

Madrid meeting
WD.1.

ACCIDENT STATISTICS
(FRONTAL COLLISIONS OF BUSES)
Presented by Hungary

DIFFICULTIES WHEN COMPARING DIFFERENT ACCIDENT STATISTICS

Different authorities in different countries, different expert groups, different road and police organizations, insurance companies, transport companies, etc. are collecting road accident statistics. They have different interests, different considerations, and different goals. Therefore the data collection has different basis, for example those accidents are considered only where:

- bus occupants were killed (at least one)
- bus occupants were injured (and killed)
- anyone were killed in the accident (partners, too)
- anyone were injured in the accident
- the damage of the bus exceeded a certain value (no need for injury)
- only a certain bus category is considered (e.g. class I. or class III. etc.)
- bus accidents on certain road types (e.g. only on highways, or rural roads, on city streets, etc.)
- collisions only with category of certain objects (heavy vehicles, fixed objects, cars and vans)
- the multiple accidents are involved or excluded

The statistical data collected and evaluated in this paper many times are not well specified from this point of view, which means that the scatter of the figures could be higher than it is acceptable in the normal technical life. But they are strong enough to show and underline the main tendencies.

REFERENCES, SOURCES

Those technical papers, sources are listed below, which are used, cited in the tables, summarizing the collected and prepared accident statistics

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STATISTICAL FIGURES AND MAIN CONCLUSIONS

Table 1. series

General bus accident statistics

Table 1.1. Bus occupant casualties in German bus accidents [3] [9] [4] [13] (The registered number of buses in Germany is in the order of 84.000)

	1994	1995	1996	1997	1998	1999	2000	2001	Σ
Fatality	36	20	24	15	2	20	9	11	137
Serious injury	525	500	555	460	430	595	435	335	3835
Light injury	4370	4100	4200	4250	4200	4550	4600	4150	34420

Table 1.2. Number and distribution of bus accidents in Germany, 1997, with injured persons (bus occupants and others) [4]

	Urban area	Highway	Rural road	Sum
Coach	192	120	146	458
City bus	3143	21	352	3516
Trolley bus	13	-	-	13
School bus	218	-	109	327
Other	1011	84	311	1406
Sum	4577	225	918	5720

Table 1.3. ECBOS statistics. Number of bus occupant casualties in 8 EU countries (Austria, Germany, UK, France, Italy, Sweden, Spain, Nederland) during the years 1994-98 [3] [13]

	EU 8	Germany
Fatality	746	99
Serious injury	11.969	2.470
Light injury	84.785	21.120

Table 1.4. Distribution of coach accidents having occupant casualties, according to the road types in Spain [14] Small buses are not involved

Spain 1993-1997 Only large coaches	% distribution of		
	accidents	fatalities	serious injuries
Urban roads	68,5	1,0	43,0
Highways and semi-highways	10,8	36,0	21,0
Rural roads	18,5	58,0	31,0
Others	2,1	5,0	5,0
	100,0	100,0	100,0

Conclusions:

- all kind of bus categories are involved
- the risk of fatality is higher on rural roads and highways, but the risk of serious injury is the highest in city buses.

Table 2. Bus accident statistics from different countries, different publications. (Injuries happened among the bus occupants or the traffic partners involved in the accident)
Small buses are not included in these accident statistics.

Bus accidents with injuries (or fatalities)	Hungarian [1]	German [3]	German [4]		Spanish [6]
			official data	special col- lected data	
time period	1978-82	1998	1996	1985-97	1984-88
Number of accident	1803	579	930	288	546
Studied bus categories	large buses and coaches	large buses and coaches		large buses and coaches	large coaches
Pedestrian overrun	27,7%	15,5%	27,9%	4,1%	16,6%
Collision with bicycle, motorcycle	27,3%	16,1%	24,2%	5,2%	7,4%
Collision with car and van	27,7%	56,1%	44,0%	53,7%	} 57,5%
Collision with heavy vehicle	12,1%	8,4%	3,7%	22,0%	
Impacting rigid object	1,7%	1,3%	-	} 8,2%	0,6%
Rollover	1,2%	1,7%	-		6,0%
Others	2,3%	0,9%	-	6,8	12,9% ⁽²⁾
	100,0%	100,0%	100,0%	100,0%	100,0%

