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Comparsion of Single Vehicle Accidents with Cars not Equipped with ESP (Electronic Stability Programme) and the Assumption the Cars are Equipped with ESP

Abstract

In recent years the boundaries between active and passive safety blurred more and more. Passive safety in the traditional term includes all safety aspects to prevent occupants to be injured or at least injury severity should be reduced. Passive Safety starts with the collision (first vehicle contact) and ends with rescue (open vehicle doors). Within this phase the occupant has to be protected by the passenger compartment whereby no intrusion should occur. Active safety on the other side was developed to interact prior to the collision whereby the goal is to prevent accidents. The extensive interaction between active and passive safety led to the terminologies “Primary” and “Secondary” safety whereas the expression Integrated Safety Concept [1] was generated.

Within this study the most well documented single vehicle accidents with cars not equipped with ESP were identified from the PENDANT database and reconstructed. Additional cases were found in the database ZEDATU of TU Graz. In comparison each case was simulated with the assumption that the cars were equipped with ESP. The differences regarding accident avoidance or crash severity as well as reduction of injury risk were analysed.

Introduction

This study is part of the PENDANT (Pan-European Co-ordinated Accident and Injury Databases) project [3]. The project itself is divided into three Work Packages. The Purpose of Work Package 1 was to ensure that in-depth accident and injury data collected by several organisations were comparable. In particular two tasks addressed the needed harmonisation of the fundamental crash parameters describing collision severity and injury outcome. The third task analysed accident causation and injury countermeasures. Within Work Package 2 the teams of eight different countries were collecting approximately 1,100 accidents. A database was developed based on an enhanced STAIRS (Standardisation of Accident and Injury Registration Systems) protocol [2]. Work Package 3 investigated existing hospital data from three countries. This type of data covered relevant injury data, treatment data and normally some general accident data of traffic casualties admitted to hospitals.

Task 3 in Work Package 1 investigated active safety even if the whole project was primarily focussing on passive safety aspects. The most well documented 30 (if available) single vehicle accidents with cars not equipped with ESP should have been identified from the in-depth database collection in Work Package 2 [4].

Due to the emphasis on passive safety the goal of 30 well documented single vehicle accidents was not reached. An additional investigation has been made in the ZEDATU (Zentrale Datenbank tödlicher Unfälle) database from TU Graz. Within this database fatal accidents from 2003 are examined. Finally 26 accidents were found in total meeting the high requirements.

In the first step, accidents were reconstructed and in a second step the assumption was made that the vehicles were equipped with ESP (Electronic Stability Programme). Accident avoidance possibilities and crash severity were documented.

Procedure

When the task started the PENDANT database had 958 accident case entries but not every accident investigation was finished. From notification of an accident by police until gathering injury data several weeks or even month may have elapsed. Approximately 44% of the collected accidents were single vehicle accidents and about 49% were accidents with two participating vehicles. In 7% of the accidents more than two cars were involved.

To facilitate the identification of single vehicle accidents the database was extended by a specific form according CARE Plus [5] data fields. Subsequent list presents the main groups of CARE Plus accident type configurations:

- Accident with pedestrians (group A).
- Accident with parked vehicles (group B).
- Single vehicle accidents (group C).
- Accidents with at least two vehicles and no turning (group D).
- Accidents with at least two vehicles and turning (group E).

As mentioned, main focus was set to single vehicle accidents. Figure 1 provides the distribution of all CARE accident types within the countries. Single vehicle accidents were most frequent in the United Kingdom sample as well as in the Spain cases. Another huge portion was found for French accidents. The amount of appropriate cases for Austria and Finland was limited.

Considering CARE glossary each main group is classified into subgroups and these subgroups are again divided into sub-subgroups defining a more detailed classification of the accident circumstances. In principle two subgroups can be distinguished in CARE main group “C” (represents level 3 in CARE Plus 2 accident type glossary) [10]:

Subgroup 1 (single vehicle accidents without obstacles on the road):

- C1L Single vehicle accidents without obstacles on the road – left.
- C1R Single vehicle accidents without obstacles on the road – right.
- C11 Single vehicle accident – leaving straight road – either side of the road.
- C12 Single vehicle accidents on the road (often two-wheelers).
- C13 Single vehicle accidents in a bend – going either side of the road.
- C14 Single vehicle accidents in junctions or entrances.
- C19 Single vehicle accidents – others.

Subgroup 2 (Single vehicle accidents with obstacles on the road):

- C2L Single vehicle accidents with obstacles on the road – left.
- C2R Single vehicle accidents with obstacles on the road – right.
- C21 Single vehicle accidents with animals.
- C22 Single vehicle accidents with obstacles on or above the road.

