The Application of the Quality Functional Deployment Method for the Development of an Independent Locking Securement System for Mobility Aids on Public Transportation Vehicles: Executive Summary

December 1992

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The Application of the Quality Functional Deployment Method for the Development of an Independent Locking Securement System for Mobility Aids on Public Transportation Vehicles

Executive Summary
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EXECUTIVE SUMMARY

Introduction

The Independent Locking Securement System Project (ILS System Project) focused on the analysis of the mobility aid securement problem, the design and construction of several securement system prototypes, and extensive testing of both the operational and engineering aspects of the prototypes.

The primary objective of the ILS System Project was to design, build, and test a wheeled mobility aid securement system that would operate with all mobility aids in "common use" on fixed route transit vehicles. The major requirements for the system were to: maximize mobility aid user independence, minimize transit vehicle operator involvement, minimize securement and release time, and satisfy all the proposed securement standards and guidelines.

Background

Providing access on public transit vehicles for persons with disabilities is a well established goal of all public transit agencies. People with disabilities use a variety of mobility aids and other assistive devices and rely on public transportation for their personal mobility. However, the diversity and styles of wheeled mobility aids creates significant problems for public transit agencies when it comes to securing them on transit vehicles.

The problem of securing mobility aids stems from the need to adequately secure the mobility aids on transit vehicles. Currently a number of different types of systems are available to accomplish this, most making use of three or four belts that hook from the mobility aid to the floor of the vehicle. They require the driver or attendant to hook each end of each belt and tighten each to ensure that the mobility aid will not shift during normal operations and not break loose during accident conditions. Difficulties with these systems arise in securing scooter and powerbase type mobility aids as there are no acceptable places to attach the belts.

Compounding this problem is the American with Disabilities Act (ADA) requirement that all fixed route transit vehicles be accessible. The ADA definition of accessibility requires that mobility aids "in common use" must be able to both get on to the vehicle and be secured once on board.

Approach

This project proceeded in three basic phases that will be introduced here, refined in the remainder of this summary and detailed in the Volume 1 and Volume 2 reports. The first phase of this project is Problem Understanding. This phase proved more critical on the project and required more time due to the infancy of securement development. After the problem was fully understood, the second phase, Design and Construction proceeded without difficulty. The final phase, Testing was carried out to verify both the customer acceptance and performance of the final product.
Problem Understanding

In this section we will describe the method used to better understand the securement system problem. Initially the requirements on the securement system were itemized as:

1. Accommodate a large variety of mobility devices, such as sports style manual wheelchairs and “scooter” style electric wheelchairs,
2. Safely secure the mobility devices and provide restraint for the passenger,
3. Satisfy the USDOT/FTA American with Disabilities Act (ADA) regulations and guidelines, as well as the proposed Canadian Standards Association (CSA) regulations for Mobility Aids Securement and Occupant Restraint (MASOR)
4. Reduce securement time and operator involvement, and provide as much independent operation by wheeled mobility aid occupant as possible,
5. Reduce time for release of mobility device from the securement system, to reduce cycle time, and permit rapid evacuation if necessary,
6. Applicable to both fixed route and demand responsive transit vehicles, and satisfy the technical requirements of the different vehicles operating in urban, suburban and rural settings,
7. Operate in all climatic conditions,
8. Prevent relative movement between mobility aid and vehicle in regular and emergency operation,
9. Maximize occupant protection,
10. Minimize operator training,
11. Operate as a continuum between the transportation vehicle-mobility aid and occupant.

Although this list seems fairly complete, the first step in any design project is insure that the requirements are fully defined. The method used to expand and refine the requirements is called the Quality Functional Deployment (QFD) method. It set the foundation for the success of the remainder of the project.

