Recommendations for Reducing Noncollision Bus Passenger Injuries

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Many bus-related injuries do not involve crashes with other vehicles, pedestrians, or fixed objects. These noncollision accidents occur when passengers are riding buses, boarding and alighting buses, and standing or walking at or near bus stops. Data for more than 5,000 bus passenger injuries from the Washington (D.C.) Metropolitan Area Transit Authority were analyzed, which revealed that one-third of all noncollision passenger injuries occurred during boarding and alighting and another one-fourth occurred during stopping. Forty-five percent of the injuries on stopping buses took place as passengers were getting up or sitting down or while they were seated. One-third of the alighting injuries happened when passengers tripped or slipped. The passenger injury rate fell by one-third between 1976 and 1990. A number of measures may be used to improve passenger safety. These measures include interior and seat design to minimize the effects of passenger impact against interior surfaces, far-side bus stops and adequate passenger loading areas, proper bus driver screening and education, appropriate transit agency policies and practices, and organized safety and security reporting.

Crashes and injuries related to buses represent a safety problem on U.S. highways that deserves further study. For example, in 1990 an estimated 64,000 of the 627,000 registered buses nationwide were involved in crashes. As a result of these accidents, approximately 35,000 bus occupants sustained minor or moderate injuries in highway crashes. Another 3,000 sustained serious injury, including 32 deaths (*1*). In addition, each year bus crashes are associated with approximately 100 deaths to nonoccupants (i.e., mostly pedestrians and bicyclists) and 200 deaths to occupants of other vehicles, according to the *Fatal Accident Reporting System* (FARS) (*2*).

Many injuries to bus occupants, however, do not involve crashes with other vehicles, pedestrians, or fixed objects. These "noncollision accidents" may involve trips and falls while passengers are boarding or alighting (e.g., leaving) the bus. While riding the bus, passengers may be injured during sudden stops or movements. These passenger injuries take their toll on passenger safety, yet they are commonly overlooked in transit agency and police accident records. In fact, the major computerized data bases—the General Estimates System, FARS, and the Highway Safety Information System (HSIS)—do not contain information on noncollision accidents. Slightly more than 21,000 personal casualty injuries and 18 deaths were reported to FTA in 1990 (*3*). (Personal casualties are noncollision events that result in injury or death.) Other noncollision accidents are not recorded. Therefore, very little is known about the frequency and severity of these accidents.

This paper reviews the literature on the nature of the injuries sustained by passengers as they ride, board, or exit the bus. It presents analyses of passenger injury data from the Washington (D.C.) Metropolitan Area Transit Authority (WMATA) covering more than 5,000 passenger injuries for July 1984 through January 1991. This paper recommends changes in bus design and bus stop location in order to reduce both collision and noncollision injuries. Recommendations pertaining to driver training and transit agency policies can reduce the number of passenger injuries by reducing the likelihood of a crash.

LITERATURE REVIEW

Bus passengers can be exposed to noncollision accident hazards while riding buses, boarding or alighting the bus, and standing or walking at or near bus stops. Studies of noncollision-related accidents on buses show that most bus passenger injuries are due to falls (*4*).

Analyses of interim data from the National Public Service Vehicle (PSV) Accident Survey showed that about 57 percent of passenger injuries were the result of falls and other incidents that occurred under normal conditions. Another 29 percent of passenger casualties resulted when a bus driver took emergency action to prevent an accident. Only 14 percent of passenger casualties resulted from collisions (Figure 1). In noncollision accidents, 36 percent of the casualties were persons 60 or older, but in collision accidents, only 17 percent were 60 or older (Table 1). For passengers 60 or older, boarding, door entrapment, and gangway accidents accounted for 19, 5, and 27 percent of all noncollision casualties, respectively. The corresponding numbers for passengers under 60 were 11, 2, and 21 percent (*5*). These differences were significant at the 0.01 level.

