INJURY EVENTS AMONG BUS AND COACH OCCUPANTS

– Non-crash Injuries as Important as Crash Injuries –

Ulf BJÖRNSTIG
Department of Surgical and Perioperative Sciences
Division of Surgery, Umeå University
Umeå, Sweden

Pontus ALBERTSSON
Department of Surgical and Perioperative Sciences
Division of Surgery, Umeå University
Umeå, Sweden

Johanna BJÖRNSTIG
Umeå Accident Analysis Group
University Hospital
Umeå, Sweden

P-O BYLUND
Umeå Accident Analysis Group
University Hospital
Umeå, Sweden

Torbjörn FALKMER
Rehabilitation Medicine
Department of Neuroscience and Locomotion
INR, Faculty of Health Sciences
Linköping University, Linköping, Sweden

Jan PETZÄLL
Swedish National Road Administration
Borlänge, Sweden

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A ten year complete data set from the health sector, comprising 284 injured bus and coach occupants from a well defined area, was analyzed. The annual injury incidence was 2 per 10,000 inhabitants, 3/4 were women. In non-crash incidents, 54% were injured; 2/3 while alighting from a bus or coach. In crashes, 46% were injured; 2/3 in collisions with other vehicles and 1/3 in single vehicle crashes. During October-March, 3/4 were injured.

In two single vehicle mass casualty crashes in slippery road conditions, high built coaches were hit by so high cross wind forces that they were blown off the road. This crash mechanism has received little attention earlier. Of those injured in collisions with other vehicles, 78% were injured in collisions with other heavy vehicles. Slippery conditions contributed to half of the alighting injuries. The proportion of moderate or more serious injuries (MAIS 2+) was highest in single vehicle crashes (48%) and in alighting and boarding (43%) incidents, and was lowest (5%) in collisions. Every seventh injured was treated as an in-patient on average in five days. Non-crash victims consumed 57% of all in-patient days.

Conclusions: The aerodynamic cross-wind factor merits more studies. Injury reducing measures against alighting injuries, addressing especially step height and slippery conditions, may have a great potential to reduce these injuries. Rear-end collisions by other heavy vehicles in urban areas, causing a high number of “whip-lash” injuries, also need to be further addressed. The newly introduced law on compulsory seat belt use in long distance coaches may have a potential to reduce single vehicle crash and some collision injuries.

Key Words: Aerodynamics, Alighting, Bus and coach, Injury incidents, Cross-wind

1. INTRODUCTION

Unlike the decreasing trend for car occupant injuries, deaths and injuries involving occupants of buses and coaches have been “stubbornly stable” over recent years in the European Union[1] and in Sweden an increasing trend has been observed[2]. These incidents span from mass casualty crashes, often with massive media exposure, to non-crash incidents with only one person involved, e.g. a passenger falling when alighting a bus. Researchers and authorities often report spectacular mass casualty crashes[3-8]. However, non-crash events may be equally interesting from an injury mitigation point of view, especially for elderly occupants, as the European Coach and Bus Occupant Safety project (ECBOS) and other have indicated[5, 9-12].

Since bus and coach incidents are relatively rare compared to other traffic injury incidents, data need to be gathered over a long time span. Moreover, as Nilsson[13] pointed out, a well-defined geographical area needs to be selected for epidemiological studies. To assess the impact of different bus and coach occupant injuries from a public health perspective, hospital data, instead of police data, are preferred[2].

The aim of the present study was to provide an overview of the injury epidemiology in both crash and non-crash injury incidents among bus and coach occupants. The data set chosen is from a well-defined geographical area and is a “total survey material” from the medical sector.

2. MATERIAL AND METHOD

2.1 General

The material comprised 284 cases with injuries sustained during a bus or coach journey within the Umeå medical district. All included patients were treated at the emergency department (E.D.) at the University Hospital in Umeå during the ten-year period 1994-2003. The hospital is located in northern Sweden and is the only hospital within a well-defined catchment area with a radius of 50-60km around Umeå. The population has increased from 125,000 inhabitants in 1994 to 137,000 in 2003. Winter conditions prevail usually between November through March.

