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INTRODUCTION

I have been retained by the counsel of the Estate of Esther Zydiak (Esther) and Russell Zydiak to review the information regarding docket # SOM-L-497-00 which involved Esther falling out of her wheelchair while riding in a paratransit van. My report encompasses the background and principles of wheelchair rider occupant protection. A discussion follows that explores the event that caused the fall and whether the fall would have occurred had Esther been properly restrained. Preliminary conclusions are provided.

BACKGROUND

People seated in wheelchairs while traveling in motor vehicles, including children traveling to school, adults traveling in public transit and paratransit vehicles, elderly traveling to and from nursing homes, and wheelchair-seated drivers and passengers of personally licensed vans have generally traveled at significantly higher risk of injury in a vehicle crash than the able-bodied population. This increased risk is not so much a result of a reduced tolerance to injury (which may also be the case) as it is due to the absence of effective occupant restraint systems, comparable to those available to travelers in vehicle seats that are regulated by federal safety standards (SAE Recommended Practice J2249 Wheelchair Tiedowns and Occupant Restraints for Use in Motor Vehicles Application Guidelines Sec. I-Introduction (ver. June, 1999)). In order to improve transit safety for wheelchair riders, numerous safety standards have been implemented or are under development to reduce the risk faced by wheelchair users. These include the Americans with Disabilities (ADA) wheelchair tiedown and occupant restraint regulations (49 C.F.R. Vol. 56, No. 173, 9/6/1991), the National Highway Safety Traffic Administration (NHSTA) School Bus Passenger Seating and Crash Protection Standard (Federal Motor Vehicle Safety Standard (FMVSS) 49 CFR 571.222, amended 1991), the Society for Automotive Engineers (SAE) Wheelchair Tiedown and Occupant Restraint Systems (WTORS) for Use on Motor Vehicles (SAE # J2249 published May 1997), and the nearly-completed International Standards Organization (ISO) Restraint Systems – Wheelchair Tiedown and Occupant Restraint Systems for Motor Vehicles – Part 1 (ISO/CD 10542 - 1).

These standards and many more local, state, and national standards both in the US and abroad, although they differ in specifics, reflect basic principles of occupant protection. The following is a statement of these principles adapted from the draft companion document to the SAE standard, RPJ2249-Application Guidelines Sec. III-Basic Principles of Occupant Protection (ver. June, 1999).

Principles of Occupant Protection

The occupant restraint system for people who ride in wheelchairs aboard motor vehicles should adhere to basic principles of occupant protection. These principles are based on the simple fact that most serious injuries in a vehicle crash are due to the occupant moving into and contacting interior vehicle components. Thus, effective occupant protection requires effective occupant restraint that is best accomplished by:

- insuring that the vehicle seat (i.e., wheelchair) is secured effectively to the vehicle.
- using both upper and lower torso restraints to minimize lower and upper body excursions.

The primary cause of occupant injury in a crash is direct contact (i.e., impact) of the body with vehicle interior components. Thus, the single most effective way to minimize injuries and reduce injury severities is to provide effective occupant restraint that reduces the probability and severity of occupant contacts within the vehicle.

For able-bodied adults, effective restraint is provided by the vehicle OEM (original equipment manufacturer) three-point restraint system and the vehicle seat. There are, however, many adults and children with disabilities for whom transfer to the vehicle seat is not practical or acceptable because of their size and/or types and degrees of disabilities. For these individuals, the wheelchair must serve as the vehicle seat, in which case the occupant restraint system installed by the vehicle manufacturer usually cannot be used effectively. In addition, the wheelchair must be secured to the vehicle so that it does not move in a crash and impose forces on the occupant and/or become a hazard to other vehicle occupants in a collision or sudden vehicle maneuver. Thus, for people in wheelchairs, an effective occupant protection system must provide *both **wheelchair securement*** and ***occupant restraint***.