Cuts, grazes, and bruises to various parts of the body were the most common injuries in noncollision accidents. Cut, grazes, and bruises to the head or neck were more frequently reported from accidents in the gangway (i.e., aisle) and when entering and leaving seats. Leg and foot cuts, bruises, and grazes were more common in doorway and platform accidents. Fractures of all kinds were most often reported for doorway and gangway accidents (*6*).

Passenger falls during the movement of the bus occur because of the forces of sudden acceleration or deceleration, lateral motion on curves, and slip- or trip-related falls. These accidents resulted in 12,103 injuries and 13 fatalities (*3*). Hirshfield found in his famous experiments to develop the President's Conference Com-

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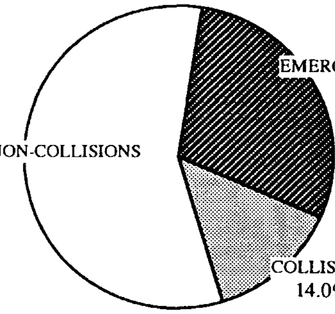

FIGURE 1 Causes of passenger casualties in the National PSV Accident Survey (5).

mittee (PCC) Streetcar design criteria that a 1.47 m/sec^2 (4.83 ft/sec^2, or 0.15 *g*) deceleration or acceleration was the threshold at which people would begin to lose their footing (*7*). Many slips occur on flooring materials that do not have good slip resistance under wet conditions. The presence of foreign materials on the floor, such as spilled beverages or food, also lowers slip resistance.

Boarding and alighting falls occur as a result of slipping or tripping within the stepwell, overstepping the step tread, or falling on the ground surface outside the bus. Accidents while boarding and alighting injured 8,168 persons and killed 3 in 1990 (*3*). Design features such as high steps, inadequate grab handles, and poor illumination of the stepwell contribute to these accidents. Older pedestrians are likely to be overrepresented in boarding and alighting falls, in large part because of their limited mobility and age-related changes in vision, balance, and coordination. Because of the characteristics of stair falls, alighting stepwell falls are typically more serious than boarding falls. In one study of stair falls in transit terminals, 94.1 percent of the ambulance-aided cases occurred in the downward direction (*8*). The reason for this difference in severity is the greater fall height and impact energy of the downward direction stair fall.

Bus stop location, walking surface conditions at the stop, sidewalk width, and illegal parking in bus stop zones are factors that contribute to passenger accidents before boarding or after alighting. In 1990, 842 people were injured and 2 were killed as a result of accidents at bus stops (*3*). Alighting passengers who step onto a rough or icy walking surface may slip and fall. Along a narrow sidewalk, a passenger may be bumped or jostled off the sidewalk into the street or down an abutting slope.

The incidence of noncollision injuries can be reduced by appropriate countermeasures, such as interior vehicle design modifications and by stop locations that passengers can use safely. More information about these countermeasures is provided in the following section.

ANALYSIS RESULTS

WMATA operates one of the largest transit bus fleets in the United States. WMATA supplied summary passenger injury data for 1976 to 1990 and more detailed data for July 1984 to January 1991. The agency also provided summary traffic accident data for 1976 to 1990.

Figure 2 shows that the collision rate (traffic accidents per million miles operated) fell from 73.8 in 1976 to 38.5 in 1986, before rising somewhat in subsequent years (*8*). Reasons for this drop are not known with any certainty. Since 1984 the number of Metrobus traffic accidents has fluctuated around 2,000 per year. The accident types reported involving WMATA buses include vehicles passing on left (26.6 percent), rear-end collisions (14.5 percent), head-on collisions (13.3 percent), angle collisions (9.2 percent), and right-passing vehicles (9.1 percent) (Figure 3). These results show that sideswipe and rear-end collisions prevailed, as was the case with the five-state HSIS data discussed earlier in this paper. For most accident types, the crash percentages by type remained relatively constant from 1976 through 1980 and 1986 through 1990, although accidents involving following vehicles (i.e., vehicles striking the bus from behind) increased from 12.4 to 17.9 percent.