At the E.D. both in- and out-patients from the area are treated. At small health care centres in the area, only a few per cent of those with vehicle related minor injuries are treated. At the visit at the E.D. the injured person answers a questionnaire about the injury incident. In some cases, these data were retrieved by later interview. Data from medical records and from police investigations are also included in the database. By checking against the hospitals compulsory E-number-registration for "external cause" to in-patient treatment[14,15] a loss of in-patients was eliminated. The misses of out-patients in the hospital's injury registration is 2-5%, mostly minor injuries[16].

2.2 Definitions

a) Buses and coaches included were M2 and M3 vehicles, i.e. vehicles with more than eight seats for passengers[17]. Buses are aimed mostly for city traffic and coaches for long distance traffic.
b) The injuries were classified according to the Abbreviated Injury Scale (AIS), where MAIS denotes the Maximum AIS[18]. AIS=1 is a minor injury (e.g. wound, finger fracture), AIS =2 is a moderate injury (e.g. fracture, concussion), AIS =3 is a serious injury (e.g. limited intra-cranial or abdominal bleeding) etc. up to AIS=6, which is a maximal (deadly) injury.
c) Days in hospital for in-patients; the days for signing in and out together were counted as one (24 hours) hospital day.
d) "Alighting and boarding"- incidents: non-crash incidents with a bus or coach at stand still.
e) "Non-crash" incidents in a moving bus or coach: injury incidents among occupants in a moving bus or coach, e.g. the occupant was stumbling, lost balance, fell etc.

In order to compute injury incidence, travel statistics were collected from local and regional bus companies, and from a survey made by local authorities[19].

The structure of the material is presented in Figure 1.

3. RESULTS

3.1 All incidents

3.1.1 Injury incidence and reporting rate

The average number of injured occupants per year was 28.4. The injury incidence was 2 per 10,000 inhabitants on average over the 10 year period. The incidence of injured in non-crash incidents increased by 24% and in crash incidents by 30% between the first and second half of the study period.

The police reporting rate to the official traffic injury statistics was 68 (38%) of the 178 who were injured in a moving vehicle, and therefore should have been reported according to the official statistics rules. However, out of the 130 injured in only crash incidents, 68 (52%) were reported, i.e. all reported by the police were from crashes.

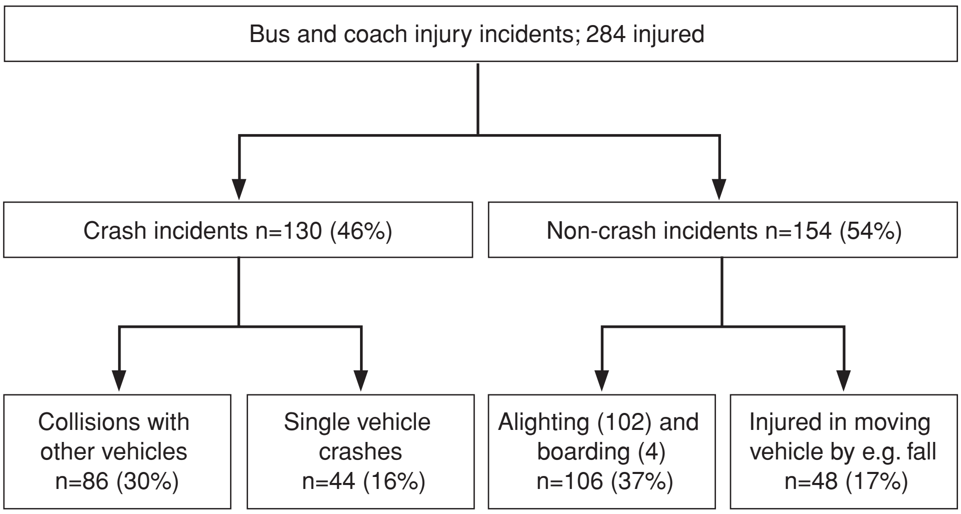

Fig. 1 Number of injured in different types of incidents

3.1.2 Age, gender and road type

The mean age was 42 years (SD 20, median 43, range 2-91). The distribution of injured by age and gender is presented in Figure 2. At least 201 (71%) were injured on urban streets/roads, while 59 (21%) were injured on rural roads (Table 1).

