A FARE TO REMEMBER
Design Research Findings Related to Wheelchair Securement On Large Transit Buses

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Introduction

> "Humans, I discovered, do not always behave clumsily. Humans do not always err. But they do when the things they use are badly conceived and designed."
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> —Donald Norman(1)

In the spring of 2002 researchers at the Human Factors Research Laboratory at Arizona State University began work on a project to improve wheelchair tie-down and securement systems (WTORS)[1] on large transit buses.[2] Before any improvements could be made, of course, we had to first understand how existing WTORS are used. To our surprise, however, what we discovered was an all too frequent pattern of *misuse*. We knew the existing design wasn't very user friendly (this was the basis for the project in the first place), but we had assumed from the start that it *was* being used. By shifting our focus to address this more fundamental issue, we came to understand *why* these systems are misused (or unused). This paper is a brief summary of our key findings.

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[1] Although the project concerns both securement (of the wheelchair) *and* restraint (of the occupant), this paper addresses primarily wheelchair securement.

[2] ASU researchers acted as subcontractors in a National Institute of Health (NIH) Small Business Innovative Research (SBIR) grant (1R43HD39567).

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As part of the Americans with Disabilities Act (ADA) public transit providers are required to accommodate "common wheelchairs".[3] The majority of wheelchair users remain seated in their chair during transport (as opposed to transferring to another seat on the bus), despite the fact that most wheelchairs are not intended for use as transport seating.[4] In order to secure the wheelchair, and restrain the occupant, most buses are outfitted with some type of wheelchair tie-down and occupant restraint system (WTORS) – the most common being a three- or four-point hook-and-strap system(2). Functionally, these systems are quite capable; they meet all the necessary regulations[5] and comply with the *letter* of ADA. When it comes to usability and human factors issues, however, these systems leave much to be desired. Indeed, surveys of transit providers, consumer organizations, wheelchair manufacturers, test facilities, and government agencies rank "ease of use" second only to "safety" as WTORS criteria (3, 4). Furthermore, while there is little in the way of injury data for wheelchair users aboard transit buses(5), a major study suggests that improper securement is the leading cause of injuries to these passengers(3). Clearly, an improved WTORS – one that meets the *spirit*, as well as the *letter*, of ADA – presents an excellent design opportunity, with far-reaching consequences.

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[3] Here the term is used generally - to describe any of the various wheeled mobility devices (including manual chairs, powered chairs, motorized scooters, etc.)

[4] The ANSI/RESNA WC-19 standard was recently established "to promote occupant safety and reduce the risk of injury for motor-vehicle occupants who remain seated in their wheelchair during transit". At this time the standard is strictly voluntary, however.

[5] The most severe portion of the existing regulation is the requirement for a 30mph/20g crash-simulating sled test.

Findings

As with all good research projects, ours began with a review of the literature. However, we moved quickly from the library into "the field" – which in our case meant large transit buses – to see firsthand how the WTORS are used. First as observers, and later as participants[6] we gained some critical insights. Specifically, we found that:

1. The bus operator is the key "actor" in the wheelchair securement/occupant restraint activity. This insight was quite evident once a detailed task analysis was performed (see Fig. 1).
2. The two aisle-side securement straps (see Fig. 2 for diagram of securement area) – those most accessible by the bus operator – are often the only straps used. (This seems to be a rather common scenario, as we witnessed this same situation repeatedly.)
3. The rear window-side strap (the most difficult for the operator to use) is rarely used.
4. The securement procedure (sequence of events, number of straps, anchor points used, etc.) varies considerably from operator to operator.
5. The occupant restraint system (shoulder/seat belt combination) is rarely used at all (during our observations, we never saw an operator offer it to a wheelchair user).

[6] Some researchers rode buses in scooters and manual wheelchairs, while others took photos and notes.