Bus accidents with injuries (or fatalities) <i>cont.</i>	Spanish [2]	German [9]	
		Official data	Special collected data
time period	1995-99	1995-2001	
Number of accident	1822	5042	386
Studied bus categories	large coaches	Large buses and coaches	
Pedestrian overrun	10,7%	17,5 %	4,0 %
Collision with bicycle, motorcycle	- ⁽³⁾	14,5 %	5,5 %
Collision with car and van	38,8 %	51,5 %	52,5 %
Collision with heavy vehicle	46,3 %	6,0 %	22,5 %
Impacting rigid object	6,5 %	} 9,0 %	} 9,0 %
Rollover	4,6 %		
Others	4,5 % ⁽²⁾	1,5 %	6,5 %
	100,0%	100,0%	100,0%

Remarks:

- (1) widely used term without any specification
- (2) some of the rollovers and head on impacts could be involved as multiple accident
- (3) could be among the "others"

Conclusions:

- if it is difficult to separate the simple accidents from the combined ones (e.g. impacting a car and after a rigid object, or impacting a car and rollover, etc.)
- collision with cars and vans, heavy vehicles and stable objects (in which bus occupants may be injured) is in the range of 40-70% of all bus accidents in which somebody is injured.
- collision with heavy vehicles and stable objects (which can be very dangerous for bus occupants) is in the range of 10-30% of all bus accidents
- the rollover of buses is in the range of 1-6% of all bus accidents

Table 3. Bus collisions with vehicles (cars, vans and heavy vehicles) and stable objects, in which bus occupants were injured. Small buses are not included in this statistics.

Type of collision	Hungarian [1]	Japanese [5]	Spanish [2]	Spanish [6]	German ⁽³⁾ [8]
Time of observation	1978-82	1992-94	1995-99	1984-88	1978-84
Number of accidents	770	106	1571	420	100
Frontal collision	57,2 %	61,5 %	63,1 %	59,5 %	61,7 %
Side impact	17,8 %	6,1 %	12,1 %	} 16,1%	17,4 %
Rear impact	22,1 %	8,4 %	22,2 %		9,6 %
Other	-	24,0 % ⁽¹⁾	1,9 %	16,6 % ⁽²⁾	4,1 %
Rollover	2,9	-	0,7 %	7,8 %	7,2 %
	100,0 %	100,0 %	100,0 %	100,0 %	100,0 %

Remarks: (1) this figure involves the rollover, too
 (2) including the multiple accidents, too
 (3) specially collected, deeply analysed accidents

Conclusions:

- the frontal impacts are in the range of 55-60% among the bus accidents in which occupants are injured
- the severe frontal impacts of buses (with heavy vehicles, stable objects) which can be very dangerous for bus occupant are in the range of 6-18% of the accidents in which bus occupants are injured.
- the other very severe accident type of buses, the rollover is: 3-8% in the sama respect.
- the most severe bus collisions: collisions with trains are among the “others”

Table 4. Types of bus frontal collisions (full, partial) and the risk of driver compartment (DC)

Type of frontal impact	Hungarian [1]	Hungarian ⁽¹⁾ [1]	Spanish [2]	German ⁽¹⁾ [7]
Time of observation	1975-76	1974-78	1995-99	1980-86
Number of accidents	478	56	920	66
	100 %	100 %	100 %	100 %
Full frontal collision			45 %	21 %
Partial frontal collision			55 %	79 %
Impact on DC - side	50 %	46 %		50 %

Remark: (1) specially collected, deeply analysed accidents

Conclusions:

- the partial frontal impact has a higher ratio (55-80%) than the full one (20-45%)
- 45 -50% of the frontal collisions endanger the driver compartment.