Since the purpose of an occupant restraint system is to minimize, and ideally prevent, contact of the occupant's body with vehicle structures, both upper and lower torso restraints are recommended to reduce knee, chest, and head excursions and potential interaction with the vehicle interior. A properly positioned lap belt alone will prevent an occupant from being ejected from the vehicle or from being thrown about inside. A lap belt should be fit snug and low across the pelvis and not across the injury-sensitive abdomen.

The primary focus of the standards effort has been to reduce the risk to wheelchair riders in a vehicle crash. However, the principles of occupant protection also apply in cases where the wheelchair occupant in exposed to forces caused by vehicle motions due to accelerating, braking, turning, or uneven pavement. In these cases, the forces acting on the wheelchair and wheelchair rider are much smaller than those encountered in even a minor crash. Therefore, riders protected by properly used wheelchair securement and occupant restraints designed for protection in a crash would be safe in events involving non-crash vehicle motion.

Most of the injuries during 1986 to 1990 that were attributed to inadequate or inappropriate use of wheelchair securement or occupant restraints involved vehicle maneuvers such as braking and turning. From 1973 to 1991, two deaths were attributed to securement-related injuries during vehicle maneuvers. (Richardson HA. Wheelchair occupants injured in motor vehicle-related accidents. National Center for Statistics and Analysis, Mathematical Analysis Division, 1991 Oct., Thacker, J and Shaw, G (1994), Safe and secure. Team Rehab Report. 5(2) : 26-30., ECRI. Positioning and Securing Riders with Disabilities and Their Mobility Aids in Transit Vehicles: Designing an Evaluation Program. Prepared by ECRI for Project ACTION National Institute for Accessible Transportation, Washington DC, 1995.)

New Jersey Standards Protecting Wheelchair Riders in Paratransit Vans

The New Jersey Department of Health and Senior Services has issued safety standards governing wheelchair securement and occupant restraints for vehicles that transport wheelchair riders (NJ ADC 8:40-4.2 (f)). The standard clearly states that an automotive-like lap belt must be used:

> 3. Each wheelchair shall have a patient seatbelt which secures the patient into the wheelchair in a configuration similar to an automotive lap belt………The seatbelt must be properly secured on the patient whenever the patient is in the wheelchair and under the care of the staff of the vehicle……

The New Jersey Department of Health and Senior Services actively enforces this regulation. The Office of Emergency Medical Services, charged with regulating paratransit providers, initiated nine enforcement actions regarding lack of proper occupant restraint from 8/99-2/00 (www.state.nj.us/health/ems/fines.htm#actions).

DISCUSSION

According to van driver Janet Beitz, Esther was not provided an occupant restraint on the day she fell from her wheelchair (Oral Deposition of Janet M. Beitz 12/13/00 case # SOM-L-497-00 pp 33, 44). This action was inconsistent with the principles of occupant protection that infuses numerous wheelchair safety standards. Specifically, it was also in clear violation of the New Jersey standard.

In my opinion, with the information I have reviewed to date, Esther would have not fallen from her wheelchair if she had been provided with a lap belt in accordance with the New Jersey standard that was fit low and snug across her pelvis in accordance with the principles of wheelchair occupant protection.

Characterizing the Event

The vehicle motion event described by van driver Janet Beitz was as follows:

> "I was slowing down for a pick-up. There was a manhole in front of the pick-up, before the driveway, and I was going like five miles an hour, and when my front wheel dipped, when I hit the manhole, I guess then I pulled up to a stop, and that's when I heard a noise…A bump….. Philomena (trainee)….. said …..'A lady fell…..The lady in the wheelchair'" (Oral Deposition of Janet M. Beitz 12/13/00 case # SOM-L-497-00 p 56)

In a Canadian test of a paratransit van executing extreme vehicle maneuvers including panic stops, the peak vehicle accelerations did not exceed 1 times the force of gravity (1 g) (Forziati T. Development of a Methodology to Dynamically Evaluate the Efficacy and Safety of Wheelchair Occupant Support Devices. Master of Science Thesis University of Virginia May 1994; Mercer, W, Billing J. Assessment of a Transportable Mobility Aid in Severe Driving Conditions – An Exploratory Test. Report No. CV-90-03, Ontario Ministry of Transportation, August 1990.)