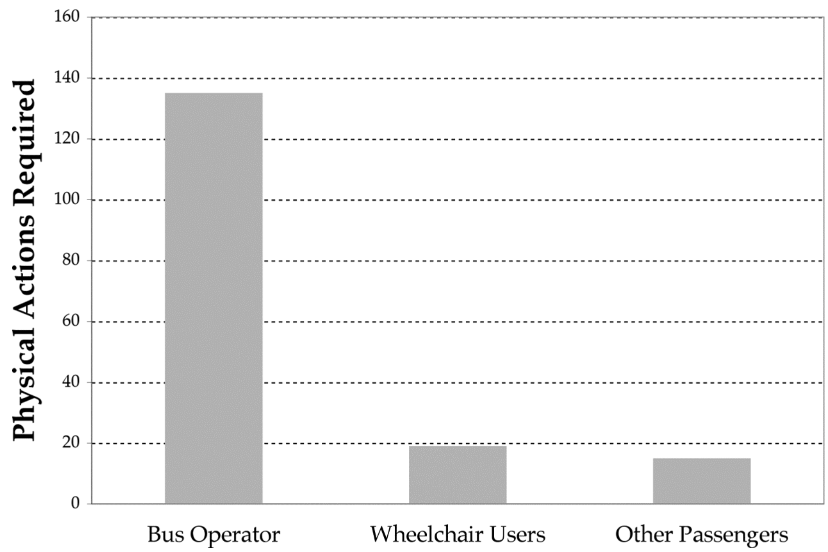


Figure 1. Number of tasks performed by each "actor" in the wheelchair securement process

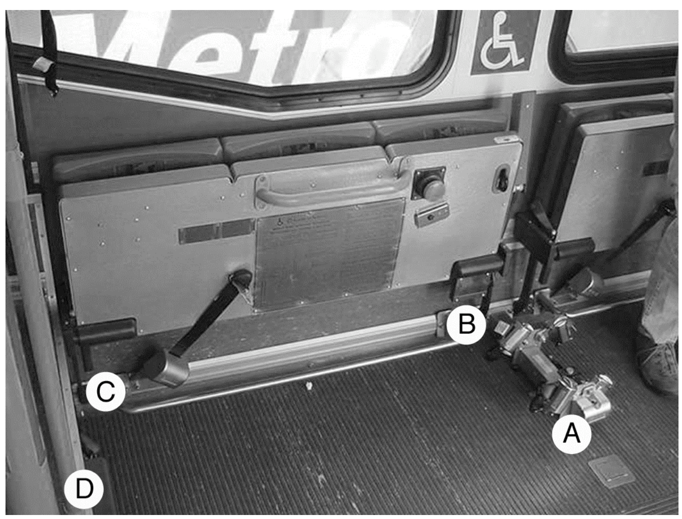


Figure 2. Wheelchair securement area on large transit bus (A=front aisle-side strap; B=front window-side strap; C=rear window-side strap; D=rear aisle-side strap (not shown))

In order to better understand what we had observed on the buses, we conducted a focus group of 14 bus operators and trainers, which provided some insights as to why the WTORS might be misused. The general consensus among the bus operators was that the existing systems are very difficult and inconvenient to use. Operators need to bend, twist, reach, and sometimes even crawl on the floor in order to properly secure wheelchairs (see Figure 3). Occupant restraint is no easier; it involves leaning over wheelchair users and invading their personal space. Add to all of this the fact that the bus operators have very little space in which to work, and need to work quickly to keep tight route schedules, and non-compliance becomes more understandable (perhaps even *expected*).