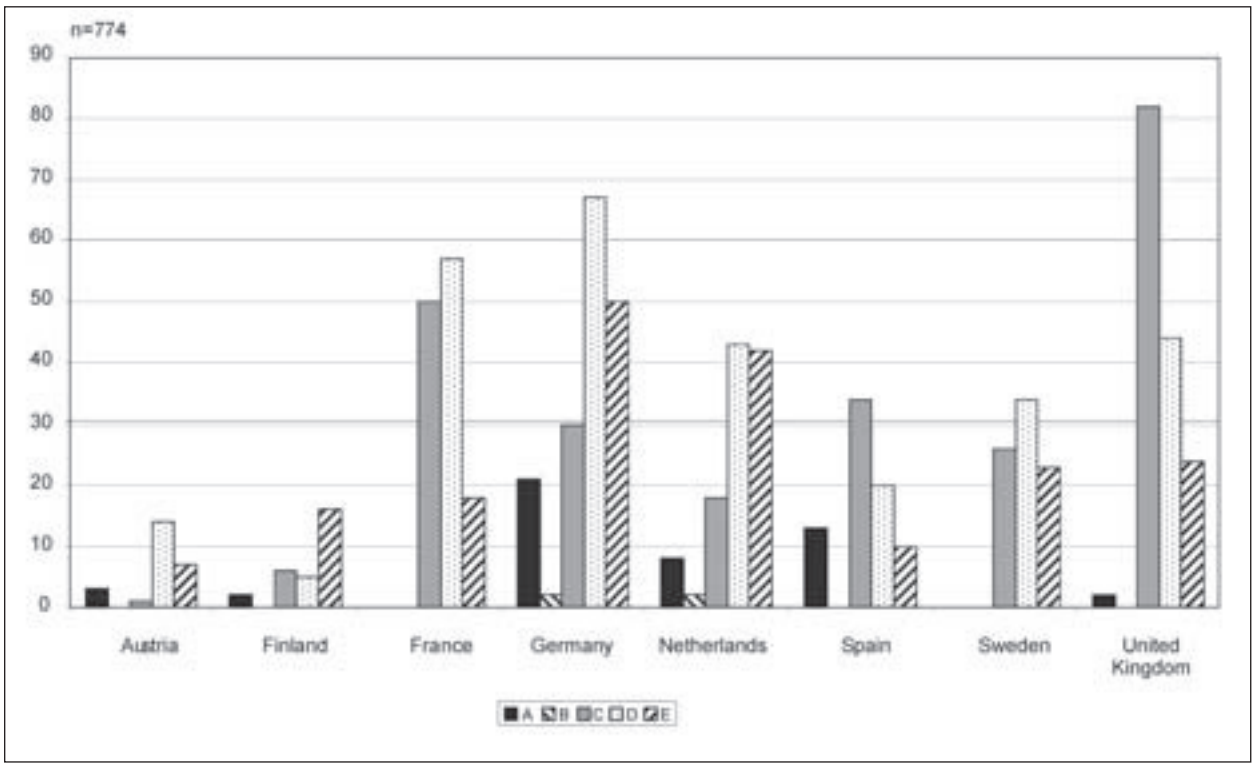

Figure 1: Case distribution CARE main group

- C23 Single vehicle accidents with roadwork materials.
- C24 Accidents between train and vehicle.
- C29 Single vehicles accidents with obstacles – others.

At this point about 254 cases were available for ESP investigation (Figure 2) whereby United Kingdom (32,68%) and France (20,08%) had the highest share. More than 50% of single vehicle accidents were collected in these two countries. Only a small number was found for Austria (0,39%) and Finland (2,36%). Spain had a share of 13,78%, Germany 12,60%, Sweden 10,24% and the Netherlands 7,87%. Due to the different relationships of investigation teams to police the differences could be explained.

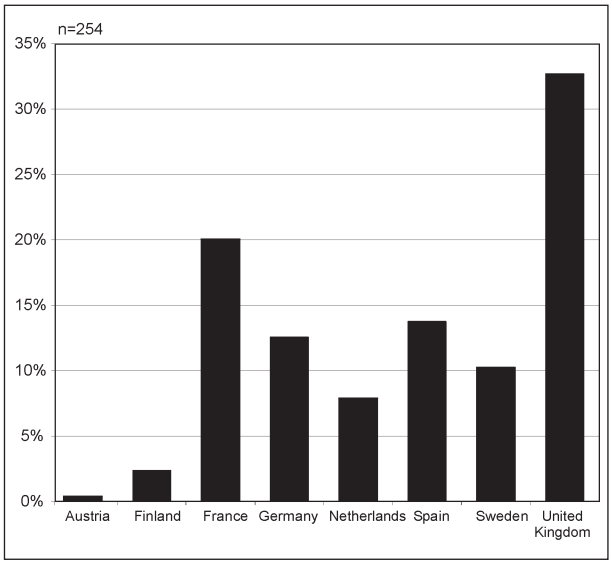

Figure 2: Accident cases CARE group C – partners

As already mentioned PENDANT focused on passive safety. Hence no pre-impact information was collected. In case of active safety only ESP (Electronic Stability Program), ABS (Antilock Braking System), TCS (Traction Control System) and ACS (Active Cornering System) were recorded as existing active safety features fitted to the vehicle. Even if there were data forms developed no attention was paid to generate guidelines to collect on-scene material. Besides PENDANT data forms only a few partners investigated in pre-impact evidence like skid marks, road design etc. anyway. Merely cases from Austria, Germany, the Netherlands and Sweden were available for the purposes of pre-impact investigation