From 1976 through 1990, slightly more than 1,000 accidents occurred involving pedestrians, which was about 2.6 percent of the total number of accidents by WMATA buses. Of the 346 bus-person collisions between January 1984 and January 1991, 72 occurred as the bus was traveling between stops. Fifty-eight pedestrians were struck as buses were leaving stops, 56 were hit in crosswalks, and 160 were struck under other circumstances.

The passenger injury rate (per million passengers) has shown a general downward trend, from 7.3 in 1976 to 4.9 in 1990 (Figure 4) (*9*). Note that the injury rate fluctuated around 7.5 for the years 1976–1982 but then dropped to around 5.0 for 1985 and later years. A possible explanation for this decline would be the replacement of older buses by newer buses with more passenger-friendly interior designs. Roughly a third of all passenger injuries occurred during boarding or alighting, and another fourth occurred during stopping (Figure 5). "Other" and "miscellaneous" accidents combined accounted for another third of the injuries. The percentage share of each passenger injury accident type remained relatively constant from 1976 through 1980 and 1986 through 1990.

TABLE 1 National PSV Accident Survey: Noncollision Casualties by Age (5)

	Estimated Age		
	Under 60	60 or Older	Total
Door entrapment	1.8%	4.6%	3.0%
Boarding	10.9%	19.4%	14.5%
Gangway	20.9%	26.9%	23.5%
Other non-collision	66.4%	49.1%	59.0%
Total	843	635	1478

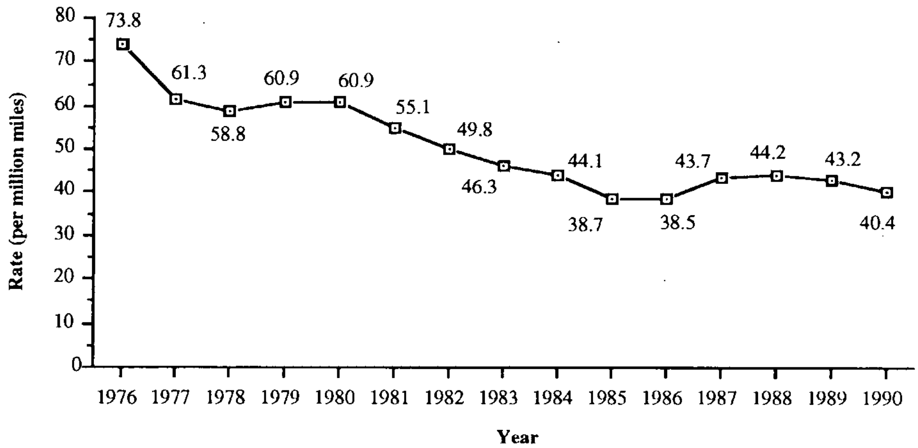

FIGURE 2 Washington (D.C.) Metrobus traffic accident rate by year (*9*).

A more detailed breakdown of 5,507 noncollision accidents that occurred in metropolitan Washington between July 1984 and January 1991 appears in Table 2 (S. Burton, unpublished reports, WMATA, Feb. 1991). Passengers were most likely to be injured while aboard a stopping bus or while boarding and alighting. Forty-five percent of the injuries on stopping buses occurred while passengers were getting up, sitting down, or remaining seated. One-third of the alighting vehicle injuries occurred when passengers tripped, slipped, or stumbled.

The WMATA data do not report injury severity for the traffic accidents and the noncollision passenger injury accidents. Information was not available on potential bus stop safety problems such as far-side versus near-side stop location or adequacy of loading areas.

RECOMMENDATIONS

Several general measures are recommended to reduce the incidence of noncollision passenger injuries. The measures described here may be classified into these categories:

- Bus design and operations to reduce passenger injuries,
- Bus stop location,
- Bus driver screening and education,
- Transit agency policies, and
- Safety and security reporting system.