3.1.3 Day and month

During the six months October through March, 212 (75%) of all occupants were injured. The proportion of journeys during these months was 63%[19]. The age groups up to 60 experienced 78% of their injury incidents during these months, and for those 60 and older the corresponding figure was 63%.

All major injury incidents, comprising five or more injured occupants, occurred during the five winter months November through March. The month with the highest injury rate was January (65/23%).

The injury frequency was on average twice as high on weekdays compared to weekend days. More than half (171/60%) were injured during five hours of peak traffic; 7-9, a.m. plus 2-5 p.m. However, half of them (83/29%) were injured during the hour between 8-9 a.m. Most of them (67) were injured in three major injury incidents.

3.1.4 Injuries

As shown in Table 1, almost one-third, had MAIS 2+ injuries (moderate or more serious injuries); 36% of the men and 29% of the women. Forty-one percent of those 50 years of age or older had MAIS 2+ injuries, as had 24% of the younger. The proportion of MAIS 3+ injuries was for men 6% and for women 5%, and for people 50 years or older 11% and for younger 2%, respectively.

The proportion of injured with MAIS 2+ injuries was higher (40%) on rural roads than on urban streets and roads (27%). At least 10 of 15 cases with MAIS 3+ happened on rural roads.

Table 2 presents the injury type and location for all the 340 injuries in the 284 occupants. Most frequent (26%) was injuries to the lower extremities, a majority of them sustained when alighting a bus or coach. Injuries to the neck were almost as frequent (24%), many of them sustained when another heavy vehicle hit from behind the subjects bus or coach. One-fifth (20%) sustained fractures, most often to the upper extremities.

3.1.5 In-patient treatment

Forty-three (15%) occupants were treated as in-patients for a total of 221 days. From non-crash incidents 22 injured spent 126 days in hospital, i.e. on average 5.7 days and from single vehicle crashes 20 occupants spent 94 days in hospital i.e. on average 4.7 days. Those 14 injured when alighting or boarding spent on average the longest in hospital time, 6.7 days. From collisions only one person was in need of in-patient treatment for one day. One elderly patient died nine days after the injury incident from cardiac complications, otherwise no one died as a consequence of their injuries.

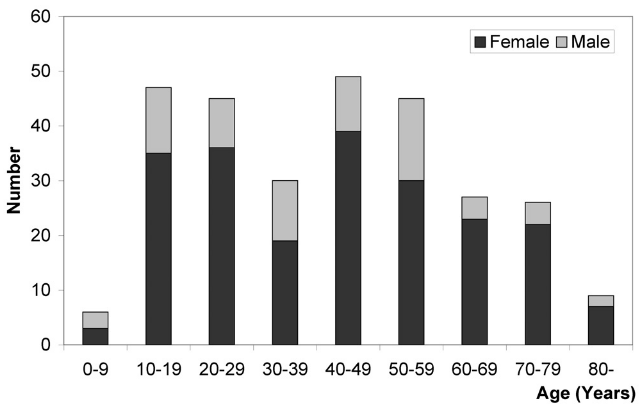

Fig. 2 Number of injured by gender and age

Table 1 Number of injured by injury severity, gender and urban/rural road

Injury severity	Urban street/road n=201 (71%)			Rural road n=59 (21%)			Unknown road/street n=24 (8%)	Total
	Men	Women	Sum	Men	Women	Sum		
MAIS=1	33 (81%)	114 (73%)	147 (73%)	7 (47%)	28 (64%)	35 (60%)	15 (63%)	197 (69%)
MAIS=2	11 (17%)	39 (25%)	***50 (25%)***	6 (40%)	8 (18%)	***14 (22%)***	***8 (33%)***	**72 (25%)**
MAIS=3	1 (2%)	3 (2%)	***4 (2%)***	1 (7%)	4 (9%)	***5 (9%)***	***1 (4%)***	**10 (4%)**
MAIS=4				1 (7%)	4 (9%)	***5 (9%)***		**5 (2%)**
Total	45 (100%)	156 (100%)	201 (100%)	15 (100%)	44 (100%)	59 (100%)	24 (100%)	284 (100%)

