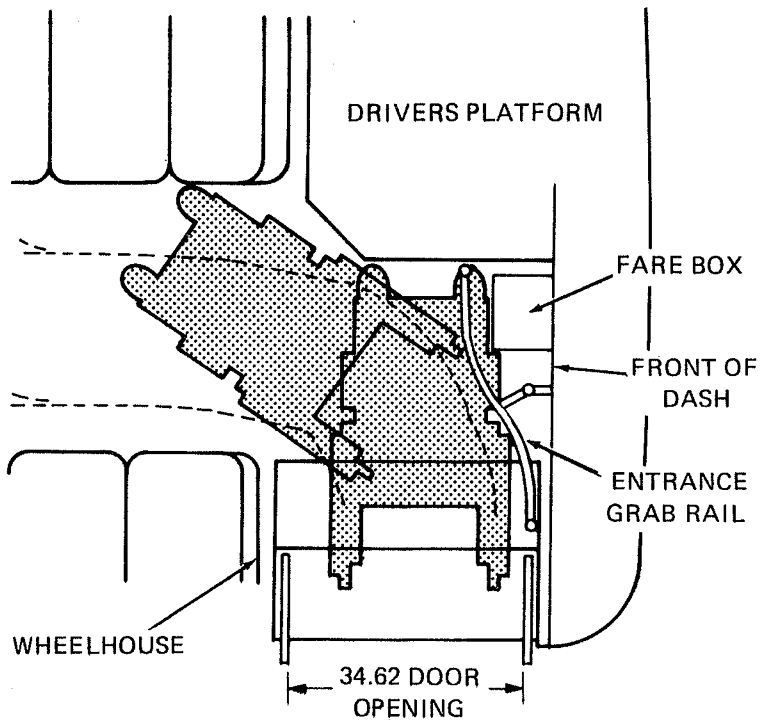


FIGURE 6. 96-INCH BUS ENTRY AREA.

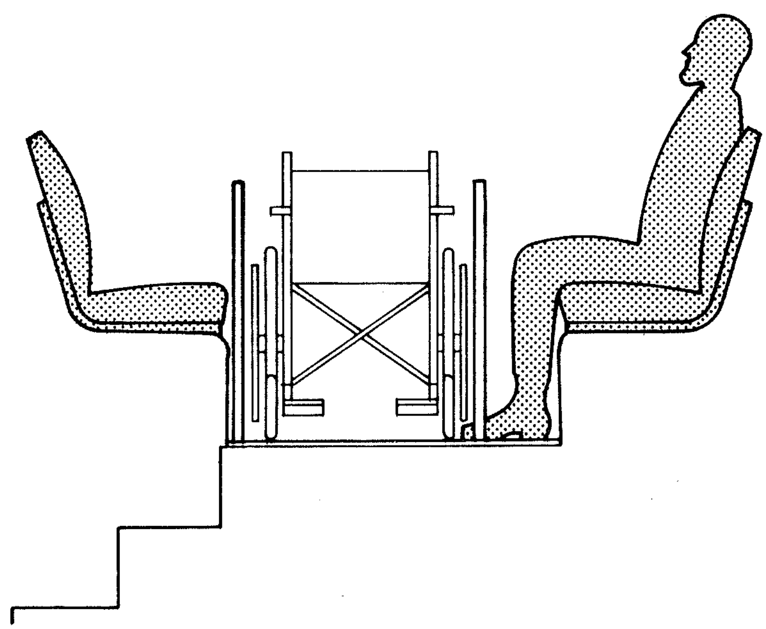


FIGURE 7. 96-INCH BUS AISLE VIEW – BETWEEN WHEELHOUSINGS.

Entrance geometry to the bus was plotted and analyzed using data from various sources, including *Designing for the Disabled* (section 23, Circulation Spaces: Wheelchairs), and the physical dimensions of the AM General 102.0-inch bus. The relative positions of the driver's platform, fare box, entrance grab rail and modesty panel stanchions were used in the studies. Access to the fare box and the main aisle area is within the prescribed limits and is reasonably convenient for the wheelchair passengers.

One point is worth discussion here: When the wheelchair passenger has entered the bus and is clear of the lift platform, the driver can start to return the platform to the normal step position. However, while there is a safety gate on the lift platform, no such provisions currently exist on the bus floor itself. If the platform is lowered while the passenger is still in the front area depositing his fare, safe space for further maneuvering becomes limited. From a safety standpoint, therefore, the driver should leave the platform in the raised position until the wheelchair passenger has entered the bus proper past the normal standee line. This will be a time penalty. If studies or actual revenue service show the resulting schedule impact is unacceptable, some secondary gate device must be considered.

As mentioned earlier, space for maneuvering past the front longitudinal seats is minimal but acceptable. Additional concern arises from the fact that the front seats will be marked as priority seating for elderly and handicapped. Normal care exercised by the wheelchair passenger while negotiating this area should prevent any problems. See Figure 7A.

7.2 In-Transit Position

The movements required to reach the in-transit position pose no unusual problems. The relationship of the wheelchair to the vehicle sidewall and other adjacent components is basically the same for the two wheelchair and the multiple wheelchair arrangements. The actual plan view layouts of these arrangements are shown and discussed in Sections 7.3 and 7.4.

Once the wheelchairs are at the in-transit positions, they are restrained by external means. Wheelchair retention is covered in Section 4.0 and discussion here concerns the conditions and effects of the position itself.

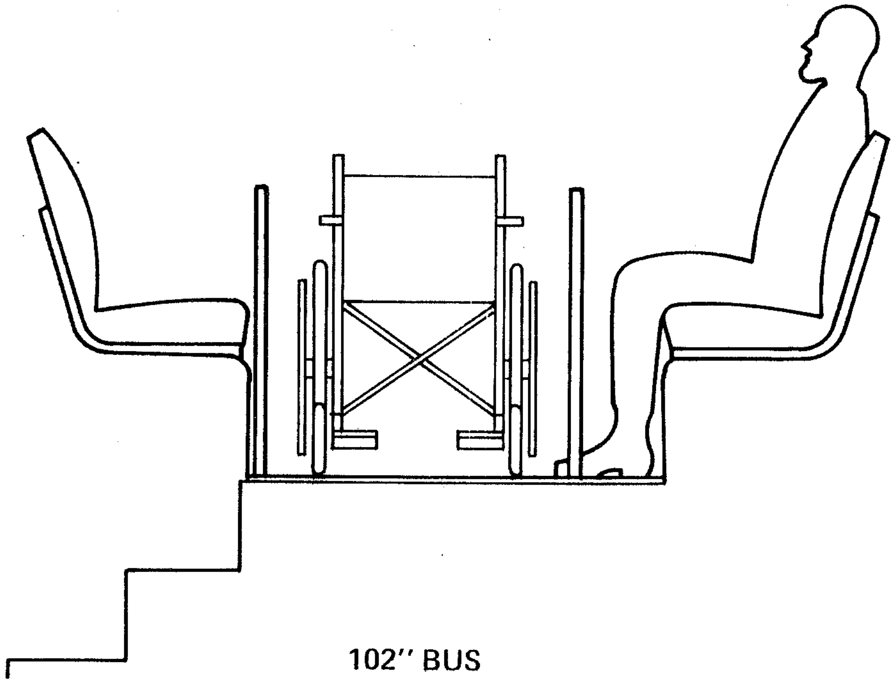


FIGURE 7A. WHEELCHAIR CLEARANCE.

