TP 13435E

Development of an On-Board Portable Lift for Intercity Buses

Prepared for
Transportation Development Centre
Safety and Security
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by
Adaptive Engineering Ltd.
Calgary, Canada

April 1999

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by
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NOTICES

This report reflects the views of the author and not necessarily those of the Transportation Development Centre.

In the course of the project, Adaptive Engineering Ltd. consulted with experts in related fields, including ergonomics, industrial design, and travelers with disabilities. However, Adaptive Engineering Ltd. has final responsibility for the report and the opinions expressed therein.

Project Team

This project was coordinated by D.W. Smith, M.Sc, P.Eng., Adaptive Engineering Ltd., with direction from the steering committee, and input from staff and outside experts. Individual contributions are recognized, where appropriate, within the body of this report.

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Lawrence Poole, President: Keroul

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

This report documents research and development work undertaken on a portable on-board lift for intercity buses. The intent was that the device would be lightweight, reasonably priced, storable in a bus baggage tank, and would involve minimal modification to existing buses.

In the course of this project, Adaptive Engineering Ltd. developed and tested a manually-powered, monorail device that provides "boarding chair access" to intercity buses (over-the-road buses).

The device developed appeared to meet all technical objectives. Additional field evaluation of the device is required.

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16. Résumé

Ce rapport décrit les travaux de recherche et de développement visant la mise au point d'un élévateur embarqué pour autocar. Le but était de disposer d'une plate-forme élévatrice légère et peu coûteuse pouvant être transportée dans le compartiment à bagages d'un autocar, moyennant tout au plus une légère modification des autocars existants.

Le projet, confié à Adaptive Engineering Ltd., a débouché sur un monorail à entraînement manuel qui permet «l'accès par chaise de transfert» à un autocar.

Le dispositif mis au point s'est révélé répondre à tous les objectifs techniques. Une autre évaluation en service du dispositif s'impose.

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Advice and comments were obtained from the following experts:

Gary E. Jacques, M.A.Sc., P.Eng.: Mechanical and Biomedical Engineer, Calgary

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Mark J. Lumbard: President of Axis Design Associates, Calgary

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Ruth M. Heron: Heron Ergonomics Incorporated, Vancouver

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Brian Clark: B. Clark Associates Ltd., Victoria

EXECUTIVE SUMMARY

This project was undertaken to develop a portable, on-board system that would provide access for travelers with disabilities to intercity buses (over the road buses). Success was uncertain for the following reasons:

- restrictive geometry of bus entryways;
- the requirement for a lightweight device;
- safety requirements;
- ergonomic limitations;
- human factors requirements;
- aesthetic preferences;
- the requirement for an easy to use device
- the requirement for baggage tank storage; and
- the requirement for low cast.

Moreover, the history of unsatisfactory attempts to develop such a device is significant.

The approach used was to apply Adaptive Engineering Ltd.'s experience and patented technology from aircraft and rail transport. About twelve concepts were considered and three were prototyped and tested. The first concept prototyped was a "twin rail" device, with one rail over the stairs of the bus and the other going down the aisle. This approach was abandoned because of the device's weight and mechanical complexity. The second prototype was a curved monorail from ground level to the floor level of the bus, using a collapsible chair that attached to the rail then detached at the top landing. This approach was not acceptable because of weight, size, and structural complications with the chair. The final prototype is a shorter, curved monorail with a detachable platform. The boarding chair is the conventional type used for access to aircraft. It allows access to all seats in the bus.

The device weighs approximately 55 kg (120 lb), including the boarding chair, and occupies about 0.5 m^3 (18 ft^3) of baggage space (5% of the capacity of a standard bus). The device can be taken from the baggage tank, used to board a traveler with a disability, and returned to the baggage tank in significantly less than 10 minutes. The cost of the device, manufactured in quantity, is estimated at $10,000. Final field testing of the device remains to be undertaken at the end of this project.

This device meets or exceeds the project's technical requirements, and involves no modification whatsoever to the existing buses.

SOMMAIRE

Ce projet avait pour but de mettre au point un système portable embarqué devant permettre aux voyageurs handicapés de monter à bord d'un autocar. Le succès d'une telle entreprise était incertain, pour les raisons suivantes:

- exiguïté de l'entrée des autocars;
- obligation de légèreté;
- prescription de sécurité;
- contraintes ergonomiques;
- exigences reliées aux facteurs humains;
- préférences esthétiques;
- critère de facilité d'utilisation;
- nécessité de rangement dans le compartiment à bagages;
- impératif de faible coût.

Sans compter que plusiers tentatives de développer un tel dispositif s'étaient déjà soldées par des échecs.