3.2. Crash incidents

3.2.1 Age and type of crash

In crashes, 130 were injured; **86** in 26 **collisions with other vehicles** and **44** in 6 **single vehicle crashes** (Table 3). Occupants injured in collisions with other vehicles had a mean age of 34 years, while those injured in single vehicle crashes had a mean age of 40 years.

A vast majority (76/88%) of the **86 collision victims** were injured in urban areas. Sixty-seven (78%) of the 86 were injured in collisions with other heavy vehicles, such as trucks (41 injured in 3 crashes) or buses/coaches (26 injured in 6 crashes). Sixteen people were injured in 15 different collisions with cars and 2 were injured when their bus collided with a bicycle and a moose respectively. In one case the collision partner was unknown. The bus or coach was rear-ended in 7 occasions, causing minor and moderate injuries (MAIS 1-2) to 64 occupants. In 9 cases, the injured were standing in the bus or coach at the crash.

Of the **44 injured in single vehicle crashes**, 43 (98%) were injured on rural roads. In two major single crashes, 40 occupants were injured. All 10 with MAIS 3+ injuries from single crashes were injured in these two crashes. The police report indicated that strong cross-winds, in combination with slippery road conditions, caused the coach to deviate off the road in these two crashes. This was confirmed by a calculation using an algorithm derived from wind tunnel testing[3].

3.2.2 Injuries

Of those 86 injured in collisions, only 5% had MAIS 2+ injuries (Table 3). The injury panorama were characterized (72%) by **neck sprain or "whip-lash" injuries** (AIS 1), caused by rear end impacts from other heavy vehicles (Figure 3).

In single vehicle crashes, the proportion of MAIS 2+ injuries was highest of all groups (21;48%).The 44 injured sustained on average 1.6 injuries per person (Figure 3). The most frequently injured body regions were **head** and face, followed by **upper extremities and chest**. One fourth of the injuries were fractures.

Table 2 Type and localization of all 340 injuries in the 284 injured

	Laceration/contusion	Sprain	Fracture/dislocation	Concussion/ intracranial bleeding	Other injury	Total
Head/face	32	—	3	***15/2***	—	52 (15%)
Neck	4	***78***	—	—	—	**82 (24%)**
Chest	14	1	8	—	2	25 (7%)
Abdomen/pelvis	10	2	7	—	1	20 (6%)
Upper extremity	36	7	***30***	—	—	**73 (21%)**
Lower extremity	34	29	21	—	4	**88 (26%)**
Total	130 (39%)	117 (34%)	**69 (20%)**	17 (5%)	7 (2%)	340 (100%)

Table 3 Number of injured in crashes by injury severity and urban/rural road

	Collision with other vehicle n=86 (66%)							Single vehicle crash n=44 (34%)	
	Urban street/road n=76 (88%)			Rural road n=9 (11%)			Unknown street/road n=1 (1%)	Urban street/road n=1 (2%)	Rural road n=43 (98%)
Injury severity	Frontal impact	Side impact	Rear impact	Frontal impact	Side impact	Rear impact	Side impact		
MAIS=1	3 (100%)	8 (88%)	***63 (98%)***	2 (67%)	4 (80%)	1 (100%)	1 (100%)	1 (100%)	22 (51%)
MAIS=2	—	1 (12%)	1 (2%)	1* (33%)	1 (20%)	—	—	—	***11 (25%)***
MAIS=3	—	—	—	—	—	—	—	—	***5 (12%)***
MAIS=4	—	—	—	—	—	—	—	—	***5 (12%)***
Total	3 (100%)	9 (100%)	64 (100%)	3 (100%)	5 (100%)	1 (100%)	1(100%)	1 (100%)	43 (100%)