Figures 8 and 9 show a plan view and cross section view of two (2) wheelchairs located opposite each other in travel positions. All current transit vehicles have heat ducts at the sidewall and floor. In general, these extend about 6.0 inches from the sidewall. With 2 to 3 inches of clearance between the wheelchair and the duct, a very acceptable 9-inch clearance to the sidewall above the duct results. The fore and aft dimension allotted to each wheelchair was selected after the geometry of turning and "parking" was defined.

The front facing position was determined to be the most satisfactory, not only from the aspect of space utilization and traffic flow, but also from the psychological affect a "different" position might have on the wheelchair passenger.

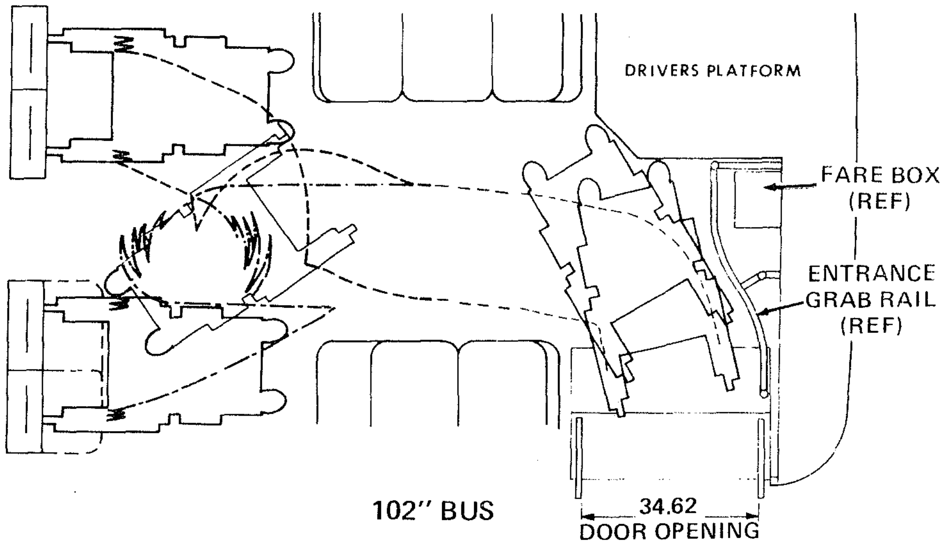


FIGURE 8. WHEELCHAIRS IN TRAVEL POSITION – PLAN VIEW.

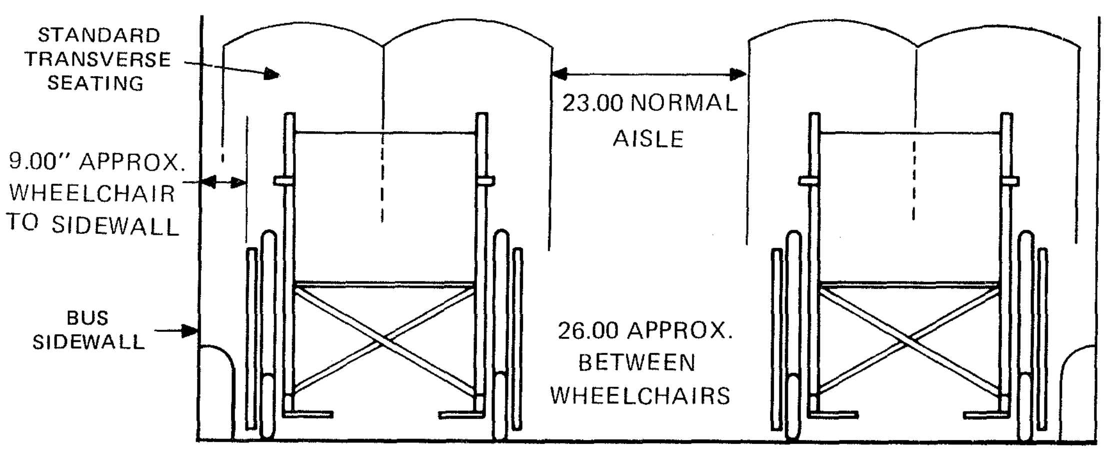


FIGURE 9. WHEELCHAIRS IN TRAVEL POSITIONS – FRONT VIEW.

7.3. Two Wheelchair Interior Arrangement

As discussed previously, opposite forward facing locations against the right and left sidewalls have been selected for in-transit positions. Immediately behind the entrance and driver area, longitudinal seats are used. This is dictated by the wheelhousings required for the front wheels and suspension. The first location available for wheelchairs near the entrance would be directly aft of these longitudinal seats. This arrangement, with pertinent dimensions, is shown in Figure 10. The arrangement results in the loss of ten (10) seated passengers when compared to the normal seating plan. See Figure 10A. However, when the wheelchair facilities are not in use, jump seats can recover six (6) of these.

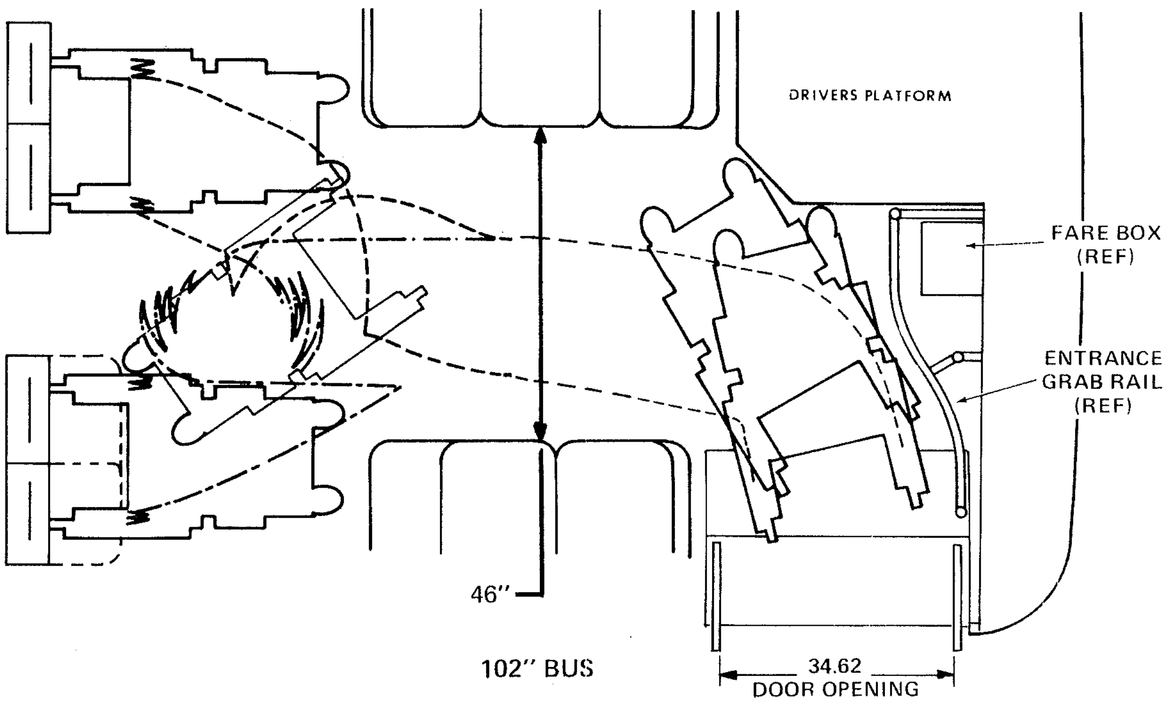


FIGURE 10. ENTRY AREA CLEARANCES.