La démarche a consisté à miser sur une technologie brevetée d'Adaptive Enigineering Ltd., utilisée dans les secteurs du transport aérien et du transport ferroviaire. Des quelque douze concepts étudiés, trois ont été retenus pour les étapes du prototypage et des essais. Le premier prototype consistait en un dispositif à deux rails – un qui permet de monter l'escalier de l'autocar et l'autre d'avancer dans l'allée. Cette solution n'a pas été retenue, en raison de poids du dispositif et de sa complexité mécanique. Le deuxième prototype était un monorail courbé, solidaire d'une chaise de transfert pliante, assurant le transfert vertical de niveau du sol au niveau du plancher de l'autocar. Cette option n'a pas été considérée acceptable, en raison de poids et de l'encombrement de la chaise de transfert et des problèmes structuraux associés à celle-ci. Le dernier prototype est un monorail courbé plus court, équipé d'une plate-forme amovible. La chaise de transfert est du même type que celle utilisée dans les avions. Elle permet d'accéder à n'importe quel siège de l'autocar.

L'élévateur pèse environ 55 kg (120 lb), y compris la chaise de transfert, et occupe quelque 0,5 m^3 (18 pi^3) dans le compartiment à bagages (soit 5% de la capacité de celui-ci, dans un autocar standard). Moins de dix minutes suffisent pour retirer l'élévateur du compatiment à bagages, l'installer pour faire monter un voyageur handicapé et le ranger de nouveau dans le comprtiment à bagages. Le coût du système, fabriqué en série, est évalué à 10 000$. Il reste á réaliser les derniers essais en serivce de l'élévateur dans le cadre du présent projet.

En plus de respecter et même de surpasser les exigences techniques du projet, l'élévateur ne nécessite aucune modification des autocars existants.

CONTENTS

LIST OF PHOTOS

1. INTRODUCTION

1.1 Project Objectives

The purpose of this project was to develop a means of providing "boarding chair access" to over the road buses using a device that could be stored in the baggage compartment. It was intended that the ideal device would involve no significant modifications to the bus and would be simple to operate, small, reliable, safe, and low-cost. It was also intended to provide access with dignity, including an agreeable appearance and low operating noise level.

1.2 Background

This project resulted from a submission made by Adaptive Engineering Ltd. in 1996 to the Transportation Development Centre (TDC), Transport Canada. The problem of providing access to intercity buses has been worked on for at least a decade by the bus industry, regulators, and groups representing travelers with disabilities. Past work on the problem has been undertaken by or with the assistance of Transport Canada and has ranged from demonstration projects with "full access on-board lifts" to carry-on boarding chairs.

The problem was complicated by several factors including:

- The number of travelers with disabilities is small and does not motivate the industry to provide services without subsidy.
- The availability of subsidy funding has declined in recent years.
- Opinions on what constitutes "appropriate access with dignity" vary.
- Political, social, and legislative pressures increasingly require that access be provided throughout North America.
- The bus industry was increasingly concerned because on most buses on-board lifts weaken the structure of the bus to the point that it could not pull a "package trailer". The ability to handle packages was increasingly important to the bus industry.

1.3 Limitations

Because of the above complications, this project was undertaken with the intent of developing a portable lift that involved no significant modification to existing buses, that would take up less than 0.56 cubic m (20 cubic ft) of baggage space, would cost in the neighborhood of $10,000, and would weigh less than 125 kg (275 lb). It was appreciated at the outset that it was not possible to guarantee results because of the very restrictive geometry of the buses, and the long history of attempts to solve the problem throughout North America.

1.4 Market Considerations

Adaptive Engineering Ltd.'s interest in this project was originally based on the whole North American market. However, early in 1998, the United States Notice of Proposed Rule-Making on access to intercity buses disallowed the use of portable lifts. Because the United States represented 90% of the potential market, the project appeared unattractive commercially, and was put on hold in May 1998. On request from Transport Canada, and
Public Works and Government Services Canada, the project was reactivated on Sept. 1, 1998, and completed in May 1999.

Specific technical aspects are discussed in the sections that follow.

2. DESIGN APPROACH

2.1 Access With Dignity

The term "access with dignity" arises in any design of equipment for travelers with disabilities. While the intent of the term may be clear, it is difficult to define in a specific piece of equipment. For example, it would be generally agreed that it is desirable to minimize noise and interference with other passengers to minimize drawing attention to the traveler with a disability. However, opinions vary as to whether it is more dignified to travel in a regular seat on the bus, or in an isolated area set aside for wheelchairs.

For the purposes of this project, the approach taken was to keep the equipment small, quiet, unobtrusive, operator-friendly, safe, and secure-feeling for the traveler with a disability. The point that was made during the project by representatives of travelers with disabilities was that the most important component of dignity was the attitude and training of operators. However, the appearance and function of the equipment was important and was the only component that could be addressed in this project.

