In-Depth Human Functional Failure Analysis of Fatal Pedestrian Accidents in Bavaria

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Abstract
In the course of the EUROPEAN PROJECT TRACE all fatally injured pedestrians autopsied at the Institute for Legal Medicine in Munich in 2004 had been analysed by using the "Human Functional Failure (HFF) analysis" method [1]
It was possible to apply this method although some restrictions have to be taken into account. The results derived from this analysis comprise first the failures the pedestrians (most often "impairment of sensorimotor and cognitive abilities") and the opponents (most often " Non-detection in visibility constraints conditions") faced in the accident, second the conflicts and tasks (pedestrian crossing the street conflicting with a vehicle from the side (which was going ahead on a straight road), the degree of accident involvement (pedestrians often the primary active part), and further the contributing factors to the accident (pedestrians most often "alcohol (> 0.05% BAC)", opponents most often "visibility constraints").

NOTATION

n	total amount/absolute frequency
n.e.	not evaluable
HFF	Human Functional Failure - P: Perception - T: Translation - D: Diagnosis - E: Effect - G: General

INTRODUCTION

Pedestrian fatalities have a share of about 17% of all traffic fatalities in the EU countries [2]. The interest in reducing the injury severity in case of an accident with these so-called vulnerable road users already also reached car manufacturers by introducing the EURONCAP ratings towards pedestrian protection. However, to prevent these kinds of accidents in the first the discussion ranges from improvement in pedestrians conspicuity [3] to educational measures, to constructional separation of different modes of traffic and accordant types of road users, and sometimes to calls for further curb parking restrictions and speed limit restrictions within city limits.
The analysis of fatal pedestrian accidents is often limited towards the documentation of facts and objective circumstances which provide of course valuable information about sites of accidents and characteristics of the involved parties in these accidents. But, a detection of the help the participants could have needed for avoiding the accident (all involved parties) is only possible by applying more sophisticated types of in-depth analysis methods.
The Human Functional Failure analysis method as developed and presented by van Elslande in 2007 [1] aims at detecting the failures and the contributing factors for these failures for each participant involved in the accident. During the "rupture phase" occurring during the stabilized driving phase of participating in road traffic ("where things start to go wrong") a failure in the information processing and aligned operations can occur on the stages detection (Perception–P), diagnosis/prognosis (Translation-T), decision (D) and action (Effect-E). By analysing these stages different needs to give the traffic participant a helping hand in avoiding the accident can be revealed. This method refrains from blaming someone as being a responsible causer for the accident but regards the Human in the context in its environmental interactions.
In Germany 838 pedestrians have been fatally injured in road traffic accidents in 2004. On behalf of the public prosecutions of Munich, Augsburg, Passau, Traunstein, Rosenheim, Memmingen, Landshut and Ingolstadt 51 pedestrians being killed in accidents were autopsied at the Institute for Legal Medicine in Munich. In the frame of Workpackage 1 (Types of Road Users, task 1.4 pedestrians and cyclists) of the EU-Project TRACE these cases served as basis for the application of the Human Functional Failure analysis [1,4] on fatal pedestrian accidents to derive new insights to accidents with vulnerable road users and to give answer to two questions. First: "is the method applicable to fatal pedestrian accidents?", and second: "can new insights be gained by this method concerning the prevention of fatal pedestrian accidents?".

MATERIAL AND METHODS

Study sample

For 48 fatally injured pedestrians (involved in 45 accidents) autopsied at the Institute for legal medicine at the LMU in 2004 the prosecution files were evaluated. Access to the files was granted for the EU-Project TRACE. The information available ranges from police reports, technical expertises, eye witness accounts to detailed medical, toxicological, and biomechanical expertises.
Out of the fatal accident cases in 2004 three files were not available; another three cases were excluded because of suicide of the pedestrian (one case) and accidents causing death of a pedestrian without any involvement of a vehicle driver (death of a worker of a construction site due to a rolling tag and one pedestrian being killed by a ripping tow rope).
One accident involved two fatally injured pedestrians, another one showed three fatalities.
The 48 pedestrians consist of 26 male persons and 22 females. 50% of the pedestrians killed in road traffic accidents belong to the age group of older than 60 years and 10% were children up until the age of 15; one child of 4 years, 4 children in the age group between 11 to 15
Nearly 87% of the opponent drivers involved in fatal pedestrian accidents are male. Only 6 of 45 drivers are female. The highest share with more than one third is represented by the age group between 30 and 40, being comparable to the normal driver population.
The opponents involved in the fatal pedestrian accidents are car, truck and van drivers in 40 cases (29 passenger cars). Another three opponents were trams, one motorcycle and one agricultural vehicle each.
The accidents happened within city limits in about 55%. In around 46% there had been daylight conditions, followed by darkness with streetlights in 31%. The majority of accidents took place between 12p.m. and 6p.m. in about 35%, followed by the first half of the night from 6 p.m. until 12 a.m. in 26%.
For further analysis 45 pedestrians and 45 opponents were taken into account. Accidents holding more than one killed pedestrian were screened if there had been different accident mechanisms or functional failures for the fatalities. But, as failures, tasks, conflicts, contributing factors, movement and mechanism of accident were homogenous for the fatalities relating to one case it was decided to select only one pedestrian being representative for all involved pedestrians per case.