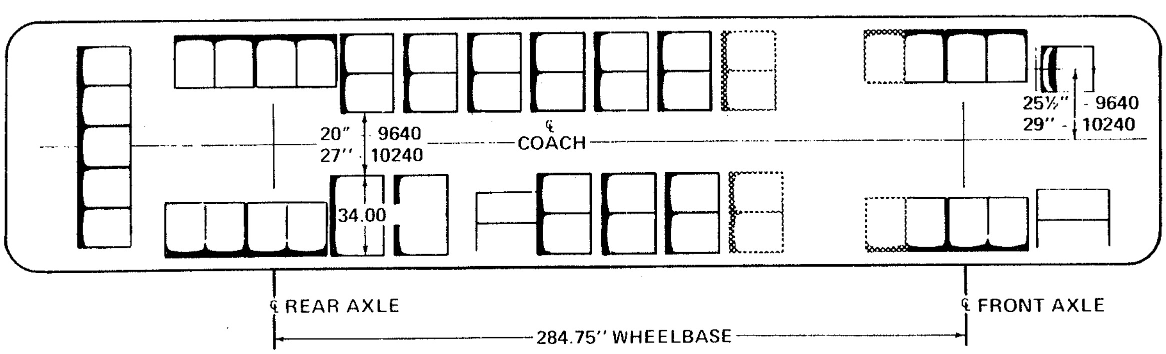


FIGURE 10A. SEATING ARRANGEMENT.

Either the left or the right position can be selected by the first wheelchair passenger aboard. The second uses the remaining location and either may leave first. No effect on non-handicapped passenger traffic flow results after the wheelchairs are in position and either wheelchair passenger can exit without effect on the other.

7.4 Multiple Wheelchair Interior Arrangement

Several approaches were studied to establish the floor plan which facilitated a near equal amount of wheelchairs and seated passengers.

Some of the factors used to determine the most practical floor plan included:

- In-transit position of the wheelchair passengers. It was felt that any position other than forward facing would be unsatisfactory for the wheelchair passenger. Although a normal seating arrangement provides some longitudinal seating, this is necessitated by the wheelhousings, and transverse seats are considered normal, and should also be "standard" for the wheelchair passengers.

- Loading and Unloading of Passengers
  Both wheelchair and non-handicapped passenger boarding and exiting were considered in evaluation of the multiple wheelchair floor plans. Some plans dictated a "last on – first off" traffic flow. For everyday normal schedule operation, this was deemed impractical. This type of arrangement might be acceptable for special service vehicles where all passengers board and exit at the same time and place.

- Maximum Use of Floor Space
  The plan selected shows eight (8) wheelchairs and nineteen (19) seated passengers. Even though this is more than double the number of seated passengers to wheelchairs, (vs. requirement of near equal seating) additional wheelchair provisions would be impractical if not impossible. The nineteen (19) seated passengers are in the four longitudinal seats over the wheelhousings and the rear lounge seat; floor space for wheelchairs is not available in these areas.

Figure 11 shows the final arrangement derived from the studies. This is considered the most practical and most feasible floor plan for the multiple wheelchair requirement.

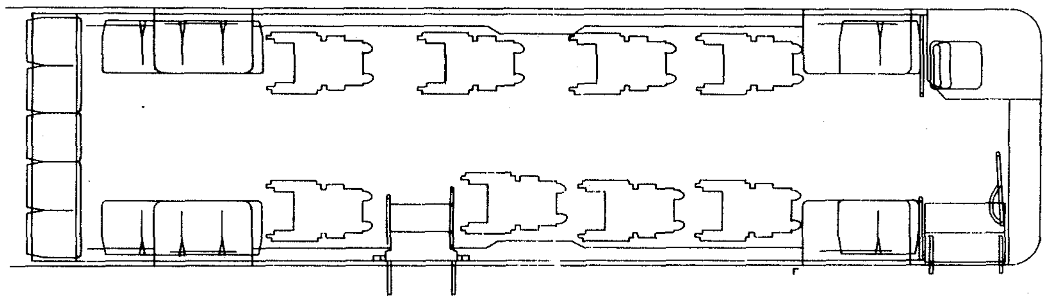


FIGURE 11. MULTIPLE WHEELCHAIR ARRANGEMENT.

As this picture indicates, any one wheelchair can board and exit without effecting the other wheelchair persons.

8.0 LIFT DEVICE CONCEPTS

Article 1, Statement of Work, paragraph 2.1, Task 1 states, "develop several tentative design approaches for incorporating a wheelchair lift device." In lieu of developing tentative designs, a survey was made of the existing lift designs available and under development throughout the industry. With proper evaluation and study, the research and development efforts of all the various manufacturers can be used to develop the most practical concept for application in a standard transit vehicle.

8.1 Survey of Lift Devices

All during the time this study was being compiled, information was gathered on many lift devices and design concepts. A total of eighteen (18) different units are encompassed in our data package. Nine (9) of these were reviewed on site personally by AM General. The information on the remaining eight (8) was acquired from literature and phone communications. A list of all the companies is included at the conclusion of this report.

Of all the devices reviewed, only five are applicable to a transit bus within the scope of this study. To satisfy the requirements, the concept must have *dual* capacity of normal passenger usage and wheelchair lift.

The remaining lift devices are all single purpose units, generally for installation in special service vehicles. These lifts are excellent for their intended purpose, but would require a third door on the transit bus. One comment is offered here on this type lift: because they are designed for one specific operation, the components can be tailored to better perform the functions of wheelchair transportation. They can cover a wide range of wheelchair dimensions and include room on the lift platform for an attendant, for example. However, as noted earlier, they are not compatible to the intent of this study, and all further comments and data in this section will be limited to the five dual purpose units.

8.2 Discussion of Lift Devices

Five sources were found to have lift devices applicable to transit bus entrance doors. These are listed here:

Environmental Equipment Corp. (San Leandro, California)
Para Industries (Calgary, Alberta, Canada)
Mr. Ed Hall (Seattle, Washington)
Sheller-Glode Corp. (Toledo, Ohio)
Trans. Design & Technology (San Diego, California)

However, Environmental Equipment Corp. and Para Industries were in the conceptual design stage only and, while Mr. Hall had a working prototype, production units were not available from these sources. Sheller-Globe demonstrated their unit installed in one of their buses and Transportation Design has units in production. Some features of each of these five lifts are outlined briefly here:

The E.E.C. concept used a diagonal platform under the standard stairwell, which when activated came out to pick up the wheelchair. The steps unfolded in order to provide a secondary platform between the lift and the bus floor for ingress and egress. This locates the lift platform completely outside the bus, requiring both sides and a rear gate to safeguard the wheelchair from falling off.

The Para Industries' unit used both steps which articulate into the lift platform. The platform lowers and raises as a unit from curb or ground level to the bus floor level. After the wheelchair passenger has entered the bus proper, the platform returns to the "STOW" position and becomes the normal entrance stepwell. Hydraulic cylinders are used to supply the power for the operation.

In the lift concept developed by Mr. Hall, the first step is the platform and extends under the second step toward the center of the vehicle. During operation as a lift, the second step and riser remain in position and are not used, nor do they interfere with the lift geometry. Hydraulic pressure is supplied by the engine power steering pump and powers a hydraulic cylinder and chain system.

The Sheller-Globe concept uses the entire stepwell for the lift platform. In this approach the second step folds to one side of the lift during deployment and operation. The horizontal and vertical movements of the platform are powered by hydraulic cylinders and a "Duff Norton" actuator and screw jack. The operation of the unit is completely electro-mechanical.