Although I do not have sufficient information with which to formally reconstruct the event and the forces that acted on Esther's body. It is possible to estimate a reasonable worst-case scenario in terms of lap belt loading (see Appendix A).

In order to restrain Esther, who was reported to weigh about 100 lbs at the time of the event, a lap belt would have had to provide a restraining force of about 200 lbf. This requires the lap belt to withstand a load of approximately 141 lbf bilaterally.

The forward tipping of the van reported by the driver may have contributed to forces tending to propel Esther forward out of her wheelchair and would have increased the required restraining force. If the driver did not execute a panic stop, (none was reported) the required restraining force would have been less. Lap belt forces reported for simulated 10 and 20 mph frontal bus crashes with wheelchair riders suggest that the estimating restraining force and belt load may be too large. The peak lap belt loads recorded for front-facing wheelchair riders ranged from 140 to 775 lbf. Note that these tests were conducted with a 167 lb crash dummy (UMTA. Wheelchair Securement on Bus and Para-transit Vehicles, California State Department of Transportation.1981).

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Lap Belt Strength Specifications

The ADA standard specifies occupant restraint belts that conform to Federal automotive standards (ATBCB. Buses, Vans & Systems, Technical Assistance Manual, U.S. Architectural & Transportation Barriers Compliance Board, October 1992; 49 CFR Part 571.209, 210 / Federal Motor Vehicle Safety Standards 209 and 210). These regulations require that lap belts and their anchorages be able to withstand a statically applied load of 5000 lbf. Given Esther's weight, such a lap belt would have held her in her wheelchair in a very severe frontal crash such as a 30 mph impact with a bridge abutment. Clearly, an ADA- compliant belt would have far exceeded the strength needed to restrain Esther in the event in question:

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Estimated belt load to provide required restraining force	ADA minimum belt load capability
141 lbf	5000 lbf

Moreover, tests conducted at the University of Virginia suggest that many wheelchair lap belts not intended for use in motor vehicles would have been strong enough in this instance. Peak loads achieved by the five products tested ranged from 285 to 1578 lbf. The highest load was recorded for a belt with automotive-type webbing and buckle (Karg P. Development of a Methodology to Evaluate the Transportation Safety of Adaptive Seating Devices. Master of Science Thesis University of Virginia January 1993.) (Fig. 1).