2.2 Technical Approach

In addition to the administrative and multi-disciplinary inputs noted above, Adaptive Engineering Ltd. has developed a specific approach to technical innovation on this type of project. This approach includes the following:

- The first step is to ensure that the problem has been properly defined, in its simplest form, and that it is constantly checked throughout the project. For example, it is not uncommon for innovators to become distracted with the details or the elegance of say, the drive system, and to forget that there may be a simpler way to solve the problem without a drive system – the fundamental purpose being to get travelers onto the bus.
- A "quick prototype" approach is used, which involves very few formal drawings. An idea is taken to the shop floor verbally or in rough sketches and prototyped for evaluation. This process allows for evaluation of a large number of concepts at minimum cost.
- A large number of ideas have to be processed to produce appropriate results. While it may sometimes happen that the appropriate idea is found at the beginning of the project, the more usual pattern is one of testing and rejection.
- Promising ideas were prototyped and tested on buses with travelers in wheelchairs. About fifteen concepts were considered, and three were fully prototyped for evaluation. These are discussed in detail in the following sections.

2.3 Manual Drive System Approach

It was decided early in the project that a manually powered drive system would be used in preference to battery or other electrical power sources. This decision arose from Adaptive Engineering Ltd.'s experience with lifts for trains, aircraft, and architectural applications.

The usual first reaction to manually powered equipment is that it is 19th century technology, but for this application it has proven to be "effective technology". In working with public access for trains and aircraft over the past fifteen years, Adaptive Engineering Ltd. prototyped and tested a number of electrically-powered units for applications throughout North America and in Switzerland. Without exception, manually powered units were selected for the following reasons:

- Reliability – powered units are more complex and less reliable. For example, lifting equipment is often not used for weeks at a time, resulting in problems with dead or stolen batteries, or motors that would not start.
- Low maintenance is a significant feature of manual equipment and is particularly important on safety equipment.
- Noise and weight – manual equipment is normally quieter and lighter than powered equipment.
- Manual equipment tends to be less sensitive to extreme temperatures and moisture.
- Simplicity of operation – manual equipment can usually be made more "user-friendly" and ergonomically obvious. This is very important where an operator may not use the equipment for a few weeks. It should be obvious how the equipment is to be used without having to find and review an operating manual.

2.4 Drive Safety Back-up

The lifts that Adaptive Engineering Ltd. builds for the public transit trains and aircraft industries have a patented double-braking system with a locking back up. In the case of bus access, it became evident that there was not room to use this system in the very restrictive geometry of the bus entrance. The basic feature of the patented drive system was retained in that the high efficiency manual drive was used, but with a single brake.

It is basic that no lifting equipment should be dependent on a single component that can fail. It therefore became necessary to develop a compact, independent, fail-safe device to be used in conjunction with the single brake. The device developed was a fail-safe "over-speed" mechanism that holds the load completely independently of the drive mechanism, and which locks if the drive moves faster than its normal speed or if there is any internal malfunction in the over-speed device.

The development of this over-speed device was a significant undertaking on this project, but the details of its design cannot be disclosed until patent protection has been established.

3. CONCEPTS PROTOTYPED

3.1 Concept 1 – Twin Rail

At the beginning of the project, a range of concepts were considered, including an over-head rail, stair-crawlers, swinging-arm lifts, and a folding station based type lift. However, the first concept considered worth prototyping was the Twin Rail system, shown in photos 1 – 6.

With this system, a custom folding seat was attached to a drive mechanism on an inclined rail set above the stairs at the bus. The inclined rail was coupled to a horizontal rail which ran along the aisle of the bus to the first seats. The seat was cranked to the top of the stairs by an operator standing in front of the traveler with a disability. The chair was then simultaneously released from the inclined dolly and clamped to a dolly on the horizontal rail.

This mechanism functioned adequately and was shown in video form to the Steering Committee. The Committee agreed that the results of this prototype justified continuing the project.

This Twin Rail system had several disadvantages, including:

- The size and placement of the rails were an inconvenience and potential hazard to other passengers and the operator.
- It appeared that at least one attachment to the bus floor would be required.
- The traveler would be limited to the first row of seats in the bus.
- The mechanism required to transfer the seat between the rails proved to be complex and potentially unreliable.
- The horizontal rail was a restriction for transfer to the bus seats in one direction.

In view of the above concerns, the Twin Rail system was abandoned in favor of a monorail.

3.2 Concept 2 – Curved Monorail With Custom Chair

The Curved Monorail with Custom Chair is illustrated in Photos 7 – 12. As can be seen in the photos, this was a long, rectangular monorail with a detachable chair. The chair was supported on a scissors mechanism, which allowed the wheels to be raised or lowered. This movement was used to couple and uncouple the chair from the rail dolly at the top of the stairs, and also provided “downward transfer” in both directions.

The chair was attached to the dolly on the monorail before the traveler transferred, requiring the rail to come back against the side of the bus, so as to clear the door and to provide enough rail length to clear the steps of the bus. This vertical clearance of the rail and wheels of the chair from the steps of the bus produced a number of complications.