* Collision with a moose

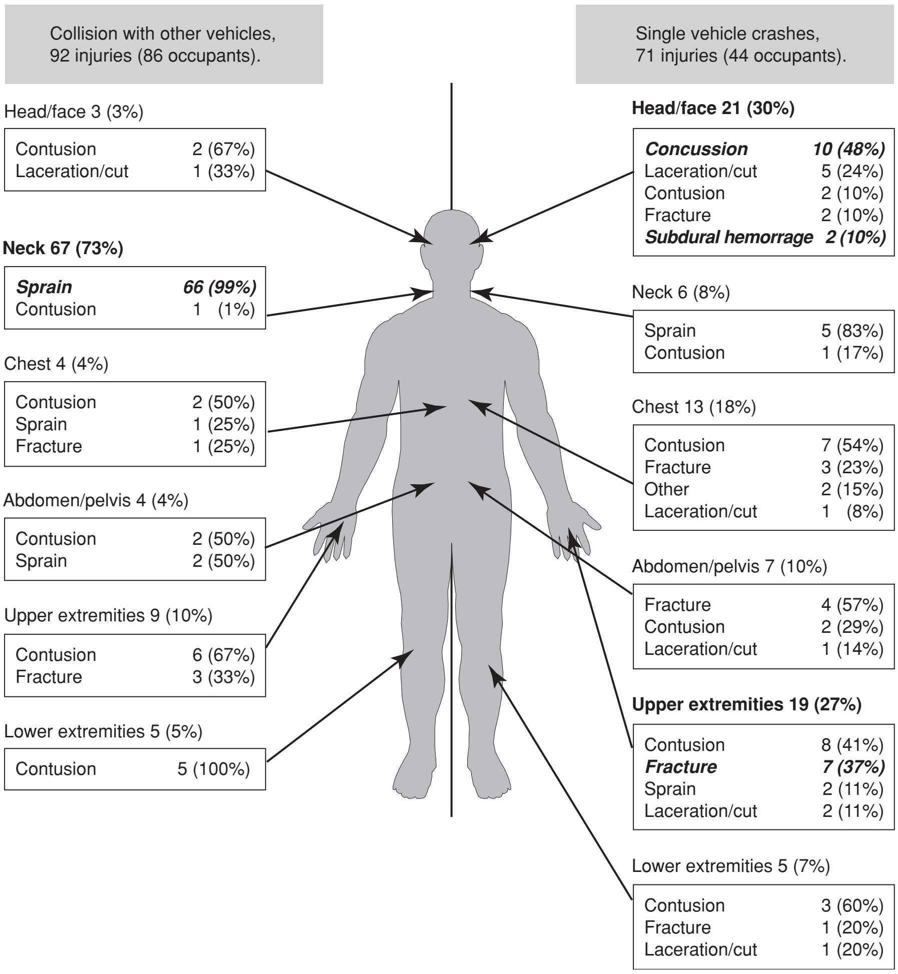

Fig. 3 Injury type and localization for those injured in crash incidents

3.3 Non-crash incidents

3.3.1 Age and type of incident

In non-crash incidents, 154 were injured; 118 (77%) women and 36 (23%) men. The mean age was 49 years for those injured when alighting or boarding and 42 for those injured in a moving bus, e.g. by falling when the bus was braking.

Two-thirds (106) of the non-crash victims were injured when alighting (102) from, or boarding (4), a bus at stand still (Table 4). Contributing causes given for alighting injuries were in 57 (56%) cases slipping on wet or icy steps, or on the ground, and in 28 (27%) cases stumbling on the way out of the bus or coach.

One-third (48) of the non-crash victims were injured by falling, or by injuring themselves in some other way, **in a moving bus or coach**. At least half (54%) were injured because the bus or coach was braking or accelerating (Table 4). Of the remaining 46%, most people were injured due to, e.g. stumbling or slipping when moving in the bus during the tour, but in two cases (4%) people were hit in the head by a falling TV-monitor and video recorder, respectively. At least 31 (65%) of these 48 occupants were standing.