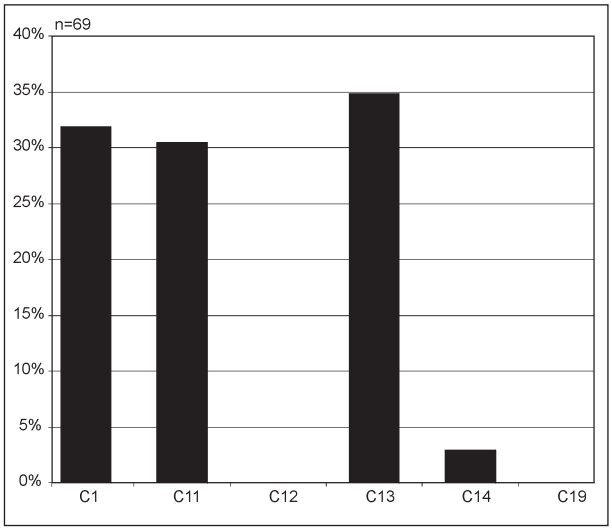

Figure 3: Single vehicle accidents CARE subgroup C1

Considering only subgroup 1 (which matched the requirements) and accident cases including. On-scene evidence 69 cases were left for in-depth studies (Figure 3). Eventually only 17 cases contained sufficient information. It has to be pointed out that not all single vehicle accidents are preceded by skidding. Vehicles already equipped with ESP were removed.

To increase the number of accidents the database ZEDATU (Zentrale Datenbank tödlicher Unfälle) of TU Graz was studied. Within the current datasets road-fatalities from 2003 were collected. Due to the accident coding system in Austria accidents vehicles skidding can be identified easily. At least one of the participating vehicles skidded in approximately 27% of 847 fatal accidents. Among accident circumstances “sideway skidding” and “forward skidding” are most frequent single vehicle accidents (53%, see Figure 4). Accidents with on-coming traffic had a share of 37%. 7% of these accidents were collisions between two vehicles driving in the same direction. All other types are negligible.

Gathering single vehicle accident cases from ZEDATU it turned out that documentation of accidents varied in quality. In particular pictures taken of scene and vehicles were inadequate. For a huge number of single vehicle accidents documentation had poor quality, especially when only the driver was involved. The reason can be found in Austrian’s legislation. There is no law to punish self-injuries – hence little effort is taken by the police in investigating single car accident thoroughly.

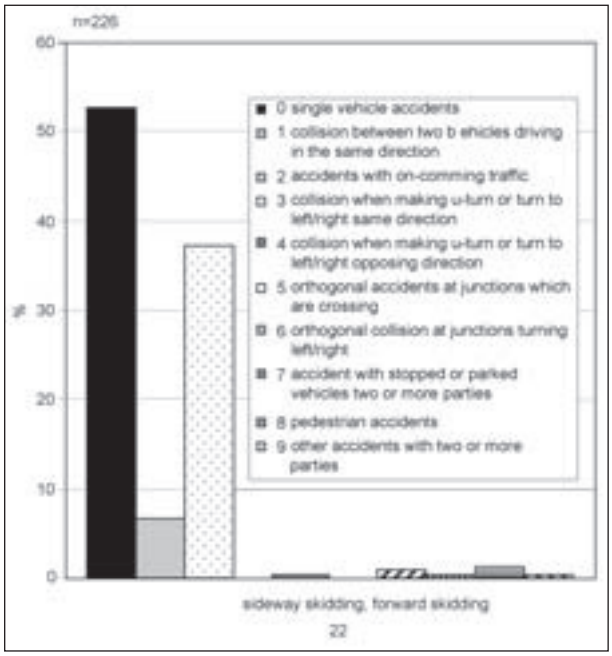

Figure 4: Vehicles sideway and forward skidding in Austrian accident main categories

To be in line with CARE main group C – "single vehicle accidents" - Austrian accident type 0 – "single vehicle accidents" were examined in more detail. Among 119 accidents 73% could be identified as passenger cars (87 cases). Analyzing the accident location more than 35% occurred in bends. Considering all criterions and on-scene material in a satisfactorly quality required for reconstruction nine single vehicle accidents could be added to the study.

It needs to be mentioned that during the PENDANT project the work for ZEDATU was in progress too and not all single vehicle accidents were collected.

Categorization of single vehicle accidents

The accidents caused by a chain of circumstances were categorized regarding street section into bends or straight roads (Figure 5). In a second level the vehicle started skidding due to unadjusted speed and/or slippery surface and intervention by the driver could not stabilize the car anymore. It was also seen that drivers tried to avoid leaving the road to the side or a collision with an obstacle on the road by turning the wheel excessively. Within this type of accidents the vehicle started skidding after the collision-avoiding manoeuvre or it was possible to counter steer certain times but resulted in an accident anyway.