The wheels had to be folded fully up so that they cleared the nose of the bus stairs, but then had to be cranked down to the level of the bus floor at the top of the stairs.

The movement of the chair at the top of the stairs produced further restrictions. The entire chair mechanism was mounted on a pivot so that it could be swung around into the aisle at the top of the stairs. While this had the advantage of simplicity, it was not flexible and had no adjustments in the way in which the traveler turned at the top of the stairs.

This mechanism was demonstrated at the Greyhound Canada Inc. bus depot headquarters in Calgary on Nov. 17, 1997. Again, the mechanism functioned adequately and was an improvement over the Twin Rail system. However, there were concerns about weight, complexity, and cost.

The Curved Monorail with Custom Chair system was abandoned in favor of a smaller monorail with conventional boarding chair.

3.3 Concept 3 – Curved Monorail With Boarding Chair (Stowaway Lift)

The Curved Monorail with Boarding Chair is illustrated in photos 13 – 27. This was the final and most successful prototype on this project, and was demonstrated at Greyhound Canada's head office in Calgary on Feb. 25, 1999. The following comments and description are taken from the Letter Report Minutes of that demonstration.

> Those attending the demonstration included:
>
> Brian Marshall, Chief, Technology Applications Division, Transportation Development Centre, Transport Canada
>
> Colin Cantlie, Co-Chairman of the Inter-City Accessibility Bus Committee
>
> Barry T. Lindemann, Community Affairs Consultant, Canadian Paraplegic Association
>
> Greyhound Canada representatives including: Roger Pike, Vice President, Prairie Region; Lorraine Card, Manager, Safety and Driver Administration; Dave Hickey, Manager, Operations Control; and Ian Noakes, Co-ordinator, Schedule Development
>
> Adaptive Engineering Ltd. representatives including: D.W. Smith, President; Endre Pataky, Export Manager; and Graham Smith, Senior Technologist

Stowaway Monorail Demonstration

Photos 13 – 26 show the Stowaway lift in service with a "Columbia" boarding chair (Note: Adaptive Engineering Ltd. staff member was used in place of a traveler with a disability because of insurance and safety considerations.) The sequence of operations was as follows:

1. A traveler with a disability arrived at the bus to be boarded.
2. The bus driver opened the baggage tank of the bus and placed the "landing adapter plate" (weight 3 kg) on the top stair of the bus.
3. The bus driver took the monorail and drive (weight 30 kg) out of the baggage tank and fits it into the landing plate. The rail and drive were balanced on a wheel and were handled in such a way that the driver was never required to lift more than 14 kg.
4. The driver removed the chair deck from the baggage tank and snapped it onto the rail and drive (weight of deck 7 kg).
5. The traveler with a disability transferred from his/her chair to the boarding chair.
6. The boarding chair and traveler were placed on the deck of the Stowaway, and the ramps were raised to secure the chair in place.
7. The driver hand-cranked the drive from behind the boarding chair until the deck was at the level of the top stair of the bus.
8. The rear deck ramp was lowered and the chair maneuvered around the corner and down the aisle of the bus, allowing the traveler to transfer to a regular bus seat.
9. The chair and drive were then taken back down the stairs and the boarding device returned to the baggage tank. Normally, the traveler's own chair would also be placed in the baggage tank, preferably in a specific compartment to protect it from other freight.

Technical Details and Comments

- The demonstration showed that a traveler with a disability could be boarded in three minutes after the Stowaway was in place, and that the Stowaway lift would not interfere with general boarding.
- The "turnaround" time was found to be under seven minutes; that is, the time required for the driver to deploy the lift, board the traveler, and return the lift to the baggage compartment ready for departure.
- For the demonstration, the Stowaway lift was shown unprotected in the baggage compartment. In actual service, the lift would be stored in its own aluminum box with wheels on one end so that it could be transferred instantly from bus to bus.
- The boarding chair would also be stored in the box with the Stowaway lift. The total weight of the lift, boarding chair, and storage box would be approx. 68 kg (150 lb). The weight of the Stowaway lift and boarding chair were verified at the demonstration as 55 kg (120 lb).

- The steel tubular rail and structure of the lift were found to provide a rigid and secure feeling to the traveler in the boarding chair (as with all Adaptive Engineering Ltd. equipment, a basic safety factor of 5 was used in the design). The design load on the lift was 145 kg (320 lb) which is the 95th percentile traveler plus boarding chair. (Test load would be 725 kg/1600 lb).
- The drive system used was based on the patented automatic braking system used by Adaptive Engineering Ltd. in their lifts for aircraft, trains, and buildings.
- The device was designed for use with an over-speed safety lock, which was not demonstrated, pending patent applications.
- The entire geometry of the bus door, stairways, landing, and aisle were an extremely restrictive environment, and there would obviously be limits to the size of the person that could board a bus. The limitations include shoulder and hip width, but it appeared that the Stowaway lift would work for people up to approx. 110 kg (240 lb).
- It was recognized by all present that the Stowaway lift does not provide "own wheelchair" access, which may in the long-term be desirable. It does, however, provide a cost-effective means of access equal to that provided for air travel, with no modification whatsoever to existing MCI (Motor Coach Industry) buses.
- Some additional work is required before test devices could be placed in service, and it was agreed between Transport Canada and Adaptive Engineering Ltd. that the next step should be the manufacture of about five units to be "field evaluated" to verify acceptability to all parties involved.
- The demonstration lift will remain with Adaptive Engineering Ltd. so that interested parties can see it. It was felt that this would provide better- controlled information than putting it on a bus where it may not be used.