3.3.2 Injuries

Of the 106 injured when **alighting or boarding** at stand still, **46 (43%) suffered MAIS 2+** injuries, as did 16 (33%) out of the 48 who were injured in "non-crash" incidents with moving vehicle (Table 4). Thirty-two per cent in the age group younger than 50 years had MAIS 2+ injuries compared to 49% in the age group 50+.

The 154 occupants sustained 177 injuries (Figure 4). **A majority of the injuries (54%)** sustained in the 106 **alighting and boarding** incidents were located to **the lower extremities**. Injuries sustained in "moving bus/ non-crash" incidents, were evenly distributed to the up-

Table 4 Number of injured in non-crash incidents by injury severity and type of mechanism

	When the bus or coach was moving n=48 (31%)				Bus or coach at a stand still n=106 (69%)		
Injury severity	Harsh braking	Accelerating from a stand still	While riding	Other and unknown mechanisms	Alighting	Boarding	Total
MAIS=1	13 (72%)	5 (63%)	10 (67%)	4 (57%)	58 (57%)	2 (50%)	92 (59%)
MAIS=2	5 (28%)	3 (27%)	5 (33%)	2 (29%)	***40 (39%)***	2 (50%)	**57 (38%)**
MAIS=3	—	—	—	1 (14%)	***4 (4%)***	—	**5 (3%)**
MAIS=4	—	—	—	—	—	—	—
Total	**18 (100%)**	8 (100%)	15 (100%)	7 (100%)	**102 (100%)**	4 (100%)	154 (100%)

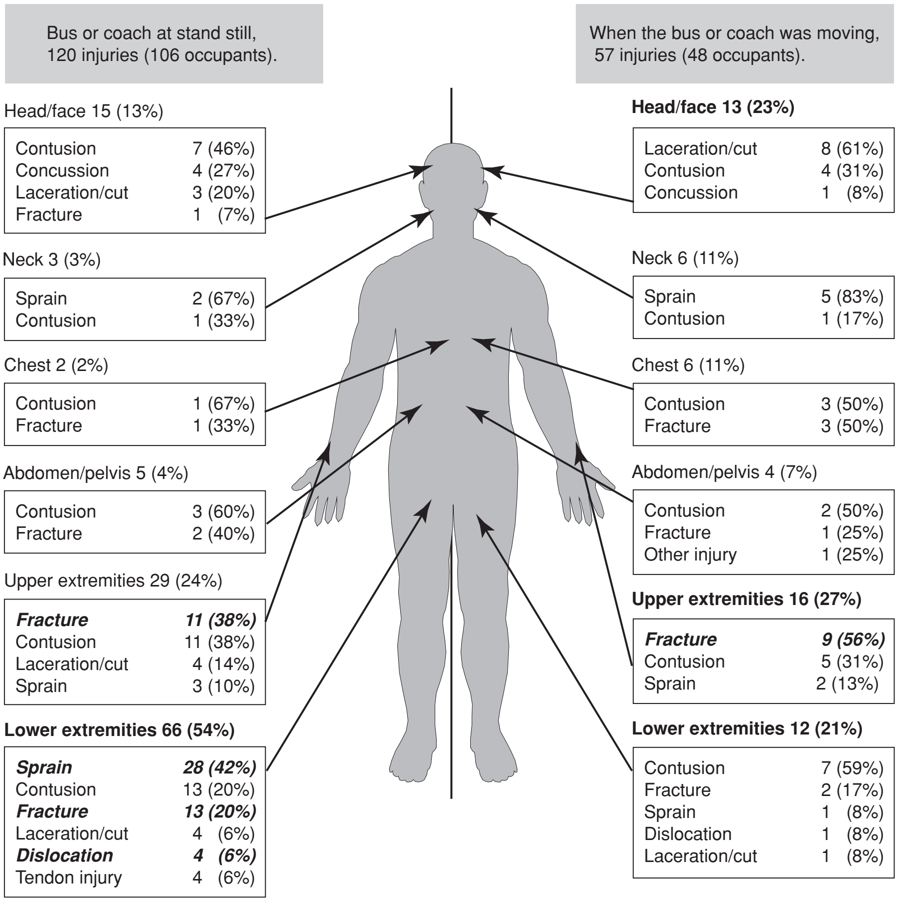

Fig. 4 Injury type and localization for those injured in non-crash events

per extremities, head and to the lower extremities.