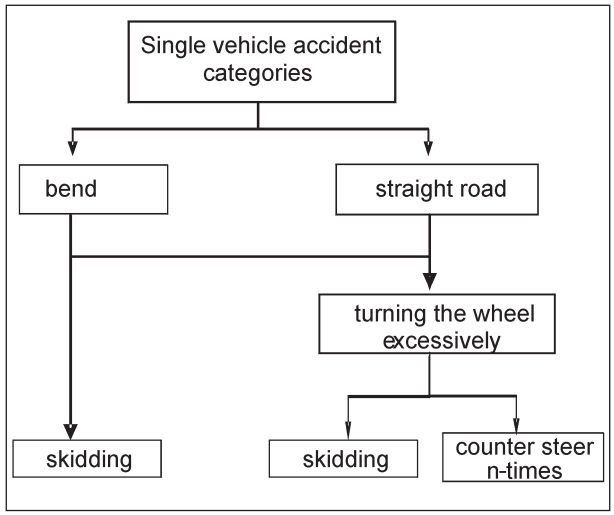

Figure 5: Single vehicle accident categories

Reconstruction of single vehicle accidents

Due to the fact more and more vehicles are equipped with ESP it was necessary to develop a tool simulating ESP in a numerical environment. ESP has a huge complex influence on vehicle dynamics and only a tool in an accident reconstruction software guarantees accurate reconstruction results. Besides Anti Lock Braking System Electronic Stability Program was implemented into PC Crash. Within the tool the yaw velocity is controlled. Based on the driven velocity of the vehicle and the actual steering angle required yaw velocity is calculated and is compared with the current existing yaw velocity. If predefined thresholds are exceeded the program intervenes by braking wheels separately depending on over or under steer.

For reconstruction of the single vehicle accidents involving vehicles equipped with ESP the following assumptions were made:

- identical vehicle path for both reconstructions (first without and second with ESP),
- equal sequences duration,
- equal braking pedal position.

Of course that will not fully match with accident reality but otherwise it gets very difficult to estimate behaviour of drivers.

Results

26 single vehicle accidents could be identified with 13 occurring in bends and another 13 taking place