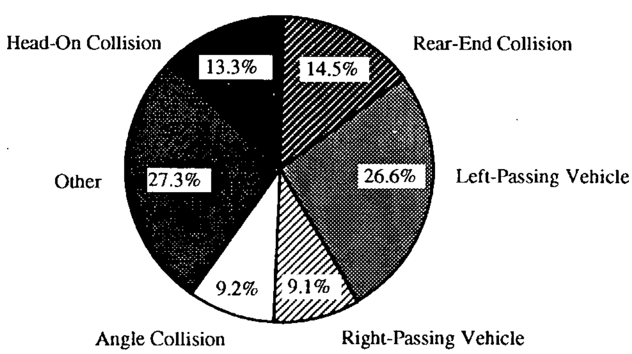

FIGURE 3 Washington (D.C.) Metrobus traffic accidents by type, 1976–1990 (*9*).

Measures relating to bus driver education and transit agency safety policies can eliminate situations in which bus drivers must swerve or stop unexpectedly in order to avoid collisions, thereby injuring passengers.

Bus Design and Operations To Reduce Passenger Injuries

Bus passengers can be exposed to noncollision accident hazards while riding buses, boarding or alighting the bus, and at or near bus stops. Studies of noncollision-related accidents on buses show that most are due to falls (*4*). Passenger falls during the movement of the bus occur due to the forces of sudden acceleration or deceleration, lateral motion on curves, and slip- or trip-related falls. Boarding and alighting accidents are generally related to slips or trips within the stepwell or overstepping of the step trend. Bus stop location, walking surface conditions at the stop, sidewalk width, and illegal parking in bus stop zones are factors that contribute to passenger accidents before boarding or after alighting.

Commercial buses are more likely to be struck by rather than to strike another vehicle, on the basis of the findings from a related study (*10*). Many of these accidents occur when a vehicle rear-ends a bus that has stopped to pick up or discharge passengers. During daylight hours, a stop arm (as is commonly installed on school buses) could be raised to warn drivers who are following the bus that the bus has stopped. Bus conspicuity at night and during inclement weather could be improved through the installation of brighter warning lights on the rear of the bus or perhaps through a special illuminated Stop sign on the rear of the bus.

Some rear-end and sideswipe accidents may be prevented by improving the visibility of turn signals on buses. Audible warning devices could be attached to buses to warn other motorists of the presence of a bus. Even closed-circuit television cameras could be installed to give the bus driver a better view of the sides and rear. To reduce injury severity to the driver and occupants of the other vehicle, energy-absorbing material may be placed at the front and the back of the bus.

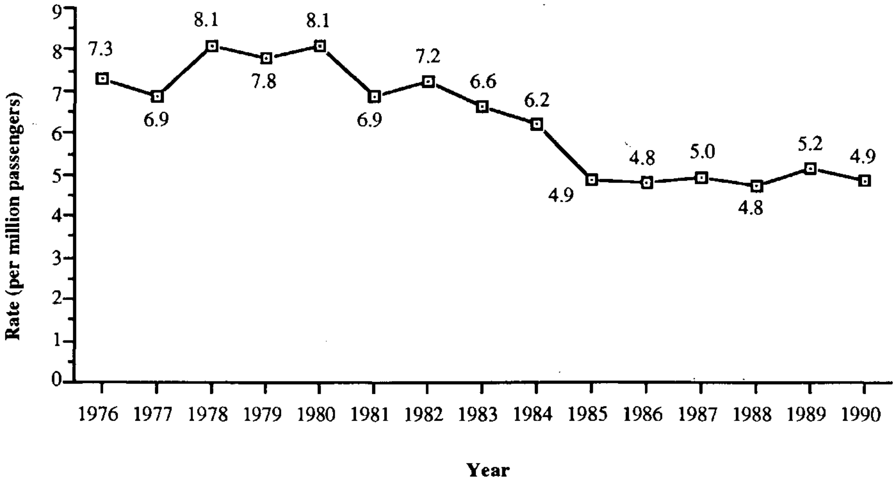

FIGURE 4 Washington (D.C.) Metrobus passenger injury rate by year (*9*).