4. DISCUSSION

The injury incidence was two per 10,000 inhabitants and year. The genuine quality of this total survey data from the medical sector provides a fair and robust indication of the injury incidence in a well-defined geographic area, as well as of the medical burden different types of incidents and injuries put on the health sector. To the increased trend of non-crash injuries from the first to the second part of the study period, improved accessibility for more vulnerable elderly and disabled may have contributed, as well as an increased number of journeys reported by bus companies in the area. The increase of people injured in crashes indicate a more uncertain trend, as a few mass casualty crashes may have a strong influence on data.

Only 38% of the bus occupants injured in a moving bus or coach were included in the official police-reported traffic injury statistics, as they should have been. This put emphasis on the importance to use data from the medical sector, instead of the official statistics, to get a representative view of the bus and coach occupant injury risks, and of the impact on the health sector.

From the medical point of view, the importance of non-crash incidents was obvious. More than half were injured in such incidents, 43% had MAIS 2+ injuries and 57% of all days at hospital were caused by non-crash events. However, also single vehicle crashes had a high proportion of non-minor injuries (48%), while the corresponding proportion for those injured in collisions only was 5%. From the health sector's view, collisions were thus no major emergency problem in this data set. Even if not represented in this data set, severe collisions between coaches and trucks are a reality[2,20] as, e.g. the recently reported collision in the neighbouring country Finland, causing the death of 23 young people[21].

Indications that aerodynamic factors related to high-sided (about four metres) coaches, strong cross-winds, and slippery road conditions, contributed to two major single vehicle crashes (Figure 5) were found. This hazard is not, or only scarcely, addressed in the literature and merits more interest. The Swedish Aeronautical Research Institute[22] has after wind tunnel studies, developed an aerodynamic algorithm usable to calculate the wind influence on coaches. Albertsson et al.,[3] have in a separate investigation of one of these crashes given an example on how the algorithm may be used and Petzäll et. al.[23], in a forthcoming paper, will report ten such crashes. Consequently, some coach operators in Sweden have, to increase the safety, recently expressed an intention to introduce speed restrictions on high-sided coaches in windy weather.

Fig. 5 A major single coach crash with 34 injured caused by severe cross-wind and slippery road conditions[3] (Photo: L. Danielsson)

The frequently reported "whip-lash" injuries from collisions may in some cases cause important long-term consequences and high sickness benefit costs[24-26]. These injuries might be reduced by higher seat backs/head restraints also in local buses, and by effective snow-clearance and other means of slip control.

Three-quaters of the injured were women and the mean age were highest (49 years) among those injured when alighting from, or boarding, a bus. This may reflect higher travelling frequency, greater vulnerability, and the 5-6 years longer average life span for women compared to men[27-29]. The lowest mean age (34 years) had those injured in collisions. High proportion of young people travelling during rush hours[19], may have contributed to the low mean age in these incidents[30].

Two-thirds of those injured in non-crash incidents were injured when alighting from a bus or coach and 43% had MAIS 2+ injuries. Similar[11], as well as higher[9,31], and lower shares[32], of alighting injuries have been reported. Alighting thus seems to be the major problem, having similarities with the well-known problem of falling in stairs, which most often happens on the last step when going downstairs[33,34]. For many years, the authorities have regulated the design of buses to make them more accessible for elderly and for people with disabilities[35,36]. From 1998, economic state subsidies equivalent to 100,000 USD per vehicle has been available to facilitate this process[37]. The subsidy requirement was, e.g. that the buses would have "low floor" entrances or a "kneeling" mechanism, reducing step height to 250mm in the first step from the ground and to 200mm in the other steps. To compare, the standard height for steps in buildings is 180 mm, while in elderly homes the recommended height is 120-160mm. This means that even in subsided buses and coaches aimed for elderly and disabled, the step height may be twice as high as in buildings.