Figure 6: Single vehicle accidents

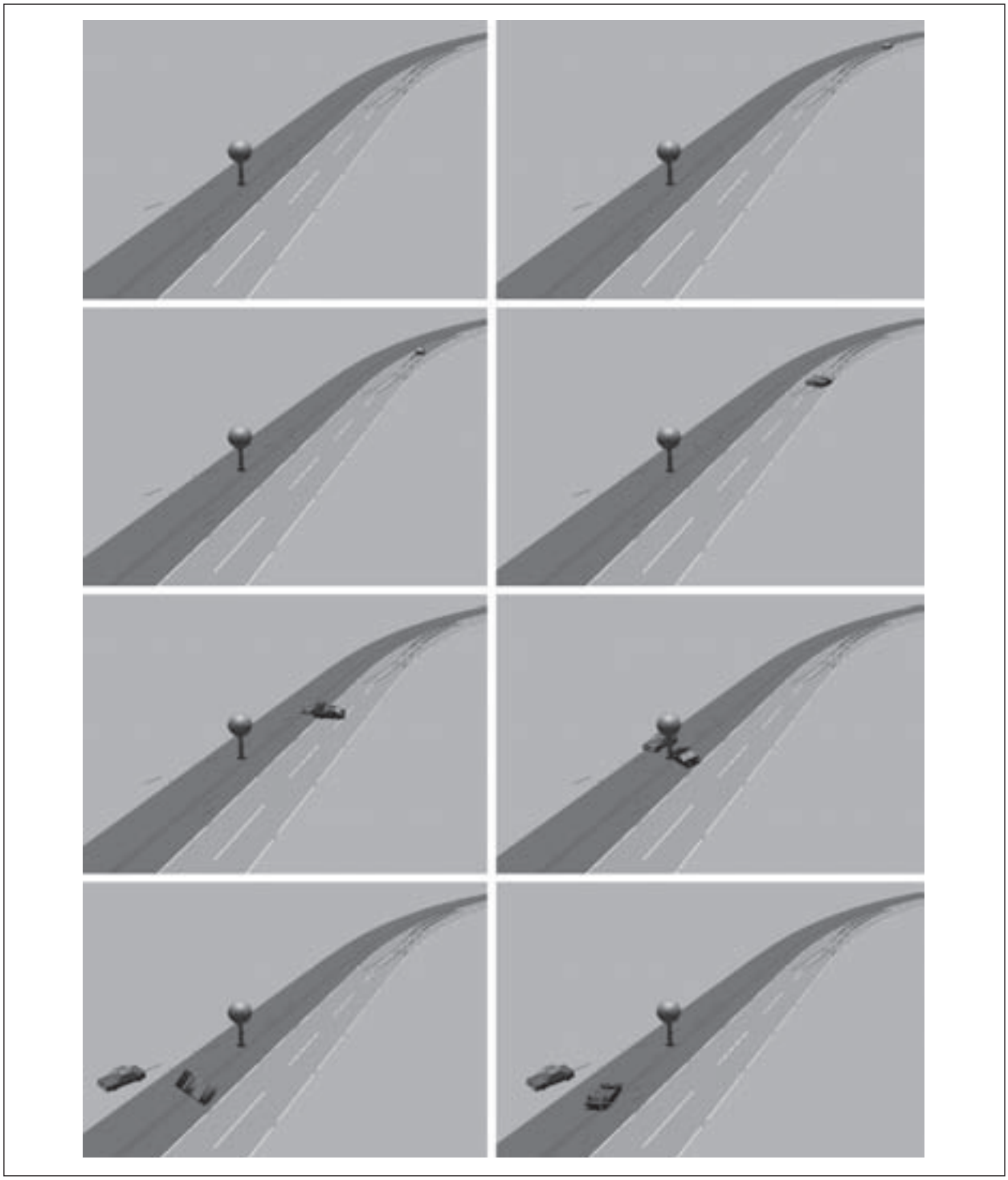

Figure 7: Single vehicle accident with 1s time sequence

on straight road sections (Table 1). Vehicles leaving the road and the wheels got stuck whilst skidding all of those resulted in a rollover (Figure 9), no matter if the accident occurred in a bend or on a straight road section.

road type	turning the wheel excessively	skidding	counter steer 3x	counter steer 2x	counter steer 1x	
bend	no	4				5
	yes	4	1		3	8
bend		8	1		4	13
straight road	no	1				1
	yes	5	1	1	5	12
straight road		6	1	1	5	13
		14	2	1	9	26

Table 1: Accident sequences

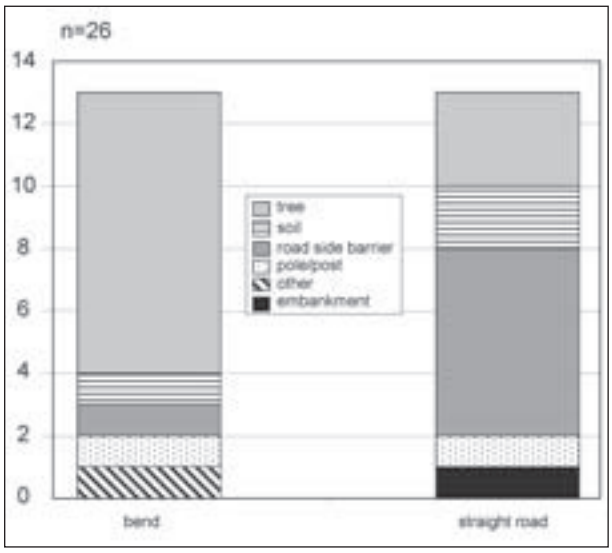

Figure 8: Collision partner of single vehicle accidents

In the example shown in Figure 6 a vehicle was leaving the road to the right into the verge. The driver turned the steering wheel sharply to stay on the road but got to the on-coming traffic road side. As he counter steered the yaw angle was exceeding the limit and the vehicle started to skid. At this point the vehicle approached the road, hit a tree and additionally the wheels got stuck at the soil. The accident resulted in a rollover. This single vehicle accident was reconstructed with PC-Crash. Assuming that the car was equipped with ESP the accident would have been prevented. However, depending on the road side infrastructure a frontal accident may have occurred.

The sequence in Figure 7 shows the movement in a perspective view at one second time step. Red coloured vehicle was equipped with ESP.

Single vehicle accidents in bends resulted mainly in collision with trees and poles/posts. In comparison most collisions happened on straight roads with road side barriers. No distinction within the type of barriers can be made in the database. Three of the single vehicle accidents on straight roads resulted in an impact with a tree and a further two got stuck in the soil whereby a rollover followed.

Figure 9 illustrates rollover regarding road category. It can be seen that rollovers occurred mostly when the wheels got stuck in the soil. Some single vehicle accidents resulted in a rollover in the category “impact”. Three rollover accidents occurred in bends after an impact, one single vehicle accident had a rollover before a contact occurred and for another one a rollover happened without a collision. On straight roads one single vehicle accident had a contact before the rollover happened and for three cases no collision arose.