Motion-Related Falls

Sudden deceleration of buses is unavoidable when the driver must stop to avoid a vehicular accident or obey a changing traffic signal. Ideally, buses should not operate with standees in the aisles, but this objective is difficult to attain. Where seats are available, every effort should be made to encourage passengers to sit while the bus is in motion and to remain seated until the bus stops. The strategic location of handholds, within easy reach of passengers in aisles, is another means of preventing motion falls. Excessive forces due to acceleration and lateral movement on curves can largely be avoided by training drivers to be aware of passenger motion hazards.

In both motion- and collision-related falls, the effects of second impacts should be minimized (*5*). These impacts occur when passengers are thrown about the interior of the vehicle. All interior surfaces, edges, trim, and such should be designed so that clothing will not be caught and the victim will not be cut by sharp edges. Interior seats, partitions, railings, and other elements should be securely mounted so that they will not loosen during normal use or under the force of a collision. Protrusions that passengers can bump into under normal use or during falls should be avoided wherever possible. The use of materials that shatter or break upon impact should also be avoided. Padded surfaces give passengers added impact protection in a collision but are also known to encourage vandalism.

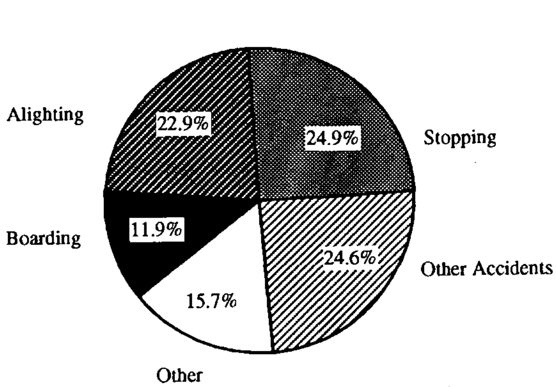

FIGURE 5 Washington (D.C.) Metrobus passenger injuries by type (*9*).

Falls Due to Trips and Slips

The selection of non-slip flooring material, careful application of these materials, and continued maintenance of a safe walking surface is necessary to reduce slipping and tripping falls in buses. The standard for a slip-resistant walking surface is set by the U. S. Architectural and Transportation Barriers Compliance Board (USATBC) (*11*). Many flooring materials that are normally considered slip-resistant will not meet that standard. Flooring materials selected for bus transit use should be tested for slip resistance using procedures specified by ASTM or their recognized equivalents (ASTM C1028-89, ASTM D2047-82). Slips on bus floors can also result from newspapers, spilled foods or liquids, mud, and other foreign materials on the floor. Slip accidents in northern climates can occur because of icing of stepwell treads.

Tripping hazards occur where the walking surface is not level. In the normal walking pattern toe clearances vary between 0.95 and 3.81 cm (0.375 and 1.5 in.), with an average of about 1.52 cm (0.6 in.) (*12*). However, passengers in buses, particularly those standing in aisles, could trip on surface differentials lower than 0.95 cm (0.375 in.) in a lateral or sideways movement of their feet as they adjust standing positions. The USATBC has set a standard of a surface height differential of 0.64 cm (0.25 in.) as the threshold at which trip hazard mitigation should occur (*13*). Tripping hazards do not generally occur with bus floor surfaces unless the surface is worn or the surface materials become loose or dislodged in some manner. This requires periodic inspection of bus floors and replacement of floors with tripping hazard defects. To avoid slipping hazards caused by spills or refuse, the consumption of food and drink should be prohibited on buses.