The QFD method was developed in Japan in the mid-1970s and introduced in the United States in the late 1980s. Using this method, Toyota was able to reduce the costs of bringing a new car model to market by over 60 percent and to decrease the time required for its development by one-third. They achieved results while improving the quality of the product. Many U.S. companies now use the QFD method regularly. There are six basic steps to the QFD method:

Step 1: Identify Customer(s)
Step 2: Determine Customer Requirements
Step 3: Understand Requirement Importance
Step 4: Benchmark the Competition
Step 5: Translate Customers Requirements into Measurable Engineering Requirements
Step 6: Setting Engineering Targets for the Design

Step 1: Identify the Customer: The Project Advisory Committee

The goal in understanding the design problem is to translate the customer requirements into a technical description of what needs to be designed. The Japanese say, "Listen to the voice of the customer." To assist in this project, an advisory committee of potential securement system customers was formed. The project advisory committee included persons with disabilities who regularly use transit. Many of these persons also represented organizations associated with disabilities. Other members of the advisory committee included accessible transit planners, transit vehicle operators, maintenance personnel, transit managers, and state government representatives. The advisory committee had representatives from Lane Transit District (LTD) in Eugene, Oregon; TRI-MET in Portland, Oregon; METRO in Seattle, Washington; and B.C. Transit in Vancouver, B.C. A number of other people provided direction for the project but were unable to attend the Advisory Committee Meetings. These included: Bill Henderson, Snohomish Senior Services; Sue Stewart and Catherine Rice, Seattle METRO; Park Woodworth, TRI-MET; Micki Kaplan, LTD; Al Little, B.C. Transit; Dave Norstrom, Battelle Memorial Institute; and David Capozzi, NESS Project ACTION. Table 1 shows the structure of the advisory committee.

Step 2: Determine Customer Requirements

Once the customers were identified, the next step of the QFD method was to determine what the customers wanted in the design. The goal here was to develop a list of all the requirements that affect the design. The importance of the customer requirements was taken into account; this procedure was accomplished with the entire design team and was based on the results of repeated customer requirement surveys. The result was a list of 11 requirements cited above and later refined to 52 customer requirements.

Step 3: Understand Requirement Importance

In this step, a questionnaire was developed to determine the requirements that the customers considered most important. This questionnaire was completed by our advisory committee and other members of the transit community. The results showed that the most important requirements were to minimize driver involvement, maximize user independence and minimize attachment and release time.
Table 1 Structure of the Advisory Committee

<table>
<thead>
<tr>
<th>Transit Agencies:</th>
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<tbody>
<tr>
<td>Lane Transit District (LTD), Eugene, Oregon</td>
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<td>TRI-MET, Portland, Oregon</td>
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<td>METRO, Seattle, Washington</td>
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<td>B.C. Transit, Vancouver, B.C., Canada</td>
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<th>Accessible Service Managers:</th>
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<tr>
<td>Micki Kaplan, LTD</td>
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<tr>
<td>Patricia Neilson, TRI-MET</td>
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<tr>
<td>Park Woodworth, TRI-MET</td>
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<tr>
<td>Robert Carroll, METRO</td>
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<tr>
<td>Roxanne Sumners, Corvallis Transit</td>
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<tr>
<td>Bruce Chown, B.C. Transit</td>
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| Vehicle Operators, LTD, TRI-MET, and B.C. Transit |

| Maintenance Personnel, LTD, TRI-MET, and B.C. Transit |

| Accessible Service Committee Members, LTD, TRI-MET, and B.C. Transit |

<table>
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<tr>
<th>State Government:</th>
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<tbody>
<tr>
<td>Paul Gamble, Washington State Department of Transportation</td>
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<td>Steve Fosdick, Oregon Department of Transportation</td>
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<tr>
<td>Dinah Van Der Hyde, Oregon Department of Transportation</td>
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<th>Consumer Groups:</th>
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<td>Paralyzed Veterans of America, Portland and Eugene Chapters</td>
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<th>Industry Representatives:</th>
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<td>Philip Gebhart</td>
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<th>Other Advisors:</th>
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<tr>
<td>Jim Flemming, Project ACTION</td>
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<td>George Izumi, USDOT/FTA</td>
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<td>Marina Drancsak, USDOT/FTA</td>
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<tr>
<td>David Capozzi, Access Board</td>
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<tr>
<td>Dave Norstrom, Battelle Memorial Institute</td>
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<tr>
<td>Robert McCowan, Battelle Memorial Institute</td>
</tr>
<tr>
<td>Bill Henderson, Snohomish Senior Services</td>
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<tr>
<td>Catharine Rice, METRO</td>
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<tr>
<td>Sue Stewart, METRO</td>
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<td>Al Little, B.C. Transit</td>
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| Oregon Architectural Barriers Committee Members |
Step 4: Benchmark the Competition

The goal of competition benchmarking was to determine the competition’s ability to meet each of the requirements. The purpose for doing this was two fold; first, it helped the design team understand similar and existing products and met some of the customer requirements; and, second, it pointed out opportunities to improve on these products.