Summary

The device demonstrated a technically viable and acceptable means of providing access to existing MCI (Motor Coach Industry) buses.

The weight of the device was less than half of the weight originally proposed, and the volume was less than about 5% of the baggage space.

3.2.1 Final Design Details

As shown on the photographs, the Curved Monorail concept with Custom Chair resulted in a significantly smaller, lighter device. The advantages included:

- Because the transfer to the boarding chair did not have to take place with the chair attached to the rail, the rail could be shortened and the curvature reduced. That is, the bus door would prevent transfer if the boarding chair were attached to the rail.
- The use of a short ramp at the back of the chair deck allowed the slope of the rail to be increased without interfering with the steps of the bus. The geometric problem here was that the chair deck must clear the nose of the lowest step, but as the slope increases, the top of the rail moves away from the top step.
- The use of a boarding chair instead of a captive rail chair gave greater freedom for maneuvering in the turn at the top of the stairs. This turning maneuver is the most restrictive aspect of bus access.
- It is interesting to note that the chair used on this concept was the Columbia boarding chair, which was originally developed as a carry-on boarding chair for buses. It is now most commonly used as a boarding chair for aircraft.
- A significant advantage of the boarding chair approach is also that if alternative or improved boarding chairs become available in the future, the access system will still work.
- In the case of an emergency, a boarding chair can be used as a "carry off" chair because it was originally designed to be carried by two people.

3.2.2 Design Specifications

The design details and parameters of the final prototype included:

- Minimum safety factor on all elements was 5.0 (the ISO code requirement on structural elements is a 3.0 safety factor, but it is Adaptive Engineering Ltd.'s standard procedure to design to 5.0 and to load-test every production unit).
- The safety factors are based on an ISO design load of 109 kg (241 lb) for the traveler plus the weight of the chair and deck.
- The drive mechanism is a triple-reduction #40 chain and sprocket system with a single Adaptive Engineering Ltd. load-activated brake, covered by U.S. Patent Numbers 4926937 and 5040638.
- The chair deck and drive are attached to a track dolly, which consists of hardened stainless steel rollers travelling on stainless spring steel rails welded to the monorail.
- The final drive is a hardened sprocket engaged on a hardened roller chain welded to the curved monorail (with the appropriate precautions for welding the hardened chain).
- The main curved monorail was a 76 mm (3 inch) diameter ERW steel tube. Internal cross-members were used to minimize deformation from welding.

- The prototype monorail was designed to be used on a surface level with the bus tires, but would also function against a 150 mm (6 inch) curb.
- While there are no specific codes for portable lifts of this type in North America, wherever possible, the requirements of CSA B355M86, ASTM, and the Americans with Disabilities Act were used in the final design.
- The prototype was developed for existing MCI (Motor Coach Industry) buses, which are the most common intercity buses in North America.

4. CONCLUSIONS AND RECOMMENDATIONS

The device developed in the course of this project provided boarding chair access to over-the-road buses to the same level available for travel by aircraft. "Own chair" access to all over-the-road buses would be ideal, but the device appeared to have a place in bridging the gap between the present situation and the ideal.

The device involved no modification or attachment to the bus, which eliminates concerns about bus structure and warranties. The weight and dimensions of the device as presented herein appeared to be acceptable to bus operators.

It is worth noting that Adaptive Engineering Ltd. also has developed a portable station-based lift, which could be useful in busy terminals in conjunction with the "Stowaway" lift developed on this project. The station-based lift is mobile and manually operated but is too large to be carried in the baggage compartment of a bus.

Recommendations for the future of this device include:

- Refine the design and tool for the manufacture of several pre-production units for field evaluation.
- The field evaluation is essential because although the device works technically, it must be shown to be acceptable to travelers with disabilities, bus companies, drivers, and regulatory authorities.
- Patent protection and other forms of intellectual property protection must be in place before public disclosure of the mechanisms.
- It is unlikely that the North American market would justify refining the concept for buses other than MCI (Motor Coach Industry) buses.

Photo 1: Full size mock-up of front of standard bus showing "twin rails" under seats and folded rail chair behind driver's seat.

Photo 2: Mock-up showing "aisle rail" being taken out of baggage tank.