Boarding and Alighting Falls

Boarding and alighting falls occur within the stepwell or on the ground surface outside the bus. Because of the characteristics of

TABLE 2 Washington (D.C.) Metrobus Noncollision Accident Types, July 1984–January 1991

Passenger injury boarding vehicle	681 (100%)
- Struck by front doors closing	34.9%
- Tripped, slipped, stumbled	32.9%
- General	9.0%
- Between street and step at front door	7.8%
- Other	15.4%
Passenger injury alighting vehicle	1215 (100%)
- Tripped, slipped, stumbled	33.2%
- General	15.7%
- Struck by center/rear doors closing	13.7%
- Between street and step at front door	9.9%
- Struck by front doors closing	7.5%
- Other	20.0%
Passenger injury on board starting bus	142 (100%)
- Walking front seat area	23.2%
- Standing front door area	19.7%
- Other	57.0%
Passenger injury on board stopping bus	1508 (100%)
- Getting up/down/seated	45.4%
- General	16.6%
- Standing front door area	10.3%
- Standing front seat area	7.2%
- Walking front seat area	7.1%
- Standing rear seat area	5.6%
- Walking rear seat area	4.3%
- Other	3.4%
Passenger injury on board moving bus	382 (100%)
- Getting up/down/seated	54.7%
- General	10.2%
- Standing front door area	9.9%
- Other	25.1%
Other passenger injury	1200 (100%)
- Injured by defective equipment while on board	24.0%
- Injured by missile while on board	19.4%
- General	17.1%
- Bus standing: trip, slip, or stumble	13.4%
- Injured by others on board	11.0%
- Bus moving: tripped, slipped, stumbled	7.8%
- Other	7.3%

stair falls, alighting stepwell falls are typically more serious than boarding falls. In one study of stair falls in transit terminals, 94.1 percent of the ambulance-aided cases occurred in the downward direction (*8*). This difference in severity is caused by the greater fall height and impact energy of the downward-direction stair fall. The elements of safe stair design are well established (*14–16*). Riser heights should be between 15.24 and 20.32 cm (6 and 8 in.) and effective tread width between 27.94 and 30.48 cm (11 and 12 in.). A well-established safety requirement is that riser heights and tread widths be consistent and equal within small tolerances in any stair flight. Handrails should be reachable and graspable and should extend beyond the top and bottom treads. Treads should be well lighted, and step edges visually well defined. Tread surfaces should be slip-resistant.

The kneeling bus was developed to reduce the height from the ground to the first step on the bus for the convenience and safety of users. Many drivers dislike using the kneeling mechanism, and it can lock in the kneeling position or otherwise malfunction, sometimes taking the bus out of service.

The low-floor bus was developed recently to overcome stepwell safety problems and to provide a simpler means of accommodating wheelchair users (*17*). The bus floor in one manufacturer's version is 36.53 cm (14.38 in.) above ground, and the ground clearance under the rear axle is only 15.24 cm (6 in.). This manufacturer also offers a kneeling mechanism option to lower the bus floor another 3 to 4 in. Wheelchair access is by way of a ramp. The bus is being tested at a major regional airport. It is claimed that the low floor is speeding up the loading and unloading of passengers with baggage, greatly reducing dwell and turnaround times.

The Americans with Disabilities Act (ADA) Subpart D, Section 37.71, entitled "Purchase or lease of new non-rail vehicles by public entities operating fixed route systems" paragraph (a), states that

> [e]xcept as provided elsewhere in this section, each public entity operating a fixed route system making a solicitation after August 25, 1990, to purchase or lease a new bus or other new vehicle for use on the system, shall ensure the vehicle is readily accessible and usable by individuals with disabilities, including individuals who use wheelchairs. (*18*)

There are few waivers to this requirement, ensuring that with the normal replacement of existing bus fleets, eventually all public buses will be accessible to wheelchairs.

Seat Design and Performance

Good seat design is an important countermeasure to reduce passenger injury either as a result of collisions or of sudden stops by the bus. Past accident studies have shown that many passenger injuries result from a lack of seat retention or from the impact of unrestrained seats with otherwise uninjured occupants.