Table 5. series

Bus frontal collision statistics based on the media reports in Hungary (Radio, TV, newspapers) [15]

Table 5.1. Time and scene of the accidents

before 2002	10 frontal collisions
during 2002 ⁽³⁾	15 frontal collisions
during 2003	57 frontal collisions
altogether ⁽¹⁾	98 frontal collisions
Hungary	48 frontal collisions
Europe (excl. Hungary) ⁽²⁾	14 frontal collisions
World (excl. Europe) ⁽²⁾	36 frontal collisions
altogether	98 frontal collisions

- Remarks: (1) 16 accidents (among the 98) were bus to bus double accidents.
 (2) The Hungarian media report only about the severe accidents.
 (3) The collection of the statistics started in the last months of 2002

Table 5.2. Categories of buses having frontal collision

Category	NUMBER
City bus (Class I. Reg.36)	12
Intercity, local (Class II. Reg.36)	23
Tourist, long distance ⁽¹⁾ (Class III.)	18
Small ⁽²⁾ (mini, midi, Reg.52.)	24
School bus, pilgrim bus	3
Unknown	18
TOTAL	98

- Remarks: (1) including HD and DD coaches, too
 (2) in media reports “small”, “mini”, “midi”, “micro” bus is used without technical specification

Conclusion: all categories of buses are included significantly in frontal collisions (see the same conclusion at Table 1. series), so all categories should be considered when regulating this subject.

Table 5.3. Casualties in the buses

Casualty ⁽¹⁾	NUMBER
Fatality	799
Serious injury	153
Light injury	169
Injury without specification	675
Mentioned “more/many injuries”	7 times
No injury ⁽²⁾	8 times

- Remarks: (1) including passengers, drivers and crews
 (2) in case of collisions with light partners (cars, vans, small buses) see Table 5.6.

Table 5.4. Casualties of bus drivers in these frontal collision

Casualties of drivers	Number	%
Reported fatality	15	15,3
Reported injury	13	13,3
Casualty with high probability ⁽¹⁾	34	34,7
No information ⁽²⁾	19	19,4
No injury ⁽³⁾	17	17,3
TOTAL	98	100,0

Assumptions:

- (1) in the case of serious frontal collision (total head-on impact, very high number of casualties, serious front wall damage) it may be supposed that the driver was also injured even if it was not particularly mentioned in the report. (Half of them killed, half of them only injured.)
- (2) “no information” means that the accident was not serious and no report about the driver casualty. It may be supposed that half of them were injured.
- (3) it was reported that the driver (or any body) was not injured in the bus.

Conclusion: a rough estimation could be made about the drivers: 33% of them were killed, 39% injured and 28% not injured. It is interesting to mention that 30% of the colliding partners were light vehicles, see Table 5.6.

Table 5.5. Similar accidents (frontal collisions) proving the vulnerability and high importance of bus drivers. [14] [15]

Date, country	Type of bus	Description of the accident	Casualties
2003 Belgian-French border	HD coach with low DC position	Likely the driver fell asleep, the coach hit the concrete barrier of the highway by the DC, the driver died, the coach took fire and burned out	12 fatalities 5 serious injuries 32 injuries
2003 Indonesia	Tourist coach	The coach - school children on the board – had a frontal collision with a truck, a van run into the coach from behind. The driver died, the coach took fire from the van and burned out	54 fatalities
1996 Spain	Tourist coach HD	A car collided the coach on its DC side. The driver died, the coach took fire and burned out.	29 fatalities 18 injuries
1982 France	Tourist coach	Bus, car and another bus were driving following each other. The first bus braked, the car also, the second bus driver reacted too late, hit the car, pushed it into the first bus. The second bus took fire from the car, and burned out. The second bus driver was injured and loss his consciousness.	50 fatalities

Conclusions:

- the primary collisions were not to severe for the bus passengers, but enough to injure or kill the driver
- the secondary accident – the fire – was tragic and fatal, the drivers could not help to the passengers, could not control the panic, the passengers were poisoned by the smoke and burned.
- There are some other conclusions related to the fire, but there are not relevant to our subject.