Photo 3: Aisle chair being installed in bus.

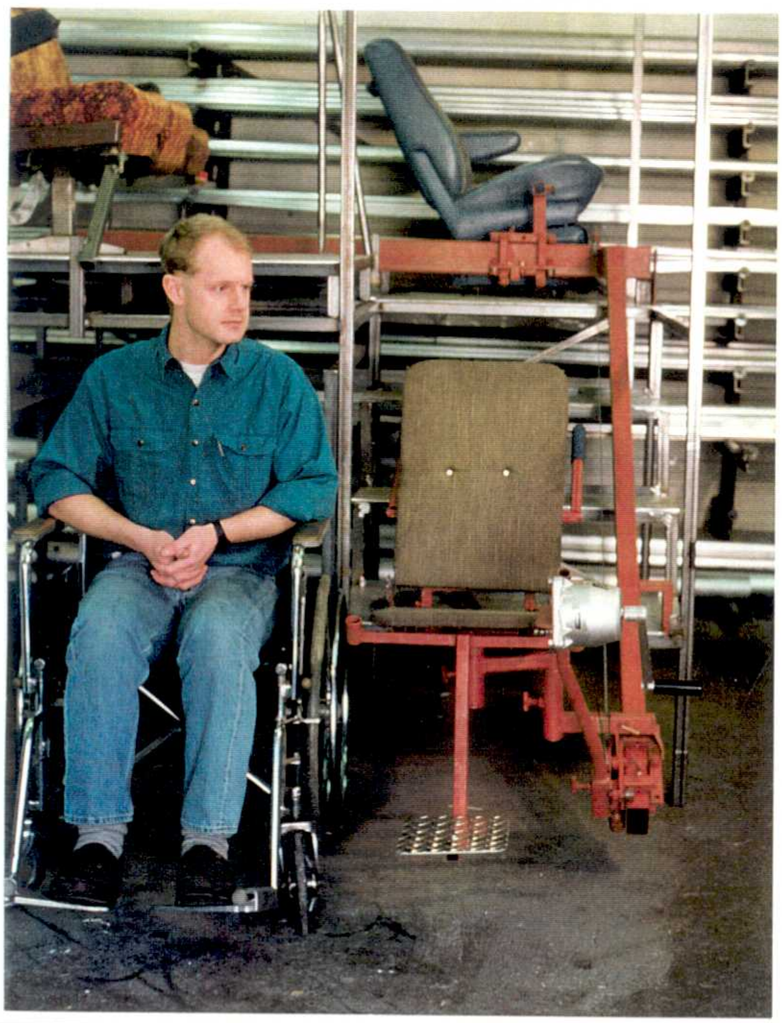
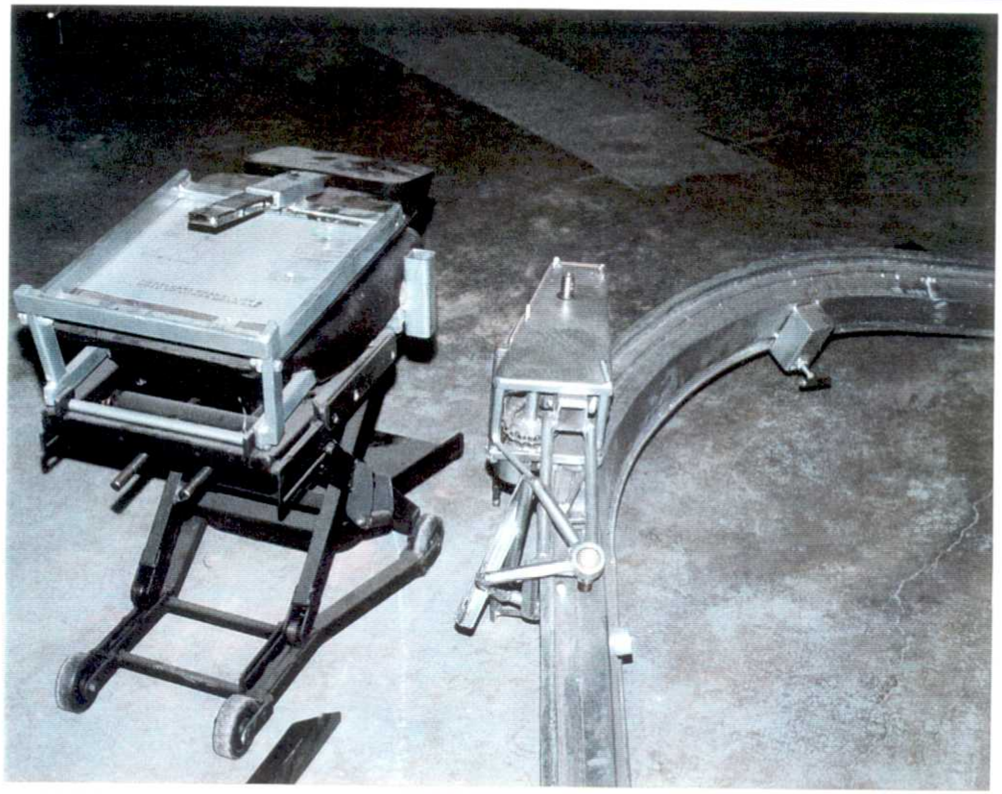


Photo 4:
Wheelchair beside mock-up, ready for transfer to chair.