HFF analysis

The method was developed on the basis of road traffic accidents where psychologists are able to interview the involved parties. In addition the method focuses not primarily on pedestrian accidents. Applying the method to fatal pedestrian accidents therefore had to be tested first. Two cases were prepared for validation, provided to experts of the institute having developed this method and feasibility could be attested.
Two investigators evaluated the files independently, afterwards comparing their results. In case of different concepts the original files were re-examined and one possible solution discussed. If no agreement could be gained a third person also trained in the method was consulted. Finally always one analysis result was decided upon and implemented in the database. In cases where no analysis was possible for single variables due to missing information giving too much space for individual interpretation it was either decided to take the most probable option, or to leave this variable as "n.e." (not evaluable). This (n.e.) might also be coded for seldom situations when evaluation scheme was not applicable.
Analysed variables comprise the Human Functional Failures, conflicts, tasks, degree of involvement and contributing factors as explained and presented in the Annex. For the evaluation of tasks a new category "crossing the street" was established which fits for almost half of the accidents (19 of 45). Included in this new category are all kinds of crossing the street by a pedestrian, including crossing either at a pedestrian crossing (with or without a traffic light) or not. An accumulation of a fixed combination of a Failure, task, conflict, degree of involvement and contributing factors is called a prototypical scenario.

Results of HFF analysis are presented for both, the pedestrians and the opponents, separately by frequency analysis and cross tabulations. Only for the most frequently occurring HFF the distribution of contributing factors is performed. Due to limited case number it is not to be expected to derive prototypical scenarios for fatal pedestrian accidents, but typical scenarios becoming apparent are presented as possible prototypical scenarios.

RESULTS

Pedestrians

HFF analysis

14 out of 45 pedestrians performed overall failures (G-failures) especially a G2-failure meaning an impairment of sensorimotor and cognitive abilities. Within this group the vast majority was detected to have had a high blood alcohol level while participating in traffic. 9 pedestrians underwent failures at the information detection stage (P-failures); by splitting up into HFF sub-groups the highest share is found for the P5-failure (neglecting the need to search for information, n=12). The failures D2 (deliberate violation of a safety rule) and T5 (expecting another user not to perform a manoeuvre) each contributed with 6 cases.
In 7 cases it was not possible to detect or define any failure, either due to unsatisfactory information (no witness of the accident, more than one failure possible) or encoding problems (rupture phase for the pedestrian unidentifiable). E.g. pedestrians were drawn into accident situation even if they did not take part in "usual" road traffic and thus caught by surprise (e.g. walking on pavement, standing at road banquet).
To get an overview over the most frequently occurring failures applying to pedestrians killed in traffic accidents the HFF groups' distribution is presented in Table1.

HFF group	explanation	**n**	**HFF sub group**	explanation	**n**
P	Failures at the information detection stage (PERCEPTION)	**9**	**P2**	Information acquisition focused on a partial component of the situation	**3**
			P5	Neglecting the need to search for information	**6**
T	Failures at the diagnostic stage (information processing stage 1) and on the prognostic stage (information processing stage 2) (TRANSLATION)	**8**	**T2**	Erroneous evaluation of the size of a gap	**1**
			T5	Expecting another user not to perform a manoeuvre	**6**
			T6	Actively expecting another user to take regulating action	**1**
D	Failures at the stage of deciding on the execution of a specific manoeuvre (DECISION)	**6**	**D2**	Deliberate violation of a safety rule	**6**
E	Failures at the psychomotor stage of taking action (EFFECT)	**1**	**E2**	Guidance problem	**1**
G	**Overall failure (GENERAL)**	**14**	**G1**	Loss of psycho-physiological capacities	**2**
			G2	**Alteration of sensorimotor and cognitive capacities**	**12**
n.e.	Not evaluable	**7**	**n.e.**	not evaluable	**7**
sum					**45**