Among designers, legislators, and researchers, it is generally agreed that seat performance should achieve two major objectives:

- In the event that a passenger impacts the seat in front, the seat should be capable of local deformation in the knee and chest area to enable "pocketing" of the passenger, thus absorbing some of the initial kinetic energy. It should also provide for controlled deformation of the seat back (without fracture) to absorb the remaining kinetic energy and prevent the passenger from ramping over the top of the seat.
- Through careful design and placement of structural members and the use of adequate energy-absorbing padding, the seat should be capable of distributing local impact forces to the head, thorax, chest, and knee areas in such a way as to prevent serious injury (*19*).

A seat should be designed with

- Strong seat anchorages to ensure seat retention,
- Provision for knee penetration to minimize femur forces and to prevent the pivoting of the upper body and consequent high head impact loads,
- Adequate seat back height to prevent ramping and unacceptable head impact.
- Suitable seat and back stiffness to allow passenger retention without premature seat collapse or excessive body forces,
- Adequate energy-absorbing padding in the knee and head protection zones to prevent unduly high localized forces, and
- Suitable seat-back angle to enhance the retention capabilities of the seat (*19*).

Bus Stop Location

The safety responsibility of bus transit carriers has been extended to bus stop loading and unloading areas under some circumstances. For example, boarding and alighting passengers may slip and fall on icy surfaces. They may be bumped off narrow sidewalk loading areas, perhaps into the street or down an embankment. In rural or suburban areas, passengers may be unloaded at unpaved areas where there is greater bus-to-road step height, poor footing, or tripping hazards.

Transit agencies should provide adequate loading areas for passengers, reasonably free from safety hazards. This responsibility will increase as ADA accessibility and facility design requirements become the common standard of practice. Bus stops should be located in paved areas with slip-resistant walking surfaces and should be free from tripping hazards. The criteria for slip resistance and tripping hazard height are outlined in American National Standard ANSI-A117.1. The stop area should be wide enough to allow for queueing passengers and to accommodate wheelchair loading and unloading without disrupting normal on-street pedestrian movement near the stop. Passengers in a single-file queue typically line up with an interpersonal spacing of 0.508 m (20 in.) and require a lateral space of 0.762 m (30 in.) (*20*).

Near-side versus far-side bus stop location has an impact on passenger and pedestrian safety (*21,22*). Factors that influence the selection of bus stop locations include the availability of curb and sidewalk space, bus routing patterns (turns), location of other stops or bus services, passenger and street pedestrian volumes, passenger accessibility, street width, one-way or two-way streets, traffic volumes and turning volumes, traffic controls, and signal cycles. From the viewpoint of bus passenger and pedestrian safety, the far-side location is the safest because pedestrians cross in the crosswalk behind the bus where they can be seen and because the bus does not block the view of traffic controls and other intersection traffic. Other advantages of the far-side bus stop include

- Reduced bus conflicts with right-turn vehicles,
- Increased intersection capacity by freeing the curb lane for through movement,
- Improved sight distances at intersections,
- Shorter curb length requirements for bus stop approaches, and
- Easier reentry into traffic after passenger loading.

Bus shelters protect passengers from wind, rain, and snow. Shelter location is an important consideration because the shelter can occupy sidewalk area needed for passenger waiting, boarding and unloading, and other nearby pedestrian activities. If the shelter is located too close to the curb, the restricted space between the fixed shelter and the moving bus can become hazardous to passengers.

Bus Driver Screening and Education

To the best of the authors' knowledge, there has not been any research that measures the effects of bus driver training on the number of collision and noncollision accidents. The National Transportation Safety Board investigates selected bus accidents to determine their causes and to recommend countermeasures. For some accidents, the safety board has recommended that bus companies review and modify the driver training process as a countermeasure after determining that the drivers' actions were the probable causes of those crashes (*23*).