Photo 5: Rail chair being cranked to the top of the stair rail.

Photo 6:
Rail chair moving along aisle rail to front row of bus seats.

Photo 7:
Custom adjustable chair with curved monorail and drive assembly.



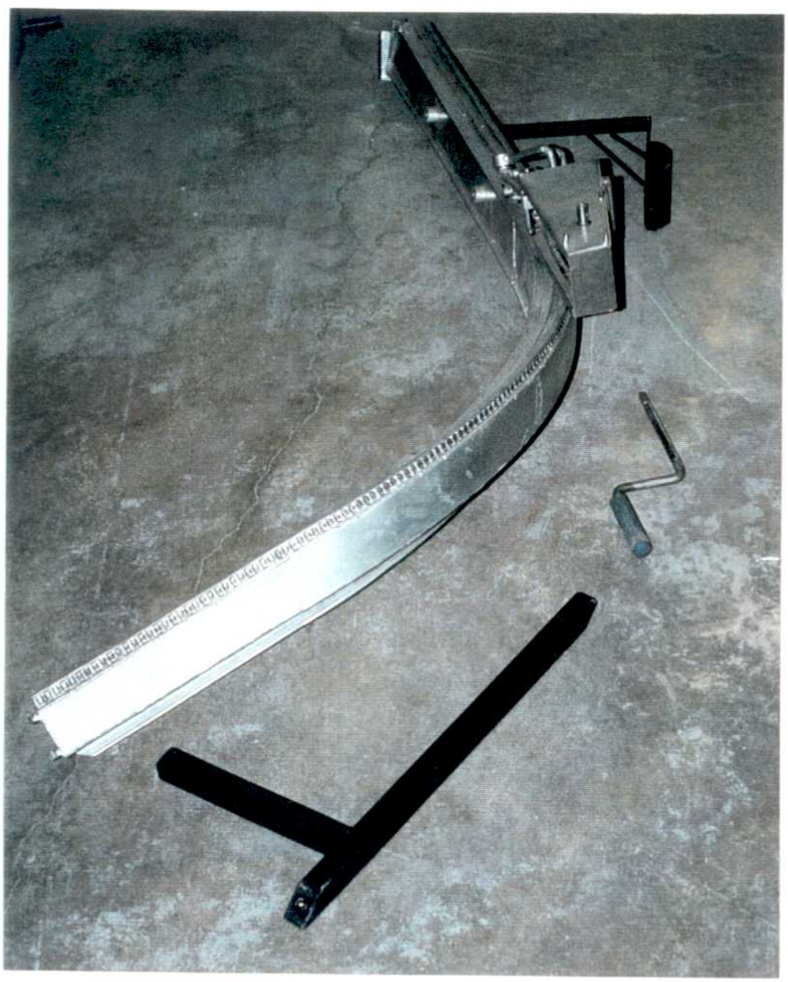


Photo 8:
Curved monorail and support components.

Photo 9:
Custom adjustable chair
in "operating" position.

Photo 10:
Monorail in bus with
passenger on custom
chair.

Photo 11:
Monorail operating in bus with passenger on custom chair.

Photo 12:
Monorail in bus with passenger at top of stairs.

Photo 13:
Driver removes Monorail from baggage tank of bus. Note that weight of rail and drive is balanced on wheel at lower end of rail.

Photo 14:
Driver moves rail into position at bus door.

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DEVELOPMENT OF AN ON-BOARD PORTABLE LIFT FOR INTERCITY BUSES

Photo 15:
Top end of rail is carried up the bus stairs and snapped into the landing adaptor plate.

Photo 16:
Monorail in operating position beside bus stairs. Note landing plate at top of stairs, which is dropped into position just before the rail is positioned. (This plate rests on the top stair of the bus but is not attached to the bus in any way)

Photo 17:
Chair deck is attached to the Monorail drive.

Photo 18:
"Stowaway" lift in position and ready for operation.

Photo 19:
Lift in position with boarding boarding chair on deck.

Photo 20:
Traveller on boarding chair, ready to be positioned on lift deck.

Photo 21:
Driver operating manual crank to raise chair and traveller.

Photo 22:
Chair and traveller at top of rail, ready to be manoeuvred around the corner and down the aisle of the bus.

Photo 23: Landing plate positioned on top step.