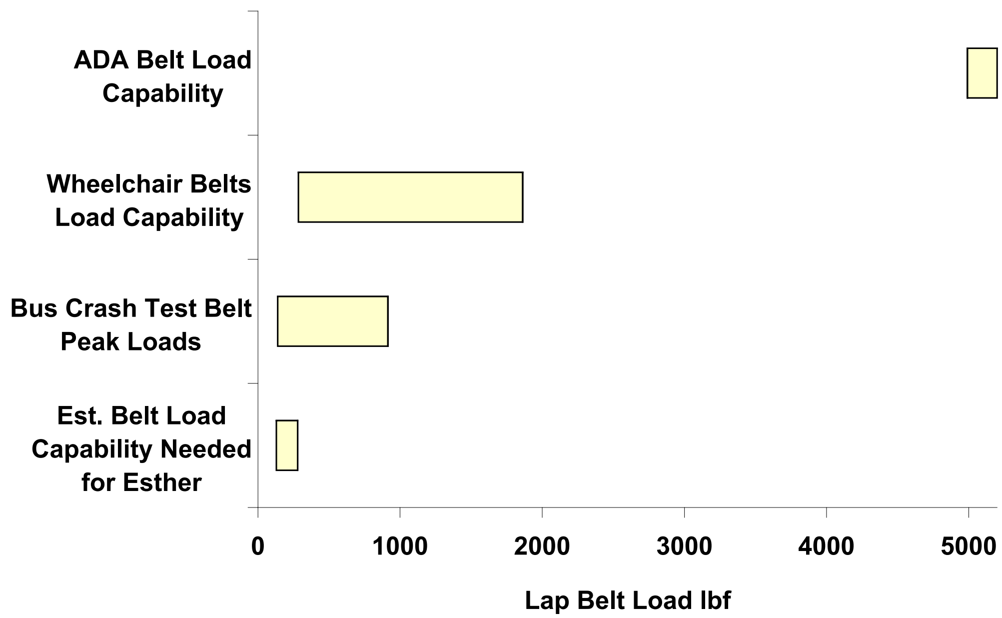

Figure 1. Summary of lap belt capabilities (ADA, Karg tests), peak loads recorded in crash tests (UMTA tests), and the estimated belt load required to provide the restraining force needed to keep Esther in her wheelchair during the vehicle motion event.

CONCLUSIONS

1. There are numerous standards with the goal of improving the transit safety of occupants who must ride aboard vans and busses seated in their wheelchairs. Most of these standards reflect principles of occupant protection indicating that the wheelchair be secured ***and*** that the wheelchair occupant be restrained.
2. Accident data suggests that vehicle maneuvers alone can eject riders from their wheelchairs with injurious results. Proper restraint is required to protect riders in both crashes and in less severe events involving vehicle motion.
3. The New Jersey regulation pertaining to the van in which Esther was riding clearly required that a lap belt be used.
4. The lap belt was not used when the event occurred.
5. The information available to me this time strongly supports the conclusion that Esther would have not fallen out of her wheelchair if a suitable lap belt had been properly fitted.

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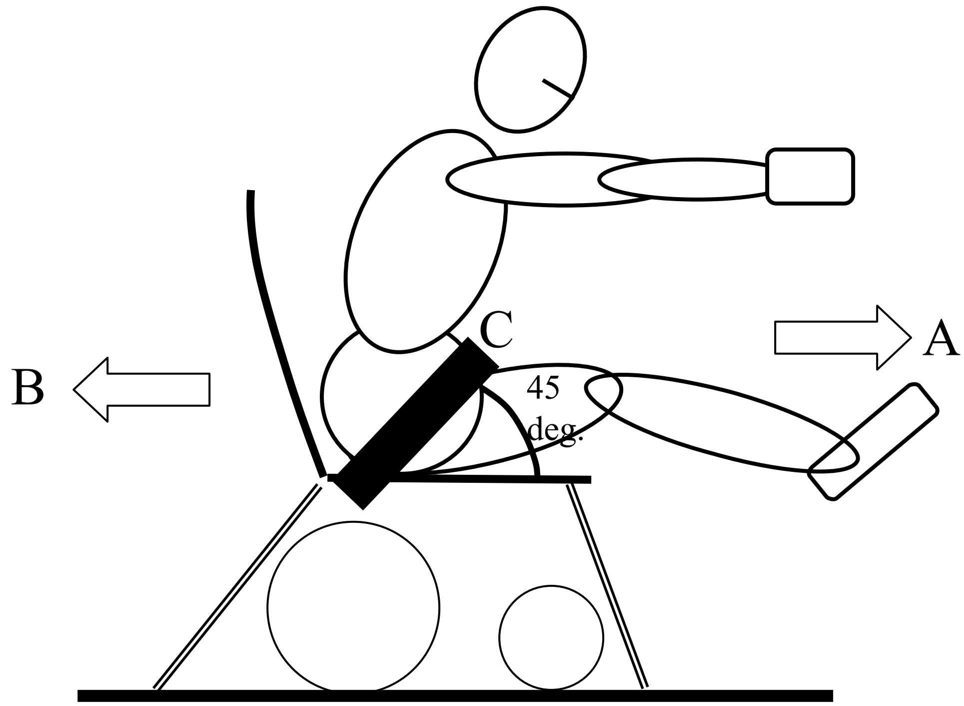

Appendix A - Calculation of Required Restraining Force

A	Forces due to van deceleration acting to eject rider
B	Equal force required to restrain rider
C	Lap belt installed at 45 degrees with respect to horizontal.