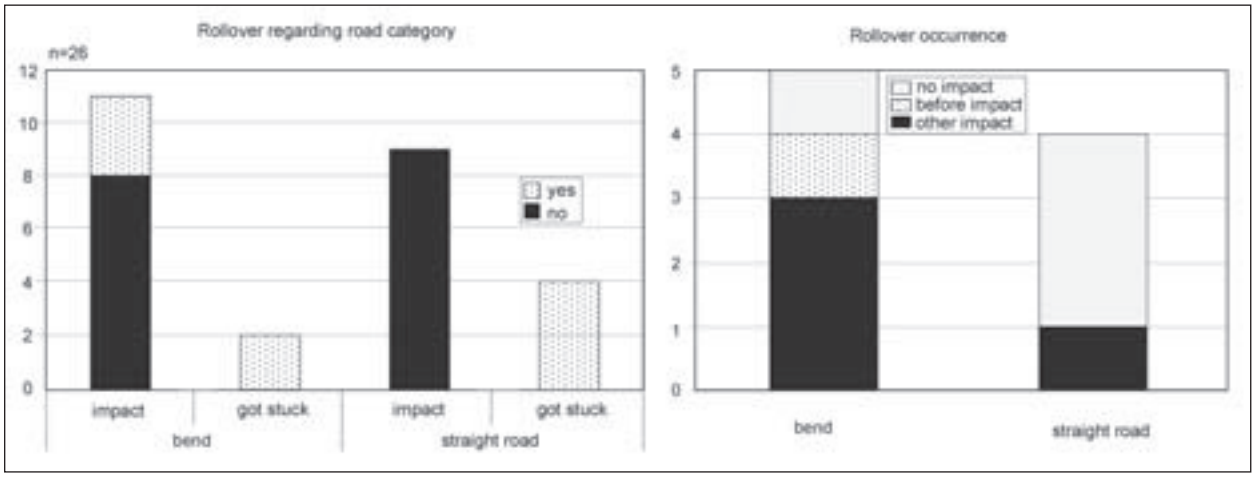

Figure 9: Rollover and road category

In bends four cases could have been avoided and on straight roads ESP would have prevented an accident in four cases. If it was not possible to avert the accident ESP led to a different impact configuration or crash severity was decreased. Delta-V as an injury severity parameter was reduced significantly due to ESP. To summarize up to 30% (eight of 26) of single vehicle accidents would have been prevented if the vehicle were fitted with ESP. Even if only a low portion of single vehicle accidents were available for investigation a good agreement can be seen with AGA and OKADA [6]. They found out a reduction of approximately 35% in single-car accidents. LANGWIEDER et al. [7] expect that ESP would be beneficial in at least 60% of the skidding related car accidents. ESP could have a probable or definite influence in about 34% of fatal accidents and 18% of injury accidents (SFERCO et al.) [8]. TINGVALL et al. [9] pointed out that on all road surfaces and in all accidents except rear-end impacts, the effectiveness of ESP is 22.1%.

For accidents which could not be prevented ESP led at least to another impact configuration. Tables 2 and 3 provide an impression of certain parameters of reconstructed single vehicle accidents. Table 2 explains those accidents which were not avoided or led to different impact configuration respectively. Table 3 shows the cases which could be prevented by ESP.

Following abbreviations were used in the next two Tables:

n/a	not applicable
ai	after impact
bi	before impact
ni	no impact

without ESP						with ESP			
impact location	PDoF	speed limit [kph]	rollover	Delta-V [kph]	occured	impact location	PDoF	Delta -V [kph]	rollover
F	01	50	no	11	n/a	R	02	5	no
F	01	70	yes	44	ai	L	11	15	no
F	11	130	no	27	n/a	L	10	9	no
F	01	130	no	40	n/a	L	09	4	no
L	08	70	yes	20	ai	F	12	52	no
L	10	100	no	37	n/a	L	10	4	no
L	08	130	no	74	n/a	L	08	64	no
L	11	999	no	58	n/a	L	10	8	no
R	02	50	no	29	n/a	R	01	8	no
R	02	70	no	49	n/a	F	01	70	no
R	12	80	no	49	n/a	F	12	70	no
R	02	100	no	57	n/a	F	01	67	no
R	01	100	no	66	n/a	R	02	5	no
R	08	100	no	66	n/a	R	02	6	no
R	07	999	no	39	n/a	F	01	23	no
T	03	50	yes	20	bi	F	12	50	no
T	00	70	yes	n/a	ni	M	00	n/a	yes
T	00	100	yes	n/a	ni	M	00	n/a	yes

Table 2: Single vehicle accidents which could not be avoided by ESP

without ESP						with ESP			
impact location	PDoF	speed limit	rollover	Delta-V [kph]	occured	impact location	PDoF	Delta-V [kph]	rollover
F	01	120	no	51	n/a	Prevented by ESP			
L	10	50	yes	22	ai				
L	11	70	no	8	n/a				
L	02	100	no	55	n/a				
R	11	80	yes	7	ai				
R	08	100	no	32	n/a				
T	00	100	yes	n/a	ni				
T	00	130	yes	n/a	ni				

Table 3: Prevented single vehicle accidents by ESP

Table 4 provides impact location and injury severity regarding Delta-V. On the left hand side vehicles are reported which were not equipped with ESP. Delta-V and injury severity were identified from database whereby injuries were assessed in hospital or from medical doctors. Frontal impacts led to side impacts whereby change of velocity Delta-V decreased as well as impact velocity. Accidents which could not be prevented and had side impact configuration resulted mainly in side impacts with a lower change of velocity Delta-V. In some cases side impacts developed with ESP in frontal collisions. Accidents in which the wheels got stuck at the soil ESP was not able to avoid a rollover.