Especially high sided, double decked, wind sensitive coaches with "low floor" entrance got this support (Figure 6). Realizing that the lifespan of such a coach would be 10-15 years, these specific problems[20,38] will remain for many years. Thus, this "good intention" subsidy seems to have created several problems and adverse effects. Further, to move between the upper and lower

Fig. 6 A typical double-decked, subsided, wind sensitive, coach with rear baggage and goods compartment further impairing stability. This type of coach is used for combined transport of passengers and goods in rural areas in Sweden. (Photo: P. Albertsson)

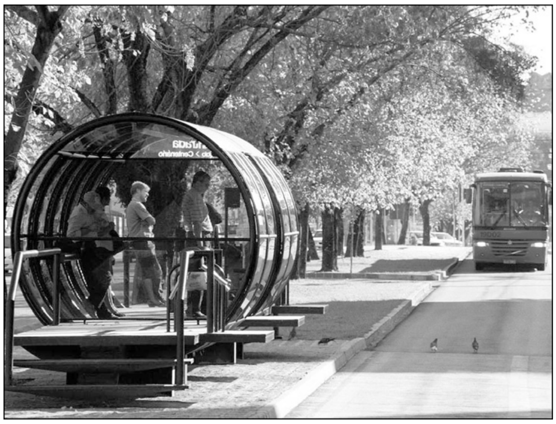

Fig. 7 An example from Curitiba in Brazil of a public transport system, minimizing level problems in boarding and alighting, facilitating and speeding up exchange of passengers and giving shelter to waiting passengers who pay before entering the tube. The system was built in cooperation with the bus manufacturer Volvo.

levels in such a coach also requires full locomotor skills. Strategies to increase safety of these vehicles thus need to be developed[39].

One good injury reducing measure would be to eliminate the level difference between the bus stop and the floor in the bus, as e.g. in the subway. A Volvo built system in Curitiba, Brazil (Figure 7), may illustrate one way to solve this problem. An additional risk factor when alighting is the risk of slipping on badly snow cleared bus stops[40-42]. Effective snow clearance and slip control measures at bus stops, heating coils in the entrance steps of the bus, and ground heating, may have a potential to reduce many of these wintertime injuries.

The finding that standing passengers, especially under sudden acceleration or deceleration, fell and were injured, raises the question of improvement of driving technique and interior design. Standing passengers may be difficult to avoid in urban traffic, why easily accessible handrails and a soft driving manner may be advocated to compensate some of these risks. Stress among drivers due to tight timetables may also compromise safety[32]. Especially during wintertime (when 3/4 was injured), this may happen. Some bus operators actually have the same timetables as during summer, despite frequent bad road conditions. The bus operator may also have to pay fines to the principal if they do not keep the timetable. All these factors may compromise safety, especially when slippery conditions prevail, as was the case in the two biggest mass casualty crashes in this data set.

At least a 1/4 were injured in such types of incidents (single crashes and collisions other than rear end impacts) that a seat belt might have reduced their injuries[8,43,44]. A study on roll-over crashes (as our major single vehicle crashes) indicated that a two point seat belt would reduce half of the MAIS 2+ injuries, and that a further reduction might be possible to achieve by a three point belt[45].

In conclusion, the aerodynamic crosswind factor is a new pre-crash factor, which merits more studies. Non-crash incidents, especially alighting from a bus, needs to be addressed with a focus on step height and slippery conditions. Rear-end collisions by other heavy vehicles in urban areas, also need to be addressed by e.g. better seats. The results from the present study may form a base for discussing different injury mitigation strategies and improvement of bus and coach safety.

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