In some companies this process is called benchmarking and is a major aspect of understanding a design problem. In benchmarking, each competing product must be compared with customer requirements. Some of these comparisons are objective and can be measured directly; others are subjective and customer opinion may be needed.

One value of the QFD method is that it encourages the evaluation of existing systems. In Step 4 the benchmarks are compared to the customer’s requirements and in Step 5 to the engineering requirements. In order to make this step manageable, all existing securement systems were represented by five examples:

Device A: a single wheel clamp system that can be used on wheelchairs only.
Device B: a three belt system that can be used on both wheelchairs and scooters.
Device C: a wheel clamp and belt system that can be used on wheelchairs only.
Device D: a center pin system that is used by mobility aid users who drive their own vans.
Device E: a wheel bracket system which is proposed for use on wheelchairs only.

None of the above Benchmark Devices met the most important customer requirements. Certain devices scored higher in some areas than others, indicating their specific design strengths. The conclusion from this comparison was that there was no present device that could be considered as a universal securement. This gave the design team the go ahead to start with new design idea generation. The device (center pin device D) that scored the highest in this comparison formed the basis for a starting point of new idea generation.

Step 5: Translate the Customers Requirements into Measurable Engineering Requirements

The goal in this step is to develop a set of engineering requirements (often called design specifications) that are measurable for use in evaluating proposed product designs. First, customer requirements were transformed to engineering requirements. Second, each engineering requirement became measurable. Some customer requirements were directly measurable and did not require translating. But requirements like “easy to attach” needed to be redefined so they could be measured.

The project began by finding as many engineering requirements as possible that indicated a level of achievement for each customer requirement. For example, the “easy to attach” customer requirement could be measured by (1) the number of steps to attach, (2) the time to attach, (3) the number of parts needed, and (4) the number of standard tools needed. Each of these was clearly measurable except the time to attach, which was dependent upon the skill and training of the customer.
An important point here is that every effort must be made to find as many ways as possible to measure each customer requirement. If there are no measurable engineering requirements for a specific customer requirement, then the design engineer will not be able to know if he has met the requirement. If no measurement can be found, it is usually an indication that the customer requirement is not well understood. Possible solutions for this are to break the requirement into finer independent parts or to redo step 3, with specific attention to that specific requirement.

The engineering requirements were developed by considering each customer requirement and asking the question, "How many ways can be found to measure this requirement?" The resulting list contained 72 engineering requirements that measured the 52 customer’s requirements and fully characterized the securement problem.

Step 6: Set Engineering Targets for the Design

In step 4, competition products were compared to the customers requirements. Here the need was to measure the product against the engineering requirements. This assumes that the knowledge and equipment exists for evaluation. Also, the values obtained by measuring the competition provide a basis for establishing the targets. This usually means obtaining actual samples of the competition’s product and measuring them in the same way as measuring the product being designed.

The last part of this step in the QFD technique was to determine target values for each engineering measure. As the product evolved, these target values were used to evaluate the product’s ability to satisfy customer requirements. There were two actions needed here. The first was to ascertain how the competition, examined in step 4, met the engineering requirements, and the second was to establish the value obtained with the new product.

Setting targets early in the design process is important; targets set near the end of the process are easy to meet but have no meaning. Some customer requirements will have ready-made targets—the requirement that a device must lift 100 Kilograms mass, for instance, is measurable and provides a specific target. But for other requirements, realistic targets need to be set. These values define an ideal product and must be based on what is physically realizable, which is why it is essential to examine the competing products.

Value of Method and Results

The QFD method was used to aid in developing an understanding for the securement system problem. The effort to develop the customers requirements led to a closer relationship to and respect of the advisory committee. It also led to an increased understanding by the designers and advisory committee of what the securement system needed to accomplish.

The development of the engineering requirements and targets was probably the most beneficial part of the effort. The need to generate measurable requirements forced deeper research into the operation of
securement systems and interfaces with mobility aid passengers. In addition the effort to benchmark the competition, although somewhat shortened, generally helped gain an understanding of the strong and weak points of existing systems. Basically, development of the above engineering requirements means that all future devices and their modifications will now have a set of design standards for comparing changes.