without ESP			with ESP							
impact location	Delta-V [kph]	MAIS hospital	impact location	Delta-V [kph]	injury severity probability [%]					
					MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6
F	11	3	R	5	86	0	0	0	5	9
F	44	1	L	15	66	20	7	0	0	7
F	27	1	L	9	79	11	5	0	5	0
F	40	2	L	4	86	0	0	0	5	9
L	58	1	L	8	79	11	5	0	5	0
L	20	1	F	52	30	40	30	0	0	0
L	37	1	L	4	86	0	0	0	5	9
L	74	999	L	64	100	0	0	0	0	0
R	57	1	F	67	33	33	0	0	33	0
R	66	2	R	5	86	0	0	0	5	9
R	49	2	F	70	33	33	0	0	33	0
R	66	4	R	6	79	11	5	0	5	0
R	49	2	F	70	33	33	0	0	33	0
R	39	999	F	23	82	8	8	0	2	0
R	29	3	R	8	79	11	5	0	5	0
T	20	1	F	50	56	33	11	0	0	0
T	n/a	1	M	0	n/a	n/a	n/a	n/a	n/a	n/a
T	n/a	3	M	0	n/a	n/a	n/a	n/a	n/a	n/a

Table 4: Impact configuration and injury severity

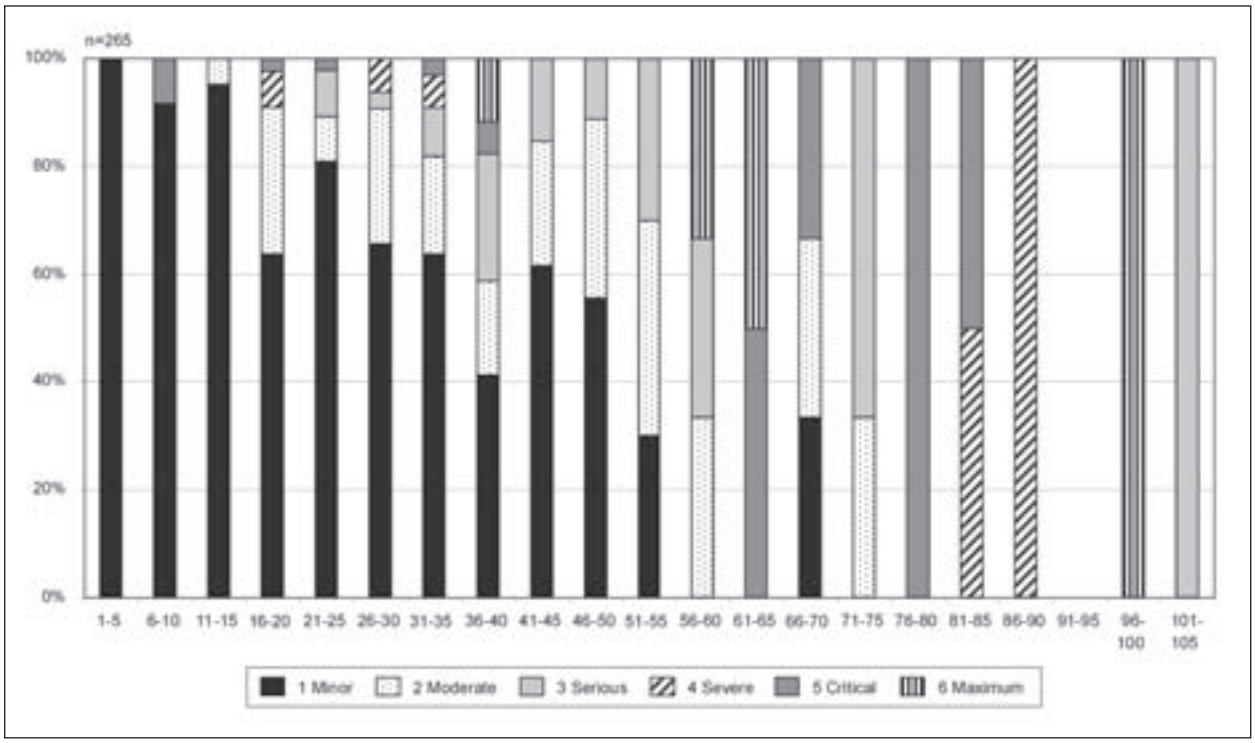

Figure 10: Injury severity of frontal accidents in PENDANT

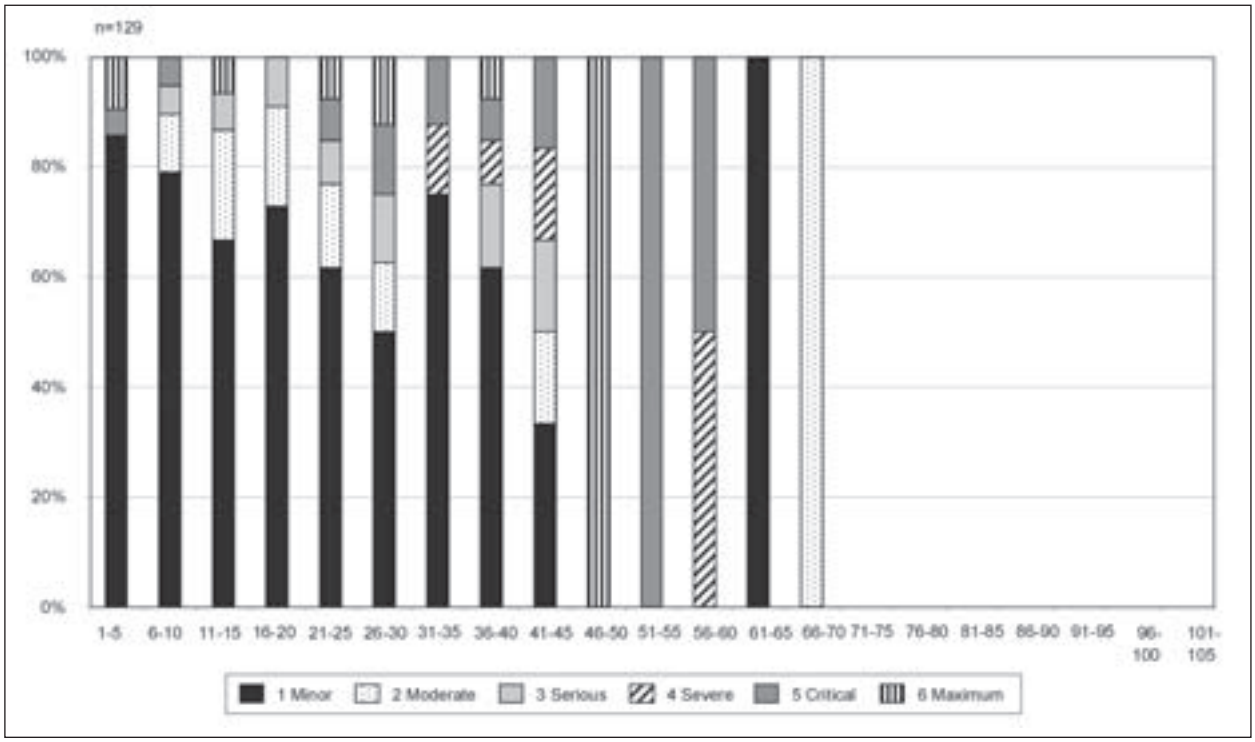

Figure 11: Injury severity of side impacted vehicles in PENDANT

Right handed side of the table provides impact location, Delta-V and injury severity probability of vehicles equipped with ESP in single vehicle accidents. Injury severity was estimated from frontal (Figure 10) and side impacted vehicles (Figure 11). Even if two databases were mixed injury severity was taken from PENDANT. ZEDATU is focussed on fatalities and it did not sound reasonable to investigate injury severity in this database. An analysis had been performed on single vehicle accidents only but the low portion of cases did not yield in satisfactorily results. Of course Delta-V is not sufficient enough and other aspects are responsible for injuries too. This could be seen especially for low values of Delta-V resulting in severe injuries.

Discussion

Even if a huge number of single vehicle accidents were available in the database only a few numbers were meeting all requirements needed for this detailed study. As it was figured out in general collection of on-scene material was not done by partners neither it was for the pre-collision phase. Especially references to skid marks, contact