Table 1: HFF groups and sub-groups, distribution for fatalities (pedestrians)

Task analysis

Most people tried to cross the street when the accident happened. However, 15 accidents could not be set into the evaluation scheme. "not evaluable" (n.e.) was applied to all pedestrians whose tasks are unknown to the investigators or performed a task not intended by the scheme (e.g. crossing tram

tracks, being stationary on a road like kneeling, laying on the ground, waiting in the middle of a road,…).
By cross tabulating HFF to tasks (see Table 2) it can be seen that the most frequently occurring combination is the general (G-) failure while crossing the street (n=6), and in all 6 cases it is a G2-failure (alteration of sensorimotor and cognitive capacities). It is followed by diagnostic and prognostic (T-) failures in combination with crossing the street (n=5) of which 4 apply to the T5 failure (expecting another user not to perform a manoeuvre). Another 4 pedestrian fatalities took place when sensorimotor and cognitive impaired pedestrians were walking along a straight road.

	HFF group						
Task	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Going ahead on a straight road	1	1	1	1	4		8
Going straight at "traffic signal" intersection					1		1
Going ahead on a left bend			1				1
Approaching pedestrian crossing	1						1
Crossing the street	**3**	**5**	**3**		**6**	**2**	**19**
n.e.	4	2	1		3	5	15
total	9	8	6	1	14	7	45

Table 2: HFF and task, distribution for fatalities (pedestrians)

Conflicts analysis

Conflicts can be described as the interaction with the opponent that the road user could be faced with during the pre-accident situation. An overwhelming majority had a conflict with a vehicle from the side. 11 out of 45 pedestrian fatalities conflicted with a following vehicle. For one pedestrian no conflict could be found as direction of crash impulse/walking direction are unknown.
By linking Human Functional Failures to conflicts (see Table 3) data show that most pedestrians performing an overall failure (G-failure) had a conflict with a vehicle from the side (n=10), especially due to impairment of sensorimotor and cognitive abilities (G2) (n=9). Nevertheless, 8 pedestrians with failures at the information detection stage, especially P5-failures (neglecting the need to search for information (n= 5), and 7 cases with failures at the diagnostic and prognostic stage especially T5-failures (not expecting by default manoeuvre by another user, n= 6) also crashed with vehicles from side.

	HFF groups						
Conflict	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Oncoming vehicle					1		1
Vehicle from side	**8**	**7**	**3**		**10**	**4**	**32**
Following vehicle	1	1	3	1	3	2	11
n.e.						1	1
total	9	8	6	1	14	7	45

Table 3: HFF and conflict, distribution for fatalities (pedestrians)

Degree of involvement

Most pedestrians were mainly seen to be "primary active" (n= 30) meaning these pedestrians initiated the situation in which the accident took place (see Table 4). 12 out of 45 pedestrians committed an overall-failure (G-failure) and were "primary active" according to evaluation scheme. 11 of these were meant to be impaired in their cognitive and sensorimotor abilities (G2-failure).

	HFF groups						
Degree of invovement	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Non-active			1			1	2
Passive					2	4	6
Primary active	**6**	**5**	**4**	**1**	**12**	**2**	**30**
Secondary active	3	3	1				7
total	9	8	6	1	14	7	45

Table 4: HFF and degree of involvement, distribution for fatalities (pedestrians)

Most frequent HFF subgroup in pedestrian fatalities

Most often G2-failures (impairment of sensorimotor and cognitive abilities) were seen in the pedestrians (n=12). Most often, these people tried to cross the street (n= 6) or were just walking along a road (n=4). Nine were confronted witch a vehicle from side and in three cases, a following vehicle was involved. The degree of involvement mainly was "primary active" (n=11) and one pedestrian was strictly “passive”.
Overall 21 contributing factors were applicable to the 12 pedestrians with G2-failures. In seven cases it was possible to assign one contributing factor, in two cases two, in two cases three and in one case four contributing factors. Most often they are found within the state of user, and the psycho-physiological condition, respectively. Eight pedestrian fatalities showed that alcohol had been taken "above legal limit". In these cases it was assumed that although a "legal" limit does not exist for pedestrians that these pedestrians were none the less impaired in acting properly. In two cases a "medical condition" of the pedestrian was found. For two cases "correctly used medication" or an "internal conditioning of performed task leading to identification of potential risk about only part of the situation" follow as third most frequently applied contributing factor. Other contributing factors were single events (see Table 5).