Conclusions Regarding the Application of the QFD Method to the Securement System Design Problem

The QFD method has permitted the design team to approach an ill defined and complex design problem systematically and orderly. The QFD method forced the designers to clearly define the “Customer” and this was the first step in understanding the problem. In this particular application of the QFD method the “Customer” was represented by an Advisory Committee. The Advisory Committee provided strong direction and guidance for the project at a number of important stages of the problem definition phase. Initially, the advisory committee assisted with the development of the QFD Information, namely, the development of all the customer requirements.

There have been no changes in the design concept since its inception, however there have been many design refinements. The advisory committee’s input strongly directed the design of the securement system. The resulting design is sensitive to the requirements of all the “Customers” and more important, it has been widely accepted by the “Customers”.

The QFD method is useful on all types of design problems and results in a clear set of customer requirements and associated engineering measures. It may appear to slow the design process but, in actuality, it doesn’t. Time spent developing information in the Problem Understanding Form is returned in time saved later in the design process.

The application of the QFD method to the development of the ILS System has shown both the potential and power of this design process. The QFD method forces the designers to fully understand the problem before development of design concepts begins, and it also promotes the development of a body of design knowledge that can be used by others approaching the same or similar design problems. The QFD method insures that the needs of the customer are integrated into the design. The OSU design team is currently using the QFD method to develop a passenger restraint system that will be used with the ILS System.

Design and Construction

Based on the requirements and knowledge developed through the use of the QFD method the design team used other design techniques to develop the Independent Locking Securement System. Specifically, organized methods were used to generate and evaluate over 20 different basic concepts for the system. These were compared to the requirements and to each other in an iterative process to choose the best. The resulting system was then refined to hardware through a series of prototypes.
The Securement System concept is made up of two parts: the capture mechanism, which is attached to the transit vehicle and the interface unit which is attached to the mobility aid. The securement system is designed to secure a mobility aid in the forward facing position; this is consistent with the policy adopted by the international standards organization. Basically, the securement system has been designed to satisfy the proposed International, Canadian, and United States Standards for the securement of mobility aids and the restraint of their occupants. The interface unit has been designed to meet the proposed standards. However, many of the mobility aids, as they are presently built, do not have the structural integrity to withstand the accelerations and resulting force loadings specified in the proposed standards. The interface units do not compensate for deficiencies in the structural integrity of the mobility aids. The capture mechanism can be fastened directly to the floor structure of the chassis of the transit vehicle.

**Capture Mechanism**

The capture mechanism is a box-like structure that is fastened to the floor of the transit vehicle, and it holds the D rings of the interface unit which are attached to the mobility aid. The capture mechanism prevents the mobility aids from moving forward, backwards, sideways, or up and down. The capture mechanism also controls rotation of the mobility aid about the longitudinal, vertical and horizontal axes. In order to limit these translations, rotations, and control forces and moments (torques), the capture mechanism must be versatile. The capture mechanism uses two latch mechanisms, derived from car door latches. These latches are mounted 14.0 inches apart on a sliding bar that sits on a rotating pedestal. The 14.0 inch dimension is required to accommodate the moments or torques that result from securing a power base wheelchair and occupant. The easy rotation and translation of the capture mechanism compensates for mis-alignment between the mobility aid and the center line of the securement system when a person backs into the securement system. Built-in stops limit the rotation of the capture mechanism to ± 10 degrees. The height of 7 inches above the floor of the transit vehicle of the latches permits the line of action of the holding force to go below the center of gravity of all mobility aids. This is essential to keep the front wheels from lifting during deceleration.

Electrical switches placed in the mobility aid station and at the operator's cockpit activate a solenoid to release the latches. A mechanical release system permits release of the latches if the solenoid fails. A disable mechanism is also provided so that when the transit vehicle is moving, the disable system inactivates the electrical system so that the solenoid can not be activated to release the latches.

An energy management system is incorporated into the capture mechanism to attenuate energy in severe driving or accident conditions.

**Interface Unit**

The Interface Unit is the hardware that attaches to the back of the mobility aid. It consists of double D-rings. That are 4 inches high in the vertical plane, 3/8 inches in diameter and are placed 14.0 inches
apart. The D-rings are constructed out of mild carbon steel. The D-rings are designed to deform under high load conditions, and this deformation absorbs some of the energy.