evidence with road side objects or throwing range of broken glass are essential. Merely Germany provided accidents from the GIDAS [11] database to PENDANT and scene sketches were investigated as a standard procedure. Besides of Germany only Sweden, the Netherlands and Austria provided single vehicle accidents with desired on-scene material. Sweden collected on-scene data for a different project whereby those accidents were used for PENDANT, too. Database ZEDATU increased the number of single vehicle accidents.

Conclusion

Single vehicle accidents can be divided into certain levels. The first level is based on infrastructure namely bends and straight road sections. In a second step the drivers could intervene by turning the steering wheel extensively to avoid a collision with obstacles or other hazards. Finally it was seen that the drivers could counter steer certain times before the yaw angle exceeded thresholds.

Though the sample was very small a good agreement with other studies is given. Roughly 30% of single vehicle accidents could be prevented by ESP. ESP led to different impact configuration when the accident was unavoidable.

Important aspects in accident investigation and reconstruction are pre-impact phases especially for single vehicle accidents. Most single vehicle

accidents last some seconds before resulting in an impact or rollover. During this phase the drivers mainly try to avoid an accident. Essential for such reconstruction activities are scaled sketches from accident scene with traces from braking or skidding. Therefore it is concluded that PENDANT cannot be used for pre-collision investigation – primary (active) safety aspects.

In principle countermeasures can be developed at human (H) and vehicle (V) or infrastructure (I) level. This study covered vehicle level. As for further investigations roadside design and infrastructure needs to be addressed and implemented in a comprehensive in-depth database which can support legislation at HVI level.

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