Table 5.6. Casualties in the buses depending on the colliding partners. The values in parenthesis show the casualty rate: number per accident

Colliding partner, object	No of accident	Fatality	Serious injury	Light injury	Injury without spec.	All casualties
Light vehicles ⁽¹⁾	29	33 (1,1) ⁽⁴⁾	17 (0,6)	14 (0,5)	31 (1,1)	95 (3,3)
Heavy vehicles	54	564 (10,4)	114 (2,1)	117 (2,2)	452 (8,4)	1249 (23,1)
Stable object ⁽²⁾	5	51 (10,2)	-	4 (0,8)	113 (22,6)	168 (33,0)
Pole-like object	5	28 (5,6)	11 (2,2)	34 (6,8)	42 (8,4)	115 (23,0)
Combined collision ⁽³⁾	5	123 (24,6)	11 (2,2)	-	37 (7,4)	171 (34,2)
TOTAL	98	799 (8,1)	153 (1,6)	169 (1,7)	675 (6,9)	1798 (18,3)

Remarks: (1) motorcycles, cars, vans, small buses
 (2) walls, bridge pillars, concrete barriers
 (3) fire after collision, multiple collision
 (4) includes a double collision of two small buses with 20 fatalities

Conclusions:

- 30% of the collisions happened with light vehicles, 65 % with heavy vehicles and stable object and
- 5% of them were combined collision.
- The 30% accident rate covers only 5% of the casualties which means that collision with light vehicles is not dangerous for bus.

Table 5.7. Comparison of two severe bus accident types: the casualty rates in frontal collision and rollover.

Accident situation	No. of events	Fatality rate	Injury rate	All casualty rate
All rollover accidents ⁽¹⁾	157	11,0	13,3	24,3
All frontal collisions	98	8,1	10,2	18,3
Rollover with unharmed survival space	32	1,0	11,0	12,0
Frontal collision with light vehicle	29	1,1	2,2	3,3
Rollover with damaged survival space	30	12,8	20,2	33,0
Frontal collision with heavy vehicles	54	10,4	12,7	23,1
Frontal collision with stable object	10	7,9	20,4	28,3
Australian data ⁽²⁾		7,0	27,0	34,0

Remarks: (1) World-wide rollover statistics, presented in GRSG
 (2) Including head-on impact, side impact and rollover. Published in the journal Australian Bus and Coach, 16. January 1998.

Conclusion: rollover is known as a severe bus accident with high casualty rate. These figures show that the frontal impact with heavy vehicles and stable objects is in the same order when comparing their casualty rates.

Table 6. Comparison of severe coach accidents in Spain between 1993-1997 [14]

Coach accidents	Related to the total values		
	Mortal accidents ⁽²⁾	fatalities	Serious injuries
Full frontal collisions	20,9 %	39,1 %	18,7 %
Frontal-side collisions ⁽¹⁾	21,7 %	18,2 %	22,6 %
All frontal collision	42,6 %	57,3 %	41,3 %
Rollover	25,5 %	24,5 %	29,5 %

Remarks: (1) frontal impact under angle and/or partial frontal impact
 (2) in which at least one coach occupant was killed

Conclusion: These figures – using different approach – underline the conclusion drawn from Table 5.7

Table 7. Driver/Passenger (D/P) injury rate expresses the casualty risk ratio between the driver and an average passenger. D/P injury rates were calculated on the basis of earlier published statistical data.