Assumptions:

1. The van in which Esther was riding stopped suddenly (assume a panic stop for a worst case) when the driver felt the front wheel dip into the depression caused by the manhole cover causing a primarily deceleration event, i.e., the principle direction of force was acting in the direction of vehicle travel. Forward tipping of the van may have also contributed to ejecting Esther from the wheelchair.
2. The maximum deceleration for this van is similar to that of the van used in the Canadian test - 1g.
3. The g-loading imposed on the belt by the wheelchair rider is approximately twice the vehicle g loading. (Derived from University of Virginia simulated frontal vehicle tests.)
4. The lap belt is installed at a 45 degree angle with respect to the horizontal.
5. The contribution to the restraining force by seat friction is negligible.
6. Esther weighed approximately 100 lbs at the time of the event.

Calculations^

A	Force due to van deceleration acting to eject rider	=	Mass of Rider	X	Twice the vehicle g-loading
		=	100 lb	X	(2) 1g
		=	**200 lbf**		

^ Based on formulas in Pytel, A, Kiusalaas, J. Engineering Mechanics : Dynamics. HarperCollins College Publishers N.Y., N.Y. 1994.

Lap Belt Load Required to Provide Restraining Force

Equal force required to restrain rider	=	Twice the Belt Load*	X	Cosine of Belt Installation angle
200 lbf	=	(2) Belt Load	X	Cosine 45 degrees
	=	(2) Belt Load	X	0.707
	=	Belt Load	X	1.414
200 lbf / 1.414	=	Belt Load		
141 lbf	=	Belt Load		

* The load in both left and right sides of the lap belt, assumed equal, are added to calculate the total contribution of the lap belt to the restraining force.

Reference Information

The following provides information regarding reference sources for Principles of Occupant Protection.

SAE Recommended Practice J2249 Wheelchair Tiedowns and Occupant Restraints for Use in Motor Vehicles (hereafter referred to as J2249) was developed over a ten year period by the Restraint Systems Task Group of the SAE's Adaptive Devices Subcommittee (ADSC) in recognition of the need to improve after-market equipment used to secure wheelchairs and restrain wheelchair occupants during motor-vehicle transportation. While a primary element of this recommended practice is a dynamic strength test of wheelchair tiedown and occupant restraint equipment conducted on an impact sled in a manner similar to FMVSS 213 for child restraint systems (CRS), the practice includes many other requirements related to basic principles of occupant protection, as well as basic principles of good engineering and design practice.

SAE RP J2249, Wheelchair Tiedowns and Occupant Restraints for Use in Motor Vehicles, was first published in October 1996. The goal of this companion document is to provide guidance in the use of J2249, and to provide interpretation, explanation, and rationale for its various provisions and parts. This guideline document is written primarily for manufacturers of Wheelchair Tiedown and Occupant Restraint Systems (WTORS), but will also be useful to consumers and third-party groups who purchase, use, or install WTORS. It provides insight into the requirements set forth in the Recommended Practice, gives the rationale behind the requirements, and clarifies the intentions and limitations of the of the requirements. It also references parallel efforts that have taken place in other countries and indicates where attempts at harmonization have been successful.

Acronyms:
SAE- Society of Automotive Engineers
WTORS- Wheelchair Tiedown and Occupant Restraint Systems
RP- Recommended Practice

Uncited Documents Containing Principles of Occupant Protection

Shaw,C.G. (1987). Vehicular transport safety for the child with disabilities, *American Journal of Occupational Therapy*, January, Vol. 41, No. 1, pp 36-42.

Sprigle, S, Thacker, J, Conley, P, and Shaw, G (1993), Setting standards. *Team Rehab Report.* 4(1) : 14-19.

Shaw, G., Lapidot, A., Scavnicky, M., Haxel, B., Bolton, J., Klopp, G. (1993). Testing procedures for wheelchair securement system standards. *Proceedings of the 16th Annual Rehabilitation Engineering Society of North America (RESNA) Conference,* Las Vegas.