Contributing factors	Absolute frequency
Medical condition	2
Substances taken – alcohol above "legal" limit	8
Substances taken – alcohol below "legal" limit	1
Substances taken – illegal drugs	1
Substances taken – correctly used medication	2
Identification of potential risk about only part of the situation	2
Little/None experience - driving	1
Distraction within user – lost in thought	1
Risk taking – traffic control (signs/signals/markings disobeyed etc.)	1
Risk taking – "eccentric" motives (competing)	1
Visibility impaired – other vehicles	1

Table 5: G2-failures and contributing factors

Prototypical scenarios for pedestrians

On the basis of previously performed HFF analysis failures, task, conflicts, contributing factors and degree of involvement were sorted into groups in order to deduce scenarios being representative for a certain group of road users. Due to low case numbers only first hints for typical scenarios can be derived.
For pedestrians most often (six times) the combination was: G2-failure (impairment of sensorimotor and cognitive abilities), "crossing the street" (task), "vehicle from side" (conflict), "primary active" and as contributing factor in 5 out of 6 cases "substances taken – alcohol above "legal" limit.
Second most often two different combinations, each one tree times, occurred. G2-failure, "going ahead on a straight road" (task), "following vehicle" (conflict), "primary active" and in 2 out of 3 cases "medical condition" in contrary to T5-failure (not expecting - by default - manoeuvre by another user), "crossing the street" (task), "vehicle from side" (conflict), "primary active" with contributing factors "identification of potential risk about only part of the situation" and "risk taking – traffic control".

Opponents

HFF Analysis

Most frequently P-failures at the information detection stage are found (n=20). The highest share holds the P1 failure (Non-detection in visibility constraints conditions, n=9). Second most often (8 cases) the diagnostic and prognostic stage accounts for the failure (T-failure), and especially the T7 failure (Expecting no perturbation ahead, n=5). In 7 cases a D-failure (decision) is found, of which 6 are due to the "Deliberate violation of a safety rule" (D2-failure). In one case of a tram driver no failure could be assigned.

HFF group	Explanation	n		HFF sub groups – HFF groups	total
P	Failures at the information detection stage (PERCEPTION)	20	**P1**	Non-detection in visibility constraints conditions	9
			P2	Information acquisition focused on a partial component of the situation	4
			P3	Cursory or hurried information acquisition	1
			P4	Momentary interruption in information acquisition activity	1
			P5	Neglecting the need to search for information	5
T	Failures at the diagnostic stage (information processing stage 1) and on the prognostic stage (information processing stage 2) (TRANSLATION)	8	**T5**	Expecting another user not to perform a manoeuvre	2
			T6	Actively expecting another user to take regulating action	1
			T7	Expecting no perturbation ahead	5
D	Failures at the stage of deciding on the execution of a specific manoeuvre (DECISION)	7	**D1**	Violation directed by the characteristics of the situation	1
			D2	Deliberate violation of a safety rule	6
E	Failures at the psychomotor stage of taking action (EFFECT)	5	**E1**	Poor control of an external disruption	4
			E2	Guidance problem	1
G	Overall failure (GENERAL)	4	**G1**	Loss of psycho-physiological capacities	2
			G2	Alteration of sensorimotor and cognitive capacities	2
n.e.	Not evaluable	1	**n.e.**	Not evaluable	1
Total		45			45

Table 7: HFF sub-groups for opponents

Task analysis

"Going ahead on a straight road" is the most frequent task (n=22) and showing up in 10 cases in combination with a P-failure. It is followed by reversing (n=4) and "Turning across traffic out of private drive" and "Going straight at "traffic signal" intersection" each three times (Table 8).