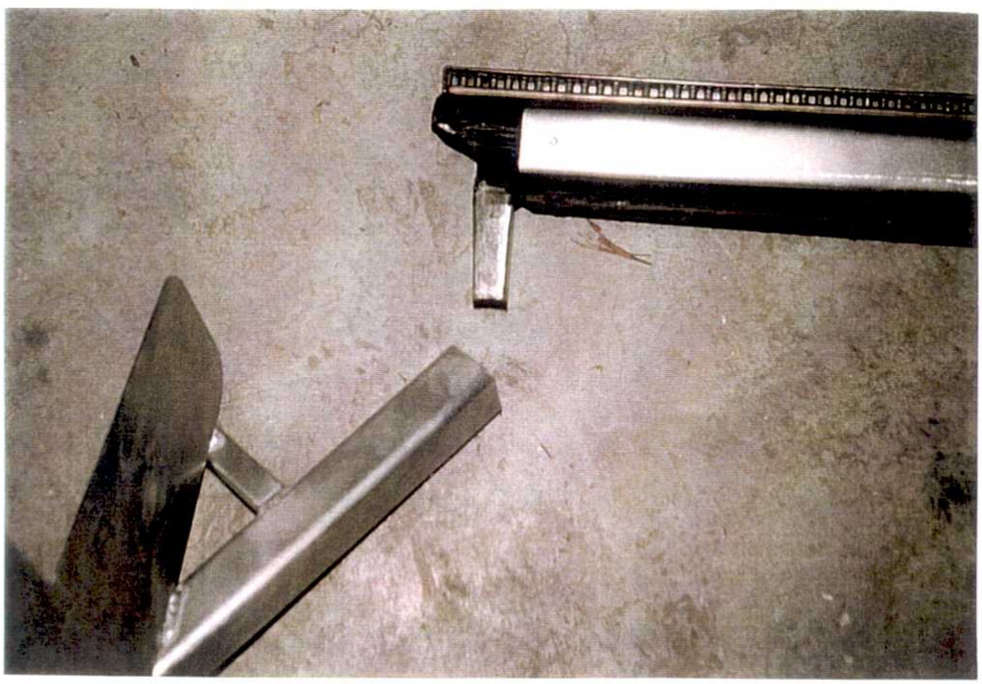

Photo 24: Monorail spigot and landing plate socket.

Photo 25:
Monorail components in bus baggage tank.
Note: these components would be in a custom box in actual service.

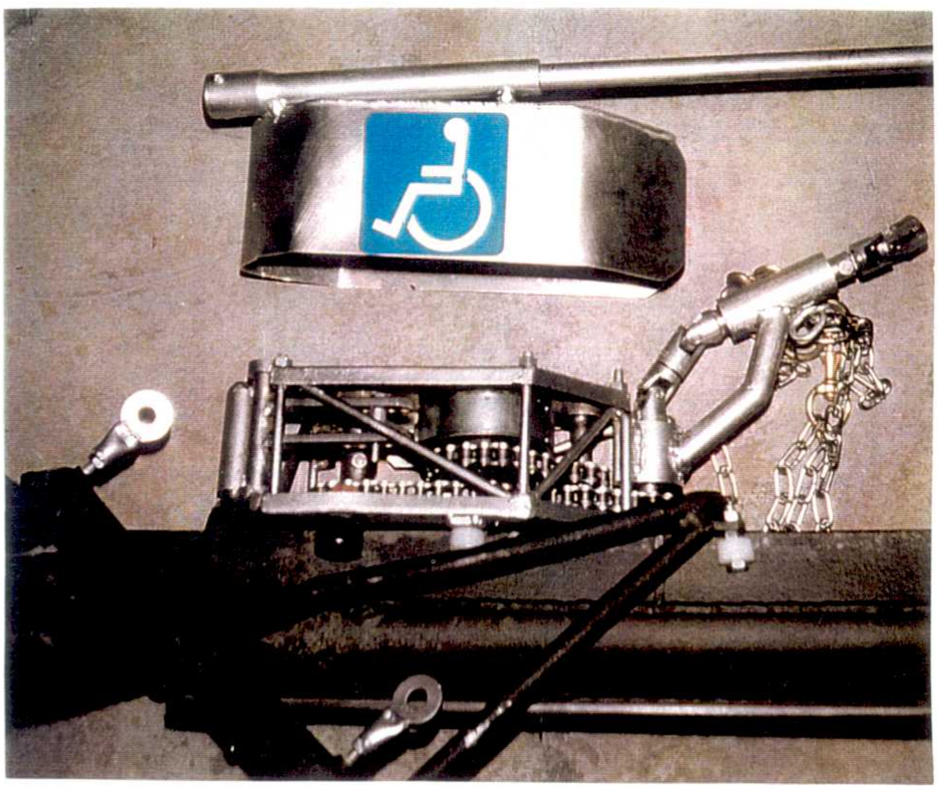

Photo 26: Details of drive, shroud, and patented braking system.