As previously noted, the Transportation Design unit is presently in production. In this concept, both steps are deployed to the platform configuration, then raised and lowered to complete the lift operation. The lift is hydraulically driven from either an integral electrical motor and pump, or the engine driven power steering pump. One set of cylinders move the components from the step position to the platform position, and a second set of cylinders raises and lowers the platform. The loading edge of the lift at the ramp has a pressure sensitive tapeswitch which halts the operation upon contact. This contact can be either the roadway, the curb, or the boarding passenger or other objects.

In the event of a system failure, making normal operation impossible, a manually operated hand pump can be employed to complete the cycle and return the lift device to the "STOW" position as steps. This feature must be considered mandatory for any lift design, as the interlocks will render the bus inoperable in any position of lift deployment.

8.3 Lift Power System Options

In evaluating the options for the lift motivation force, several paramenters were developed. Some are mandatory, while others are desirable or recommended, and include:

- Mechanical linkage of some design is required to satisfy the geometry of lift travel;
- A power source must be added to properly operate the lift;
- Reliability should be a prime factor of system selection;
- Noise, smoothness of motion and other characteristics should be added considerations; and
- Effect on standard vehicle systems also must enter into the determination of the most practical power system.

The cylinders used in the lift operation can be either hydraulic or pneumatic. The source of pressure for each of these has three options; electrical, pneumatic and hydraulic. In analyzing each of these for application in a standard transit bus, the following data has been compiled:

a. An electric motor for driving, either an air pump or a hydraulic pump is feasible, but not necessarily a practical solution. It has been estimated that the power requirement to cycle the lift device will be somewhere between 60 and 120 amps. This will introduce problems if most of the electrical components are operating, especially the air conditioning, lighting or both.

b. Using the existing air system for pneumatic cylinders again can be done. However, the problems here include additional reservoir capacity requirements and the larger cylinders required would create greater packaging problems. Using the existing air system to drive a hydraulic pump also requires additional air tanks and is not considered practical.

c. The engine driven power steering pump can supply the required hydraulic pressure. This can be utilized economically even if the vehicle does not have a power steering system. Because the lift will only operate while the vehicle is stopped, at no time will the dual requirements of the steering and lift systems be imposed on the pump.

The power system which appears to best fulfill the design goals, and is therefore recommended, is a mechanical/hydraulic over hydraulic. One additional factor concerns the manual return of a failed system. An auxiliary hand pump can easily be incorporated into this system to provide the means to return the lift to the stow position.

3.4 Lift Concept Summary

In reviewing the data and discussion within this section, the following information is summarized:

- Although the majority of current lift devices are designed for use in special vehicles, enough different concepts exist for transit bus application to make a logical determination of the best type lift device.

With all available information, the recommended lift device will include the following features:

- Front stepwell configuration to be deployed into the lift platform configuration.
- Hydraulic cylinder operation with pressure supplied by the engine driven power steering pump.
- Proper controls with interlocks to provide safe, dependable performance.

The description of the lift device finally determined to be the most suitable for transit bus application is contained in Section 9. This section includes the detailed information on the lift operation as an integral part of the total system recommendations.

9.0 RECOMMENDED DESIGN CONCEPT

The recommended design discussed in this section is based on the premise that wheelchair-bound passengers are able to propel themselves in a chair and have the dexterity to manipulate restraining devices. This obviously excludes the more severely handicapped and those that must be accompanied by an attendant. The exclusion seems appropriate, however, when assessing the introduction of lifts, restraints and transport of wheelchair passengers on standard buses operating on regularly scheduled routes. Given the realities of current bus design and the economics of public transit operations, no lift device and restraint system can be all things to all people.

9.1 Restraints

A combination of wheelchair restraint and belts appears to be the most satisfactory restraint system for use on standard buses.

The wheelchair restraint should be of the mechanical jaw type since it is relatively inexpensive, requires no major changes to the bus as would the cylinder powered underfloor type, and can be easily relocated or removed when needed.

The system should also include a set of belts that will restrain both the upper and lower body. Current belt systems could be improved by designing them to retract into a rigid sleeve. The sleeve could extend forward on either side of the wheelchair to eliminate the need to reach toward the rear to grasp the buckle and insert. The sleeve should be mounted to the seat frames or bus wall on a rotating pin that would permit vertical adjustment in the extended position and also permit the sleeves to be rotated either upward or downward out of the way when not in use.

9.2 Wheelchair Positions

Maneuvering and positioning studies discussed in Section 7.0 show that only a 102-inch wide bus will provide the required space for adequate wheelchair maneuvering in the bus.

Analysis of possible seating arrangements in Section 7 also suggest that the two-wheelchair, forward facing floor plan offers the most practical mix of wheelchair and non-handicapped passengers. (Refer to Figure 8.)

The 102-inch bus with accommodations for two (2) wheelchairs is recommended as the most practical configuration for buses used in regularly scheduled transit service.

9.3 Platform Lift

The recommended lift device is hydraulically driven and incorporates a folding platform design that assumes the configuration of a standard stepwell in the stowed position. A general arrangement of the installation is shown in Figure 12.

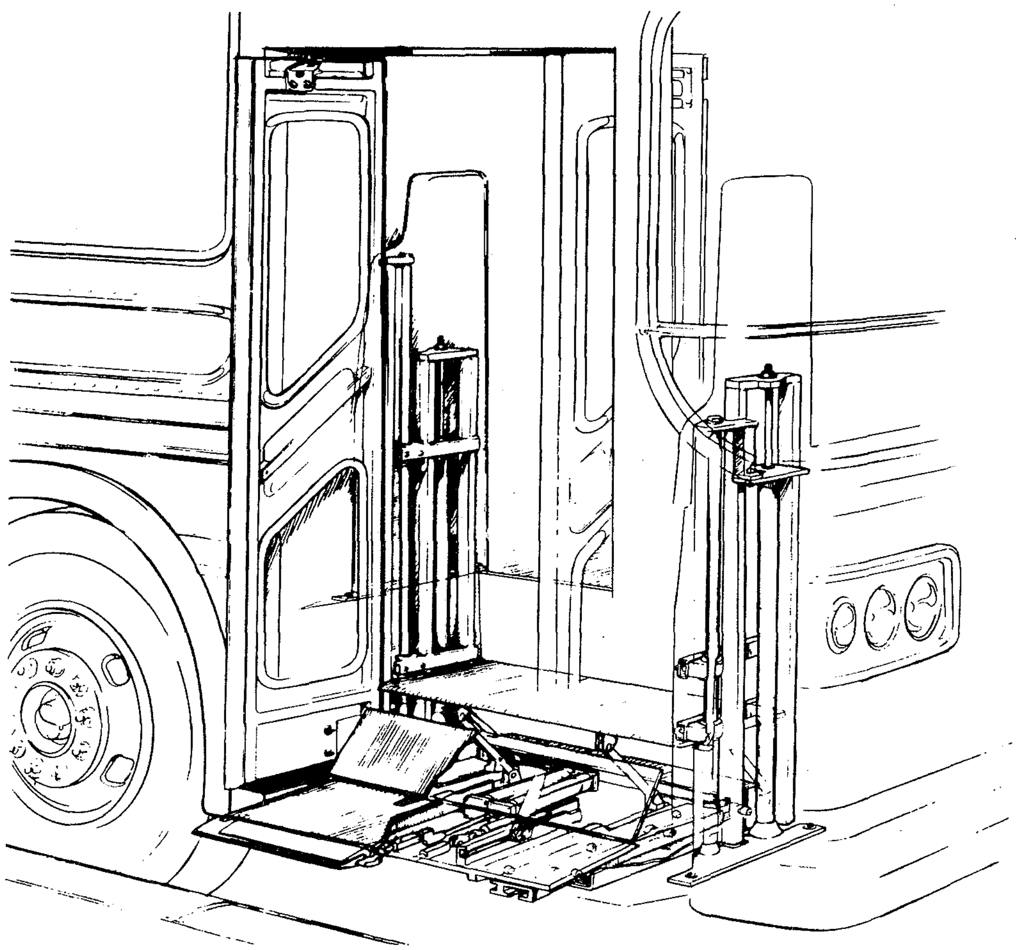


FIGURE 12. LIFT PLATFORM INSTALLATION.