	HFF group						
Task	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Going ahead on a straight road	**10**	**5**	**3**	**2**	**2**		**22**
Going ahead on a left bend					1		1
Going ahead on a right bend	1			1			2
Approaching intersection where road user has right of way		1					1
Going straight at "traffic signal" intersection	1		1		1		3
Turning across traffic at "traffic signal" intersection	1						1
Starting (not at junction)	1	1					2
Turning away from traffic from main road into private drive	1						1
Turning across traffic out of private drive	3						3
Reversing	2		2				4
Driving in wrong direction				1			1
Approaching pedestrian crossing				1			1
Approaching railway crossing		1					1
n.e.			1			1	2
total	20	8	7	5	4	1	45

Table 8: HFF and tasks, distribution for opponents

No task could be found applicable to the tram drivers in general. The 3 tram drivers in the opponents sample were going ahead on tracks and this option is not defined in evaluation schema. One tram driver was nevertheless able to be put into the evaluation scheme as he was approaching a railway crossing. Thus only two tasks remain encoded n.e.
Most of the drivers who were “going ahead on a straight road” underwent a P1-failure (n=6) or a T7-failure (Expecting no perturbation ahead, n=4).

Conflicts analysis

Considering conflicts (Table 9) drivers had to cope with while going ahead, one can find an overwhelming majority of the situation that a “pedestrian is crossing over the street” (n= 30 out of 45). Further seven drivers had to face a “pedestrian walking along the street”.
Among those whose conflict was a “pedestrian crossing over” P-failures are dominant above D- and T-failures (14 vs. 7 and 6 out of 30). In detail, especially P1-failures (non-detection in visibility constraints conditions, n=5) and D2-failures (deliberate violation of a safety rule, n=6) could be detected.
No conflicts could be defined for those who encountered a problem not listed in given schema e.g. pedestrian sleeping on road (can't be defined as "stationary obstacle"), fallen asleep while driving, medical problem, diverting from road due to high alcohol intoxication, losing control of the car.

	HFF groups						
Conflict	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
None					2		2
Stationary vehicle ahead		1		1			2
Pedestrian crossing over	14	6	7	2		1	30
Pedestrian walking along road	4	1		1	1		7
n.e.	2			1	1		4
total	20	8	7	5	4	1	45

Table 9: HFF and conflict, distribution for opponents

Degree of involvement

Most opponents are "secondary active" (n=22), followed by "primary active" in 13 cases. Considering the combination of failures and degree of involvement 10 drivers dealing with P-failures (and especially P1 failures, n=9) were meant to be "secondary active" in taking action, another 6 were non active and another 6 drivers with T failures were also secondary active (Table 10).

	HFF groups						
Degree of involvement	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
n.e.					1		1
Non-active	6	1	1			1	9
Primary active	4	1	2	3	3		13
Secondary active	10	6	4	2			22
total	20	8	7	5	4	1	45

Table 10: HFF and degree of involvement, distribution for opponents

Most frequent HFF subgroup in opponent analysis

Most frequently occurring failure in analysing opponents is the P1-failure (non-detection in visibility constraints condition, n=9), followed by D2-failure (deliberate violation of a safety rule, n=6), P5-failure (neglecting the need to search for information, n=5) and T7-failure (expecting no perturbation ahead, n=5), respectively.
Opponents committing P1-failure comprise eight car drivers and one truck driver.
Within P1-failure, most opponents were going ahead on a straight road (n=6) while being confronted with a pedestrian on road. Conflicts aroused when pedestrians tried to cross the street (n=5) or walked along road, not on pavement (n=2). In five times the opponent has to be regarded as "non-active" and four times as "secondary active".

24 contributing factors were applicable to those 9 opponents undergoing a P1-failure. In three cases four contributing factors were applicable, in two cases each one, two or three contributing factors. It has to be noted that particularly visibility impairment factors occur at large. Most often, opponents had to deal with a situation in which visibility was impaired, e.g. due to night, other vehicles or vehicle lighting (see Table 11). Risk taking speed also influenced accident development and progress.

Contributing factors	total
Visibility impaired: Night	**6**
Visibility impaired: Other vehicle(s)	**4**
Visibility impaired: Vehicle lighting	**3**
Visibility impaired: Weather	**3**
Risk taking: Speed	**2**
Identification of potential risk about only part of the situation	1
Risk taking: Traffic control	1
Road width	1
Visibility impaired: Road lighting	1
Maintenance: Windscreen/Glass	1
Maintenance: Exterior lights	1
	24

Table 11: P1-failure and contributing factors, distribution for opponents

Prototypical scenarios for opponents

For opponents three scenarios occur most often of which each holds three cases. First the combination of P1-failure (Failure to detect in visibility constraints), "going ahead on a straight road" (task), pedestrian crossing over" (conflict), "visibility impaired – other vehicle(s)" (contributing factor) and in two out of three cases "secondary active" (Degree of involvement).