D/P injury rate	All type of bus accidents					Front impact only
	Japanese [10]	Spanish [2]	German [12]	U.K. [11]	Hungarian	Japanese [10]
Fatality	83:1	6:1	8:1	5:1	5:1	125:1
Serious injury	13:1	3 2:1	10:1	4:1	3 3:1	18:1
Light injury	7:1		6:1	3:1		4:1
Total number of casualties	4800	2400	4500	234,616	4300	3200
Time of observation	1992-94	1984-88	1979	1971-92	1987-92	1992-94

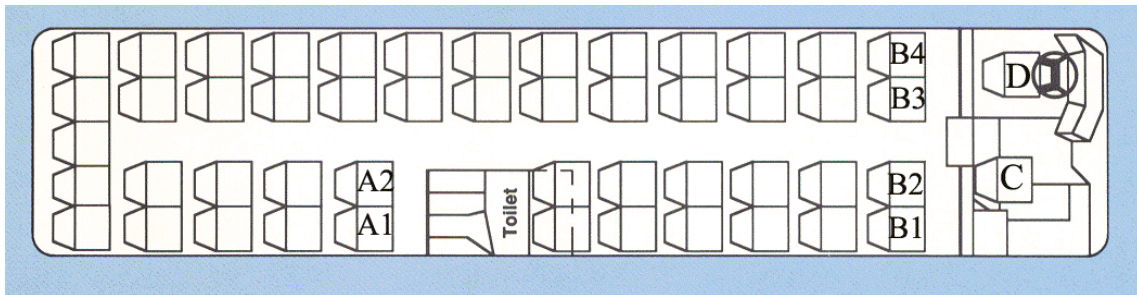
To estimate the D/P injury rate from the statistical data, the following assumptions (simplifications) were made:

- a) The injury probability (IP) of the driver and the passenger related to each other in the different accident situations:
 - frontal collision: the driver has higher IP
 - rollover: equal IP
 - side impact: the driver has lower IP
 - rear collision: the driver has lower or equal IP
- b) The average passenger capacity of a bus (coach) is 50
- c) The buses (coaches) are fully loaded in the accident (frontal collision) that means 1 driver belongs to 50 passengers
- d) The IP of the passengers is equal in case of frontal collision. (It is not absolutely true, it will be shown later in Table 8., but it may be used as a first approach)

Conclusions

- The D/P casualty rate, considering all type of bus accidents is significantly higher than 1:1, that means the drivers have higher IP than the passengers.
 - Considering assumption “a” above, the only reason of this higher IP is the frontal collision
 - Only the Japanese data show direct D/P rate for frontal collisions. The reason of the extreme high D/P rate in this statistics is the very low number of the passenger fatalities.
 - The Japanese data show that the D/P casualty rate for frontal collisions may be estimated from that rate of all accidents using a multiplier of 1,5.
 - The data from the four countries have a wide scatter, but the following ranges for D/P casualty rates in frontal collisions:
 - Fatality (5-100):1
 - serious injury (4-15):1
 - light injury (2-6):1
- underline the urgent need to protect the drivers.

Table 8. The most dangerous occupant positions in coaches based on detailed study of 7 frontal collisions in Spain [16] and considering some other experiences.



Remarks:

- The types of the 7 frontal collisions
 - 2 frontal collisions with car (the frontal impact was not too severe) but followed by fire and rollover,
 - 3 frontal collisions with trucks (front to front)
 - 2 frontal collisions with trucks (running into trucks from rear)
- The seats having extra (additional) injury risk in frontal collisions
 - A seats behind a staircase, partition (no seats in front of them)
 - B seats in the first row
 - C crew seat in the front overhang
 - D driver seat

Seat	Fatality	Serious injuries	Light injuries	Remarks
A	-	4	2	2 seats were empty in the 7 collisions in two coaches no C seat, in one case no crew
B	7	8	2	
C	-	2	1	
D	4	1	2	

Conclusions:

The extra (additional) injury risk in the seats

- “A” seats: no suitable retention, extra biomechanical loads when contacting bad design partition (*)
- B3 like “A” seats (*)
- B1,B4 seats: like “A” seats and they could be in the direct deformation zone in high energy impact under angle (**)
- B1,B2 seats: like “A” seats and their passengers could be ejected through the windscreen (***)
- C seat: like “A” seat and it is in the direct deformation zone and also the danger of ejection should be considered (****)
- D seat like “C” seat, adding to that the left side frontal collision has higher probability than the right side (****)

The higher number of stars means higher injury risk.