Total weight of the lift device is a major factor in the design. Added weight not only has a negative effect on fuel consumption of the bus but an excessively heavy design requires heavier and more expensive components to operate the system. In addition, the weight of the lift device could pose structural problems to the bus.

The proposed design incorporates aluminum parts where possible to minimize weight. Cast aluminum is used for the steps which are supported by heavy-duty aluminum articulating arms, this design eliminates the need for hinges on the platform sections. Hinges are not recommended because they are susceptible to corrosion, contamination, binding and failure due to torsional stresses. Estimated weight for the proposed design is approximately 375 pounds.

The articulating arms pivot on sixteen (16) permanently lubricated bronze bushings. Support for the platform in the extended position consists of eighteen (18) Camrol roller bearings sliding in a cast steel track. Bearings are packed in lubricant and sealed for protection.

Hydraulic cylinders are operated by using either the power from an existing power steering pump or adding a pump to the bus. A power steering pump, whether or not the bus has power steering, is sufficient to operate the lift platform device. If the bus has power steering, only a driver operated conversion valve is needed to divert the hydraulic power between steering and lift mechanism as needed. The conversion valve can be connected to the lift switch so that hydraulic power is diverted automatically to the lift and back to steering as the lift mechanism is cycled from start of deployment to stowed position.

A total of five (5) hydraulic cylinders are used. A dual set of 2.0-inch diameter cylinders, arranged in-line, operate the folding steps and extend or retract the outermost platform section. A small 1.5-inch cylinder raises and lowers the gate on the forward edge of the platform. The gate is raised into position before the platform is lifted as a barrier to prevent a wheelchair from rolling backward off the platform.

A 2.0-inch diameter cylinder is mounted vertically on each side of the door opening to provide vertical platform movement. The cylinders have a maximum lift load capacity of 3,000 lbs. However, the complete system has a recommended load capacity of 1,000 lbs. This offers a satisfactory safety factor based on an estimated 350 lbs. for a wheelchair and large occupant.

The underfloor mechanism is protected from contamination, road dirt and slush by baffles and covers. In the stowed position, the safety gate folds downward to form a protective cover for the platform edge and ends of the roller tracks.

An added feature recommended as part of the proposed system is a manually operated hydraulic pump that can be used to complete a lift cycle in the event of certain types of failure.

The pump should be located within reach of a seated driver, possibly under the raised driver's platform. A typical installation would provide access to the pump through a plate or door easily opened by the driver.

A detachable handle could be inserted and moved back and forth, or up and down, in a manner similar to a jack handle.

This safety feature provides an emergency method for retracting the lift device into the fully stowed position, deactivating all the interlocks, and driving the bus until repairs to the lift device can be made. It is not intended as an alternative method of operating the lift during normal use.

The pump would require double plumbing to all cylinders to ensure operation in the event of a failure in the primary hydraulic lines.

Compared to other lift devices, especially some designed for vans and small buses, the recommended design is relatively simple in construction. The hydraulic system appears superior to other systems using cables, chains, electric motors, air pumps, etc., and should offer advantages in durability and minimum maintenance.

9.4 Lift Operation

The platform lift is completely under control of the seated driver at all times. Switches are located to the right of the instrument panel so that all switching operations can be made without the need to look away from the entry door area.

Three (3) separate switches are required to operate the mechanism. A typical switch panel arrangement is shown in Figure 13.

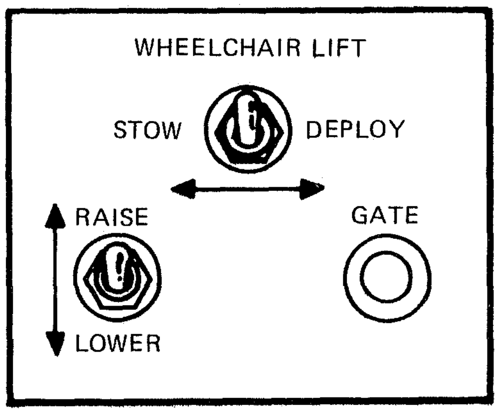


FIGURE 13. LIFT PLATFORM CONTROL SWITCHES.

Both the "STOW-DEPLOY" and "RAISE-LOWER" switches are spring loaded toggle type that automatically return to the center "OFF" position unless held down by the driver. The gate switch is a spring-loaded momentary push-button type.

The normal deployment sequence is illustrated in Figures 14a through 14c. Note the normal step and step riser arrangement in the stowed position.

FIGURE 14a.
NORMAL
STOWED
CONFIGURATION.

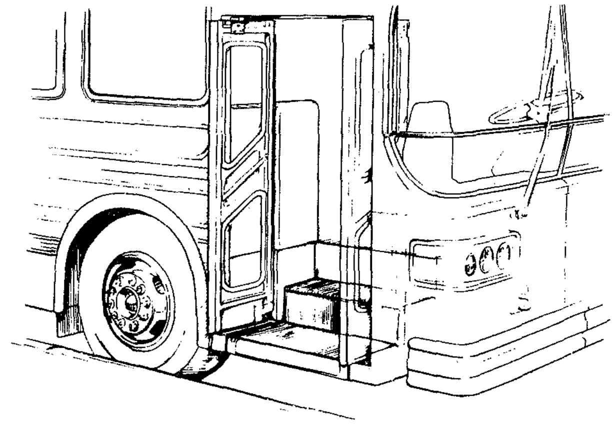


FIGURE 14b.
PARTIAL
PLATFORM
DEPLOYMENT.

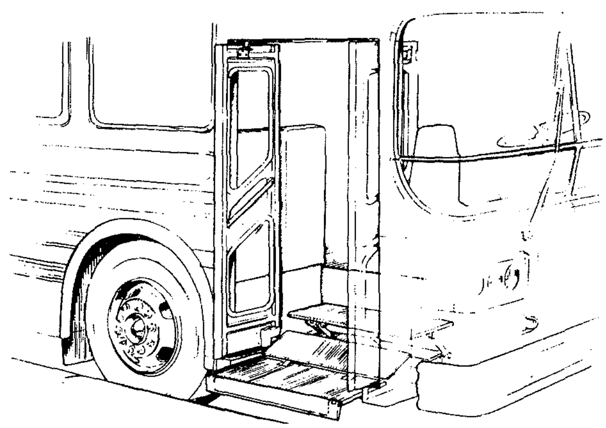


FIGURE 14c.
FULLY
DEPLOYED
PLATFORM.