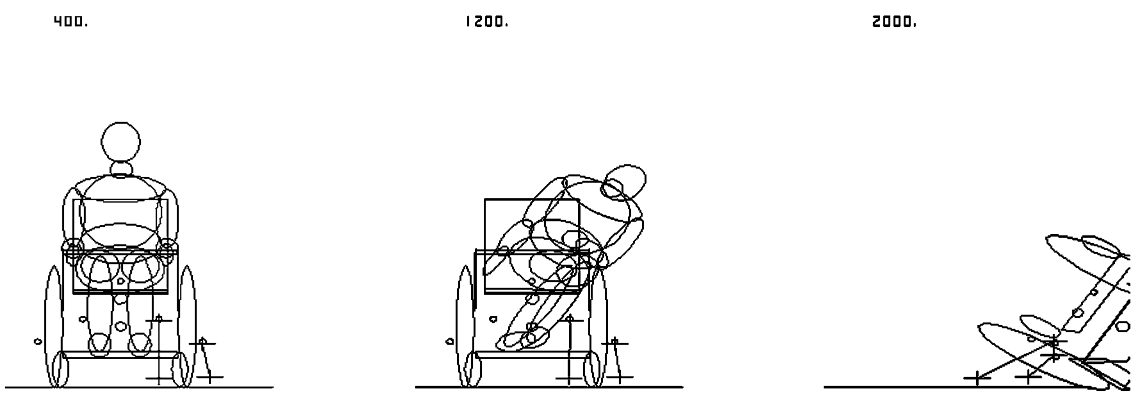
Figure 3. Operators securing a manual wheelchair into a transit bus.

To further complicate matters, the procedure for proper securement and restraint seems to be unclear, despite initial training from the transit provider. It is important to note that, in general, the participants expressed concern for the safety of their passengers, and that they understood the need for accommodating all wheelchair users. We concluded, therefore, that the non-compliance we had observed was caused primarily by a failure of *system design*, and not as failure on the part of the bus operator.

Computer simulations are often used to predict WTORS performance during severe crashes. However, we used these same simulations[7] to predict what might occur to an improperly secured wheelchair (such as we'd seen so many times) under "emergency driving conditions"[8] – conditions that, while not everyday occurrences, occur with far greater frequency than do severe crashes.

The computer simulation results showed clearly that:

1. Use of only the aisle-side straps for securement (a scenario we frequently observed) may lead to tipping of the occupied wheelchair (see Fig. 4);
2. Without the use of a lap belt (part of the rarely-used restraint system), the wheelchair user is likely to be ejected from the wheelchair during "emergency driving conditions".



[7] During this phase of the research we worked closely with the Rehabilitation Engineering Research Center (RERC) at University of Pittsburgh (Pitt), leading experts in the field of wheelchair transportation safety.
[8] "Emergency driving conditions" were simulated with 0.7g braking and 0.6g turning forces.

Figure 4. Images from computer simulation showing wheelchair tipping into the aisle when only the aisle-side straps are used for securement (20 mph/0.6g turning maneuver, 400, 1200, and 1600ms "snapshots" shown)

Discussion

At the core of our findings is one that seems utterly obvious: *the bus operator is the primary user of the WTORS*. And if wheelchairs are being improperly secured due to human error, then it's because – to use Norman's words – "the things they use are badly conceived and designed." We are confident that a well-designed WTORS (meaning one that considers the usability needs, ergonomics risk factors, and human factors issues of bus operators) will achieve greater compliance, and therefore improve the safety of all passengers.

It seems to us that one of the reasons for the poor usability of existing WTORS is a strong emphasis on safety regulations, some of which have recently been called into question.[9] Obviously, safety must be the number one concern for WTORS, but if human factors considerations are neglected, compliance suffers. As Nils Bohlin, the man who invented the three-point seat belt (credited with saving a million or more lives worldwide), has noted(6):

> "In a way, my design works as much because the belt is comfortable for the user as it does because it is safer."

[9] Specifically, the 20g deceleration level has been questioned as it applies to large transit buses because, in general, the literature indicates that such severe crashes are extremely rare.

Like Bohlin, we recognize the relationship between comfort and safety. Without comfort (i.e. human factors considerations), compliance suffers; without compliance safety suffers. The best way to ensure safety, then, is by way of good design.

Future Work

The Human Factors Research Laboratory recently applied for an additional grant that would allow research in this area to continue. In addition, the lab recently received a seed grant to begin development of a digital anthropometer.

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