Recommendations for improved bus safety as affected by the bus driver have been developed by the Wisconsin Department of

Transportation and other sources (*24,25*). They include the following:

1. Thoroughly screen potential bus drivers. The screening process should consider the applicant's past driving record and include a physical examination, a drug test, and a background check.
2. Properly train newly hired drivers, covering both standard and emergency operating procedures. Driver training should consist of four stages: classroom training, off-the-road vehicle training, road work and route familiarization, and revenue service under observation.
3. Develop a structured recurrent training program. Such a program should include classroom instruction as well as simulator or behind-the-wheel instruction. The program should be geared toward maintaining and reinforcing good driving habits. Additionally, remedial training should be developed for and given to "problem" drivers.
4. Continually monitor and evaluate the performance of drivers. This assessment should be done by someone who is familiar with the driver's record, qualified to interpret it, and authorized to impose appropriate measures such as remedial training or disciplinary action.

Transit Agency Policies

A number of policies and practices by transit agencies can help to minimize risk of collisions and passenger injuries related to transit bus operations. These include (*24*)

1. Routing should lower accident exposure by minimizing turns, allowing for intersection controls, avoiding dangerous intersections, and not crossing several lanes of traffic. Schedules should incorporate adequate running time so that drivers do not feel compelled to speed. Transit bus schedules should also include layover time to give drivers a short break and to allow for traffic delays.
2. Inspect and maintain the bus regularly. Effective preventive maintenance not only makes buses safer, but also adds to their useful life and reliability. Daily inspections are needed to check fuel tank and other fluid levels, replace burned out lights, and so on. Pretrip inspections should include vehicle systems, access doors, and the bus interior. Periodic inspection should be made to detect damage before major repairs are necessary.

Inspection and maintenance are especially important for older buses, since the analysis showed that older buses are overrepresented in crashes (*26*).

Ideally, specific departments or individuals within transit agencies should be assigned responsibility and authority for implementing, performing, and monitoring various safety activities. These activities should include equipment and facility inspections, safety instruction, monitoring of employee work habits, incentives, accident reporting and investigation, meetings, and program documentation. A safe driver award program, based on the number of days without a collision or on-board accident, can offer a strong incentive for drivers to operate their buses more safely.

Safety and Security Reporting System

An organized safety and security reporting program is important for bus transit carriers to monitor the number and types of incidents occurring in the system (*27*). Buses should be equipped with two-way radios so that the dispatcher can be notified when an accident has occurred. To facilitate accident investigation, a report needs to be completed for each accident and a supervisor should be dispatched to the scene. These data can provide useful insights on the potential causes of these incidents and help to identify appropriate preventative measures. A thorough record of an incident can prove to be invaluable if there is a subsequent litigation related to it. At times, facts can be altered where there is no record or the record is incomplete.

Future Research Needs

One area of needed research would involve a more extensive data base, to be obtained from local transit agencies, of noncollision accidents. These data would allow better comparisons of different bus designs and operating practices. More information is needed on how bus design affects passenger injuries. Buses are manufactured to varying specifications pertaining to seat type, floor material and aisle width, handrail placement in stairwells, step height, and other design features. Different models should be tested to identify those whose specifications minimize boarding and alighting falls, motion-related falls, and the likelihood of injuries.

Buses should be subjected to crashworthiness tests to determine the level of driver and passenger safety offered by various bus designs. Computer simulation of bus crashes could also be attempted. Accident reconstruction studies of bus crashes could help to identify specific crash causes.

Research is also needed on accidents in which the bus contributed to an accident but did not collide with other vehicles or persons. For example, pedestrians may step in front of buses and be struck by passing automobiles. However, for such accidents bus involvement would not have been coded in the data base. It would probably be very labor intensive to collect adequate data samples in these two areas, but the results would probably be useful for transit agencies.

Research should be undertaken to quantify the characteristics of bus stop accidents, such as boarding and alighting riders who trip on slippery or uneven surfaces at stops, waiting riders who are forced to stand out in the street because of an inadequate waiting area and are thus struck by an approaching bus or other vehicle, and alighting riders who are struck by motor vehicles while trying to cross the street in front of the bus. Data would be readily available if transit agencies adopted a safety and security incident reporting system.

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