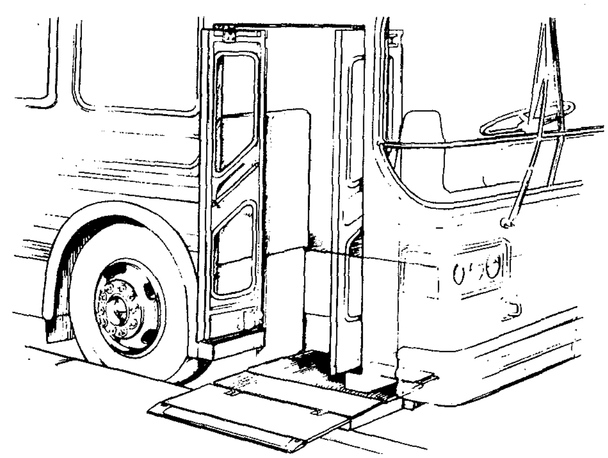


FIGURE 14. LIFT DEPLOYMENT SEQUENCE.

Figure 15 illustrates a wheelchair passenger fully raised to the interior floor level. Note the raised safety gate that prevents the chair from rolling backward and off the platform.

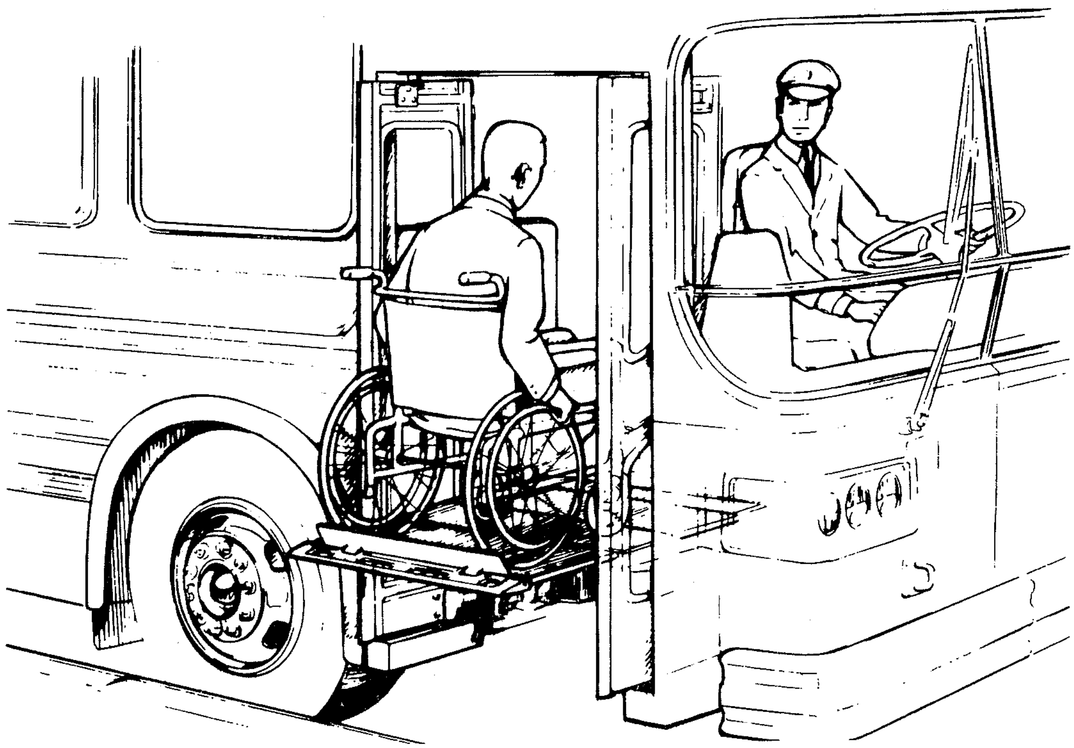


FIGURE 15. WHEELCHAIR RAISED TO FLOOR LEVEL.

The complete system function follows the following steps.

Step 1. Driver opens entry door.

Step 2. Driver activates "DEPLOY" switch. This causes activation of the front door, brake and accelerator interlocks. Platform folds out into a fully extended position. Switch must be held open in the deploy position until platform is fully extended. Engaging the switch also activates an exterior flashing caution light located near the door and an interior signal audible to the driver.

Step 3. Driver activates "LOWER" switch causing the extended platform to descend to either curb level or street level. A sensitive switch located in the platform edge will automatically stop the platform descent if any obstructions are contacted. The same switch also will stop the platform from fully extending if an obstruction is contacted.

Step 4. The safety gate is normally in the raised position during either "RAISE" or "LOWER" phase. When the platform is fully lowered, the driver lowers the gage momentarily pushing the "GATE" button.

Step 5. When the wheelchair is properly positioned on the platform, the driver activates the "RAISE" switch. This causes the safety gate to automatically raise into position before the platform begins ascent. The platform then ascends until it reaches the interior floor level.

Step 6. The wheelchair passenger moves off the platform, pays the fare, if required, and then moves toward the open wheelchair position.

Step 7. The driver activates the "STOW" switch causing the platform to retract into the full stowed position. When full stowed position is reached, the audible and visual caution devices are automatically switched off, the safety gate drops into position, and the front door, brake and accelerator interlocks are deactivated.

Step 8. The driver closes the front door, checks to see if the wheelchair passenger is in position, and moves away from the curb.

No mention has been made of a "kneeling" feature in this sequence since kneeling is not a mandatory requirement for lift operation. Total vertical movement is limited only by the height of the vertical towers enclosing the cylinders and tracks and the cylinder stroke length. Cylinder stroke and track lengths can be sized and designed to provide necessary vertical platform movement for buses with or without kneeling.

For buses that do have a kneeling feature, the above eight (8) steps would change only to include activation and deactivation of the kneeling switch. The kneeling capability would probably be interlocked to prevent operation during the lift platform cycle.

Cycle time for the lift operation is adjustable by use of a hydraulic pressure regulating valve. The valve is located in the underfloor area of the bus and is intended to be accessible to maintenance personnel only and not the driver.

Minimum cycle time from start of deployment, to full deployment, and back to fully stowed position, is approximately 40 seconds, plus the time required to board and unboard the wheelchair person.

Simulated loading and unloading operations have been timed on a prototype lift device very similar to the recommended design. The tests were run with non-handicapped occupants using a wheelchair and some allowances should be considered for wheelchair user's unfamiliarity with maneuvering in a chair. Average times recorded were:

- Loading – one minute, fifty seconds
- Unloading – one minute, twenty seconds

9.5 Estimated Option Cost

Estimated costs of a wheelchair lift and restraint system option are presently in the range of $6,000 to $8,000 per bus for equipment similar to the recommended design.

There are several factors that must be recognized at this time when evaluating this estimate. The most important factor is that only two (2) manufacturers are currently ready to produce lift devices suitable for current design 40-foot transit buses, and neither of them has yet produced equipment in any quantity. This means that current prices almost certainly reflect non-reccuring costs for development and tooling.

It is reasonable to expect prices to decline in the future when:

a. A viable market for lift devices evolves and competion between manufacturers increases.

b. Non-recurring development and tooling costs are amortized.

c. Increased quantities permit economy of mass production.

d. Design improvements and cost reductions are incorporated based on actual long-term experience with the equipment.

Another factor that influences current prices is the cost of design changes to the bus required to incorporate a lift device. Some of the specific changes required on the AM General bus are discussed in Section 10, Applicability To AM General Bus.

While the changes were not difficult, they did include modifications to the bus door and underfloor structure and changes to the door assembly and control mechanisms. This cost penalty would also be expected to decrease once the tooling and fixturing costs are recovered and the redesign incorporated into a regular production option package price for a lift device.