The attachment of the D-ring assemblies is dependent on the design of the mobility aid. All interface units attach to the mobility aid at main structural points. The interface unit for the manual wheelchair is made up of two parts. A bracket is fastened to the main axle area of the manual wheelchair. Inserted into the bracket is a rod consisting of the D-ring assembly. The total weight for the two rods and two brackets is three and a half pounds. The brackets that are permanently attached to the wheelchair only weigh one and a half pounds. The interface unit does not project outside the envelope of the mobility aid and it still allows a manual or sport wheelchair user to collapse their wheelchair or to jump curbs. The additional weight of the interface unit has a negligible effect on the center of gravity of the mobility aid.

The interface bracket that is attached to the back of the scooter consists of a ring that helps to stabilize the seat post and two brackets that fit onto the back axle.

**Securement System Operation**

To use the securement system, an individual backs onto the transit vehicle, as is standard operating procedure for most transit operations. To use the capture mechanism the mobility aid user simply backs in and is latched. A green light just beside the release switch indicates to the mobility aid occupant that the mobility aid has been correctly secured. If the mobility aid has not been correctly secured, the mobility aid passenger simply presses a low resistance switch to release the securement system and tries again. A duplicate light in the driver’s cockpit indicates to the vehicle operator that the mobility aid has been latched in.

To release the securement system, the mobility aid user simply presses a switch and drives out. If the mobility aid user is unable to press the switch, the operator can release the securement system with a switch in the operators’ cockpit.

**Other Features**

During one of the advisory committee meetings, many mobility aid users who use transit complained that when the floor was wet there was no traction. It is recommended that non-slip flooring materials be used in the securement station.

**Testing**

The testing and evaluation program included human factors testing and static and dynamic structural performance testing. The human factors testing determined how well the system performed from the perspective of the user, the vehicle operators, maintenance, and transit management. A second part of the human factors analysis determined how well the prototype satisfied the design specifications and met the customers’ requirements, in other words the prototype was “benchmarked”.
Engineering tests were carried out both on a transit vehicle and in the laboratory to demonstrate first that the securement system would meet (a) all ADA specified requirements for mobility aid motion and strength and (b) the engineering design specifications that resulted from the QFD analysis. Testing on the vehicle allowed in-service measurement of mobility aid motion under normal and severe operating conditions. Laboratory testing included quasi-static strength tests (for ADA strength requirements) as well as side load testing, sled tests to simulate the dynamics of a vehicle frontal crash, and dynamic latch mechanism testing.

Human Factors Tests

Human performance consists of behaviors and actions performed by personnel in the course of completing a task. This performance is often degraded because of poor system designs. Here human factors testing consisted of the observation and objective measurement of mobility-aid users performance using the ILS System. It also included the measurement of attitudes of the system users and transit personnel. The purpose of the human factors tests in this project was to ensure that the securement system matches the capabilities and limitations of mobility-aid users.

The results of the human factors testing are:

1. Safety — The subjects indicated that they felt secure when their mobility-aids were latched to the capture system. Video recordings of the tests showed that the capture system was successful in limiting the motion of the mobility-aids.

2. Skill Development Time (Training) — The design of the securement system is a major departure from any other securement system users have seen, as a result, the target of zero training time for mobility-aid users was unrealistic. However, a simple training sheet and 5 to 10 minutes discussion of the system was provided prior to the beginning of each test. This proved to be sufficient. Training for the transit operator was approximately 15 minutes, less than the goal of 20 minutes.

3. Satisfaction (Acceptance) — The users’ acceptance of the system was the most encouraging outcome of the tests. Five out of the six mobility aid passengers tested liked the system. The sixth did not like the interface unit on his chair. The transit operators surveyed indicated that they liked the system and that the basic design concept was sound and practical.

4. User Independence — The most attractive feature of the securement system for all subjects and transit operators was the total user independence in securing and releasing the mobility-aids. Subjects who used the system were able to back their mobility-aids into the capture system, latch their mobility-aids, and then release them from the capture system without any assistance. The transit operator’s role
was limited to verifying that the mobility-aid was latched by simply checking the light indicator located in the driver's cockpit.

5. Speed — The ease and speed with which users were able to use the securement system was the most impressive part of the tests. The average time was found to be 11 seconds. Approximately 69 percent of the time mobility-aid users were able to latch to the capture system on the first attempt. Approximately 28 percent of the time mobility-aid users had to make a second attempt in order to latch to the capture system. Only 3 percent of the time did mobility-aid users have to make a third attempt to latch to the capture system.