10.0 APPLICABILITY TO AM GENERAL BUS

The AM General standard 40-foot transit bus is representative of current design buses manufactured in the United States. The bus physical characteristics pertinent to this study, such as overall size, floor and step heights, door locations and widths, seating capacity and interior arrangement, etc., are very similar and, in some instances, identical from one manufacturer's bus to another. As noted at the beginning of this report, a high degree of commonality in basic design is assured through the transit operator's procurement specification. This commonality permits a reasonably accurate extrapolation to all current standard bus designs of data derived from the AM General bus.

10.1 Entry Door

A conclusion was drawn in Section 5, BUS DOOR REQUIREMENTS, that a 38.0-inch wide front door clearance was required to effect safe and efficient passage of a 26.0-inch wide wheelchair. The entry door area of the AM General bus was carefully reviewed to determine if a 38.0-inch or wider door opening could be achieved.

Results of the evaluation show that a maximum door opening of 34.62 inches is possible with minimum amount of structural changes involved. The width could not be increased further without major design changes and probable impact on the right front suspension system, wheelhousing and axle location.

Entry door width is severely constrained by the factors listed below and illustrated in Figure 16.

- Current procurement specifications mandate entry door location forward of the front axle.
- Approach angles are normally specified at 10 degrees with approximately 9 1/2 degrees as minimum.
- Sufficient structure is required in the right front corner and under the door area to minimize damage from accidents.

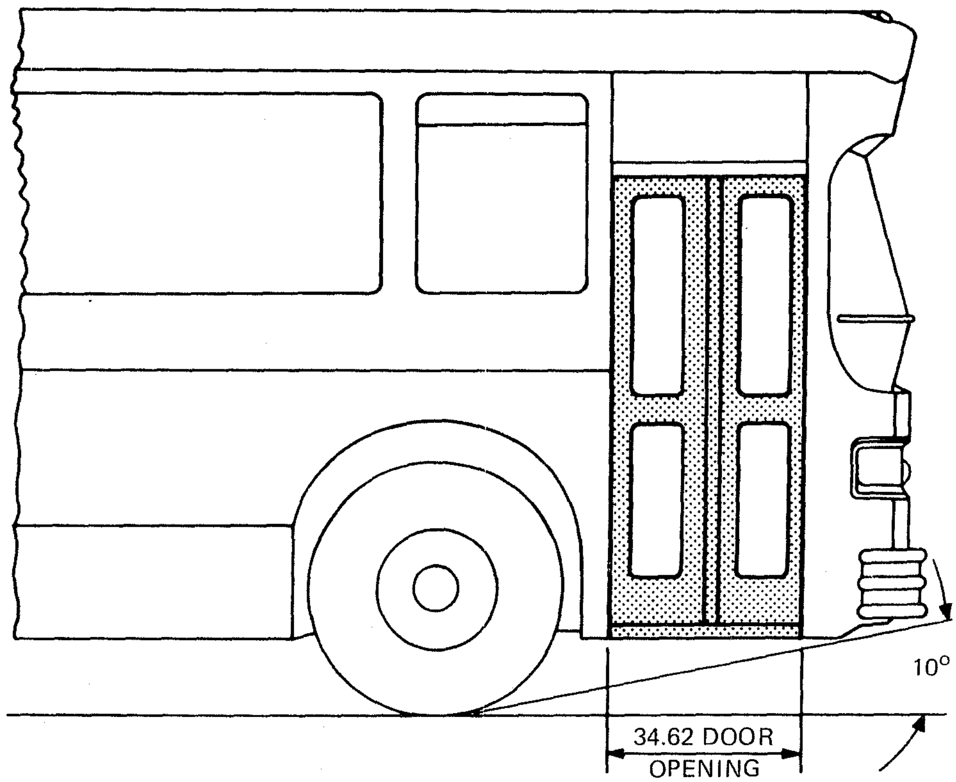


FIGURE 16. ENTRY DOOR SIZE CONSTRAINTS

As one can see from the illustration, the approach angle, in effect, controls the front axle location. As the approach angle increases, it causes the front axle and wheelhousing to move forward, thus decreasing the area available for an entry door. This condition is common to all current design 40-foot buses.

To account for manfuacturing tolerances and door adjustments, a clear door opening width of 34.62 inches was accepted as the maximum possible dimension. Although this width is 3.38 inches less than the recommended dimension, it will permit passage of a 26.0-inch wide wheelchair assuming reasonable care and caution during maneuvering and positioning on the platform.

10.2 The Lift Device

Installation of a lift platform device with most of the recommended design features can be achieved on the AM General bus without significant impact on existing structure or design.

As mentioned earlier, AM General was in the process of packaging and installing a platform lift device for three transit property procurements during the period of this study. This provided an opportunity to observe the actual design changes made to the bus and the installation of a prototype lift platform device.

The major changes required were:

- Relocation of a diagonal brace running just behind the existing stepwell and used only with optional energy absorbing front bumpers.
- Elimination of the stepwell.
- A slight relocation of the fore and aft transverse bulkheads to accommodate increased width of the entry door from 30.0 inches to 34.62 inches.
- Some additional reinforcement at the edge of the bus floor to compensate for deletion of the stepwell.
- Relocation and reinforcement of the entry door rear pillar.
- Rearrangement of the front bumper reinforcements.

The lift platform itself replaces the stepwell. In the stowed position, the platform folds into a set of steps and step risers that are very similar in appearance to the standard stepwell arrangement. (Refer to Figure 14.)

One of the most difficult parts of the installation was to arrive at a clean, protected and efficient packaging of the underfloor mechanisms, vertical guide rails and operator controls.

11.0 SUMMARY

The objective of this study was to determine:

a. Feasibility of incorporating a lift device into current 40-foot transit buses, and

b. if it is practical to offer such a device as an option in the manufacture of new buses.

Data and observations presented in this report support a determination that it is feasible to incorporate a lift device on current design buses.

Lift design technology is advancing rapidly at this time and some transit operators have already placed orders for buses with wheelchair lifts.

Determination of practicality is another matter altogether because it involves a myriad of variables having to do with the handicapped population, climate, terrain, economics of operation, training, and transit operator liability. The question of practicality is discussed in more detail at the end of this summary.

11.1 Wheelchair

Data gathered on wheelchair sizes and types demonstrates that an almost infinite variety is available. A statistical analysis of wheelchair sales by sizes show that wheelchairs up to 26.0 inches in overall width would accommodate approximately 85% of the wheelchair user population. Although specially built wheelchairs can, and do, greatly exceed 26.0 inches in width, the 26.0 inch dimension was established as a realistic wheelchair size to base further dimensional requirements on.

11.2 Lift Location and Door Size

The bus front entry door was selected as the best location for a lift device. This conclusion was based primarily on an analysis of actual bus driving conditions which pointed out the relative ease with which the driver can properly position the front door in comparison to a mid-bus or rear door location.

Safe and proper operation of the lift platform is greatly enhanced when the bus is standing most parallel to the curb line. The ability of the driver to completely control and visually monitor the complete lift operation cycle is fundamental to maximizing safe use of the device.

The front door location was also the choice of wheelchair users. Statements made by spokesmen for elderly and handicapped organizations strongly supported the front door choice for both safety and socially related reasons.

Based on the 26.0 inch wide wheelchair parameter, the study supports a minimum recommended door opening width of 38.0 inches. This provides a 6.0 inch clearance on each side as the chair maneuvers through the bus door. Such a clearance appears desirable to permit safe and efficient entry, and to accommodate the hands, knuckles, winter clothing, and some tolerable misalignment of the wheelchair on the lift platform.

The maximum door width attainable on the AM General standard bus is 34.62 inches. Due to the similarity of design between all current standard design buses, it is reasonable to assume that a 34.62 inch clear door opening is the maximum attainable for a standard bus from any of the three current manufacturers.

11.3 Wheelchair Retention

Retention systems currently available consist of some type of mechanical jaw that entraps and holds some part of the wheel rim plus passive lap and shoulder belts. Such systems are versatile and inexpensive but require sufficient manual dexterity and strength on the part of the wheelchair occupant to operate the devices.

Other retention concepts have been developed with the intent to decrease the degree of occupant dexterity required. These concepts commonly are based on electrically controlled cylinders mounted under the bus floor that raise wheel barriers (or stops) through the floor. The concepts are interesting but would require significant changes to the bus design and are judged to be expensive. In addition, such concepts only decrease a little further the occupant dexterity required but do not eliminate the requirement totally.

11.4 Interior Arrangement

Maneuvering studies demonstrate conclusively that only 102.0 inch wide buses will provide the minimum amount of clearances and floor space required for the necessary interior maneuvering and positioning of wheelchairs. Maneuvering studies with the 96.0 inch bus show that great difficulty will be experienced in reaching the fare box, negotiating the 90 degree turn from the vestibule toward the aisle, and negotiating past the feet and legs of passengers occupying the longitudinal seats mounted atop the front wheelhousings. It is highly improbable that an unaided wheelchair occupant can successfully complete the required maneuvers.

An analysis of possible seating arrangements strongly suggests that a maximum of two (2) wheelchair occupants can be accommodated on a bus in regularly scheduled service. The recommended stations are the areas immediately aft of each front wheelhousing with the wheelchairs in a forward facing position. This arrangement requires the use of a fold-up jump seat to provide the total wheelchair space required and necessitates the permanent removal of two (2) transverse seat assemblies and one (1) longitudinal passenger seat on each side of the aisle. This results in the loss of ten (10) passenger seats, six (6) of which can be recovered when the jump seats are in use.

11.5 Recommended Design

The recommended lift design is controlled by the driver by a set of electric switches. It is powered by hydraulics from either an existing power steering pump or a separate pump.

The platform folds into a normal step and stepwell configuration when in the stowed position and has no effect on normal bus operations. It adds approximately 400 pounds to the weight of the bus and has a recommended maximum platform load capacity of 1,000 pounds.

Normal time required to either load or unload one passenger is approximately one and one-half minutes. Cycle time is adjustable, by maintenance personnel, through a hydraulic pressure regulator valve.

A manual hand-operated hydraulic pump is available to allow the driver to retract the lift into a stowed position in event of electrical or hydraulic failure. The pump is intended only as an emergency method of putting the bus back into a drivable condition until lift repairs can be made. It is not to be used as an alternate lift control.

The recommended design is in the early stages of production at this time and no experience is available for determination of durability, reliability and maintenance requirements.

11.6 Option Cost

Cost of lift and restraint devices similar to the designs recommended in this report are estimated to add approximately $6,000 to $8,000 to the price of a standard bus. It is reasonable to expect this price to decrease after initial development and tooling costs are amortized and if a viable market develops that will strengthen competition and permit economies of quantity production.

11.7 Installation Impact on Standard Buses

Based on the installation of a prototype lift device on an AM General bus, no major design problems would be anticipated for the installation of such a device on any current design 40-foot transit bus.

Changes required to the AM General bus were limited to minor modifications of the door pillars and underfloor structure to provide clearance for the lift mechanism. A wider door obviously requires new door assemblies and modification to the door operating mechanism and controls.

11.8 Comments on Practicality

If the question of practicality of an optional lift device is framed with respect to whether or not a suitable lift device is available, if it can or cannot be installed in a cost-effective manner on current buses, and will it or will it not perform functionally – the answer is affirmative. Availability, installation and operation has been demonstrated on an AM General bus.

If the question, however, is viewed from the transit operator's position, the answer is much less certain.

Practicality from the operator's point of view must be determined with respect to the many variables and nebulous factors mentioned earlier. For example, consider the following operational questions:

a. Will the lift operate as successfully in Minneapolis with severe ice and snow conditions as it does in Southern California?

b. Can wheelchair passengers be evacuated from the bus in case of fire or severe accident?

c. What is the operator's legal liability if a wheelchair user is not physically capable of manipulating the restraining devices – or refuses to do so?

d. Is there a legal liability if a passenger in an oversize wheelchair is refused entry to the bus?

e. How does the operator ensure that other passengers will agreeably vacate the fold-up jump seat if a wheelchair is boarded onto a full bus?

f. How does a wheelchair passenger exit from the bus if the lift or front door becomes inoperative?

It is very difficult to assess the impact on bus schedules and normal operations. Each time the lift is deployed it will clearly increase the dwell time at that stop. The more often the lift is deployed, the more schedules are delayed. The more often the schedules are delayed, the more likely it is that non-handicapped riders will change to alternate means of transportation.

All these questions have been raised repeatedly in other studies and reports, and most of them still await resolution. It appears reasonable to speculate that occasional use of the lift device on regularly scheduled routes could be tolerated without significant negative impact on the overall services provided by a public transit system. As the frequency of use increases, one could predict an increasing disruption of normal schedules and services. In the view of the authors, it is that fine line between how much disruption can and cannot be accommodated that determines "practicality".

APPENDIX A

PLATFORM LIFT MANUFACTURERS

Listed below are platform lift manufacturers either contacted or visited during the performance of the contract.

Companies listed No. 1 through No. 8 were visited to observe their lift designs. Companies No. 1 through No. 5 were judged to have platform lift designs that were applicable to standard 40-foot buses.

1. Environmental Equipment Corp.
   San Leandro, California — 2 Different Lifts

2. Mr. Ed Hall
   Seattle, Washington

3. Para Industries, Ltd.
   Calgary, Alberta, Canada

4. Sheller-Globe Corporation
   Toledo, Ohio

5. Transportation Design & Technology
   San Diego, California

6. Handi-Ramp, Inc.
   Mundelein, Illinois

7. McFadden Corporation
   (Installers for Collins Ind.)
   Lansing, Michigan

8. Fred Scott & Sons
   Elk Grove, Illinois

9. Biltz Body Corporation
Chicago, Illinois

10. Braun Corporation
Winamac, Indiana

11. Carpenter Body Works, Inc.
Mitchell, Indiana

12. Collins Industries, Inc.
Hurchinson, Kansas

13. Lance Interprises, Inc.
Bloomfield, Conn.

14. Target Industries
Springfield, Mass.

15. Recreational Industries, Inc.
Warren, Ohio

16. Ontario Transportation Development Corp.
Toronto, Ontario, Canada

17. Wayne Corporation
Richmond, Indiana

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2. *Designing for the Disabled,* Second Edition, Selwyn Goldsmith, Published by McGraw-Hill.

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6. *Specifications for Adult-Seat Van Type Passenger Buses,* Iowa Department of Transportation, December, 1976.

7. *Transbus Public Testing and Evaluation Program,* Final Report, Simpson & Curtain, Philadelphia, Pa., prepared for Booz-Allen Applied Research, Inc., under contract to the Urban Mass Transportation Administration, Washington, D.C., January, 1976.

8. *Transporation Problems of the Transportation Handicapped,* Volumes 1 through 4, Crain and Associates, Menlo Park, California, for DOT, Office of Urban Mass Transportation Administration, Washington, D.C., August, 1976.

9. *Travel Barriers – Transportation Needs of the Handicapped,* ABT Associates, Inc., Cambridge, Mass., for DOT, Office of Economic & Systems Analysis, Washington, D.C., August, 1969.