6. Misalignment Compensation — It is unreasonable to expect a user to have perfect alignment either laterally or rotationally when backing into the capture system. The capture system has the capability to compensate for user misalignment. However, the results of the test showed that the required compensation was less than originally expected. Tests showed that lateral compensation of \( \pm 1 \) inch is actually needed. This is one half of the \( \pm 2 \) inches originally designed into the system. Also the prototype capture system had the capability to compensate for \( \pm 10 \) degrees of angular misalignment. But the test results showed that only \( \pm 5 \) degrees are sufficient, however \( \pm 10 \) degrees is provided.

The results of the human factors tests were generally positive and encouraging. The subjects felt that the securement system is safe and easy to use. They were particularly impressed by the independence that the system offered them in securing and releasing their mobility-aids without any assistance. The built-in capability of the capture system to compensate for users’ misalignment in backing their mobility-aids proved to be a major source of users’ acceptance of the system.

**Engineering Tests**

An important feature of any securement system is its performance under load. In this case performance means two things: (1) how much motion of the mobility aid is allowed by the securement system under normal operating conditions and (2) does the securement system have the required strength to prevent unwanted movement of a mobility aid during crash conditions.

The approach taken to measure these engineering performance parameters was to test the prototype securement system in progressively higher loading conditions up to a final sled test which imposed an instantaneously applied force of 4200 pounds on the system. As often happens when conducting engineering tests, some of the results led to additional, unplanned testing to answer questions about why the results turned out the way they did.
Normal Operations Testing

A prototype securement system was installed on a lift equipped Lane Transit District bus in Eugene, Oregon. The bus was driven on the road as though following a normal bus route and the movement of the mobility aids (manual wheelchair and three-wheeled scooter) was observed and recorded on video tape. In addition, the bus was driven in a parking lot to extreme conditions for turns left and right, for acceleration, and for stopping. The accelerations corresponding to those conditions were measured and the movements of the mobility aids were recorded on video tape. The maximum movement of a mobility aid throughout these tests was less than one inch. This occurred during a maximum rate turn; the rear wheel of a three-wheeled scooter lifted approximately 3/4 inch before the securement system stopped the tipping motion.

Side Slip Testing

As a result of the normal operations testing, it was decided that more information was needed about the effect of side loads on stationary mobility aids. A tilt table was built and a manual wheelchair and three-wheeled scooter were tested for movement due to side loads both with and without the securement system. In addition, a power base was tested for movement without a securement system. The general conclusion is that powered mobility aids will not move appreciably under normal operating conditions because of their inherent electrical braking, but manual wheelchairs will move very easily if not secured.

Quasi-Static Testing

To demonstrate the strength of the securement system (both the capture mechanism and the interface unit), the system was loaded in an INSTRON tensile test machine to 6000 pounds. This load corresponds to a 300 pound mobility aid being held by the securement system during a 20 G crash.

Sled Testing

Two prototype securement systems, a 200 pound power base and a 120 pound three-wheeled scooter were taken to the sled test facility at University of Michigan Transportation Research Institute UMTRI. First, the scooter was tested with a 50th percentile male dummy in a 20 MPH 10 G crash to simulate a typical expected crash load in a large bus. The scooter was then tested without the dummy at 30 MPH and 20 G to simulate a crash in a van. The second securement system was then installed and the power base was subjected to the same test conditions. A major conclusions was that rear attachment at slightly above center of gravity is a good approach. For both mobility aids, there was little motion during the 20 MPH 10 G tests. During the 30 MPH 20 G tests, a flaw was uncovered in the way that the latch/keeper mechanism was installed in the test prototypes. This flaw resulted in the release of a latch in each of the high energy tests.
Latch Mechanism Testing

Following the sled tests, a test facility was built to impose either a static or a dynamic load on a single latch mechanism. This facility was used to test a theory on why the latches failed during the high energy sled tests. The theory was confirmed and a minor modification to the latches has been designed to eliminate the problem.

Conclusions

The human factors testing results indicated the strong "customer" satisfaction with the ILS System. The engineering tests provided information on both the static and dynamic structural integrity of the ILS System. The dynamic tests indicated a problem with the design of the latch mechanism, and further testing confirmed the mechanism of failure. Since the mechanism of failure has been analyzed, refinement of the mechanism is possible.