Second: D2-failure (deliberate violation of a safety rule), "going ahead on a straight road"(task), "pedestrian crossing over" (conflict), "risk taking – speed" (contributing factor), "secondary active" (Degree of involvement) and in two out of three cases "visibility impaired – night"(contributing factor).
Third: P2-failure (Focalised acquisition of information), "turning across traffic out of private drive"(task) and "pedestrian crossing over" (conflict). In two out of three cases the opponents were regarded as "secondary active" (Degree of involvement). As contributing factors each two times "design – visibility" (contributing factor) and "distraction outside vehicle – searching for information/road construction/other perceived danger" (contributing factor) could be found.

DISCUSSION

By applying the method introduced by van Elslande in 2007 [1] for the in-depth analysis in the EU-Project TRACE to the fatalities database for pedestrians at LMU a kind of feasibility study was successfully performed on the one hand. On the other hand some reasonable insights could be gained.

The pedestrians killed in road traffic accidents were nearly evenly distributed for sex, and the majority was more than 60 years old. The pedestrians most often underwent G2-failures, meaning they were impaired in their sensorimotor and cognitive abilities. The task they performed was "crossing the street" when the conflict with a vehicle from the side occurred. In most cases the pedestrians had to be regarded as "primary active". The most frequently found contributing factor for this failure*task*conflict combination was alcohol above the legal limit (as would have been applied to drivers with a value of 0.05% BAC).
A study conducted in France in the early 90ies [5] proposes four different groups of pedestrians being involved in fatal accidents. Elderly traffic participants crossing the road and the problem of alcohol are found in this sample comparably. That alcohol and pedestrians is a risky combination not only for fatal accidents in some of the European countries is known for the UK and Germany [6].
Pedestrians' factors most often were found within the state of user and the psycho-physiological condition. It has to be noted that for opponents particularly visibility impairment factors occur at large
For the opponents as being the drivers involved in the fatal pedestrian accident the distribution of sex is shifted towards males, and show an age distribution comparable to the driver population in general. For the drivers most often a P1-failure (Non-detection in visibility constraints conditions) could be detected. The task they were performing was going ahead on a straight road most frequently when conflicting with a pedestrian crossing the street. In most cases the drivers have to be regarded as "secondary active" as the pedestrian initiated the situation, although in police records most often the opponent is seen as the "causer" of the accident. The contributing factors found for the drivers comprise visibility constraints like night, other vehicles, weather, and vehicle lighting.
Whereas Langham [7] cannot show clear evidence for improving pedestrian visibility for preventing accidents in a review because of the included studies methodological differences, still conspicuity and visibility are regarded as main factors for pedestrian and bicycle accidents. "Visibility aids have the potential to increase visibility and enable drivers to detect pedestrians and cyclists earlier. Public acceptability of these strategies would merit further development. However, the effect of visibility aids on pedestrian and cyclist safety remains unknown. Studies which collect data on simple, meaningful outcomes are required." is the authors' conclusion of an updated review from 2006 [3]. In this sample it can be found that the drivers were faced with visibility constraints when crashing with the pedestrian. The conspicuity of the pedestrian doesn't show up as a contributing factor. In addition often the drivers neglected the need to search for information in the first (not expecting any pedestrian to be around or crossing the street because of site, time or weather conditions).

A first set of three prototypical scenarios for fatal pedestrian accidents are possible to propose for the pedestrians' point of view:
Fatal pedestrian scenario No 1 (Ped: Pedestrian): a pedestrian impaired in sensorimotor and cognitive abilities due to alcohol crosses the street, initiates as primary active participant the conflict situation and is hit by a vehicle from the side.

Fatal pedestrian scenario No 2 (Ped): a pedestrian impaired in sensorimotor and cognitive abilities due to medical conditions was going ahead on a straight road and initiates as primary active participant the conflict situation with a following vehicle.
Fatal pedestrian scenario No 3 (Ped): a pedestrian wants to cross the street and before doing so identifies a potential risk of crossing the street only on a part of the whole situation or shows risk taking behaviour regarding traffic control and due to the failure of not expecting a manoeuvre of the vehicle crosses the street and is hit by the vehicle from the side.
The translation of the scenarios to prevention suggestions is difficult for overall failures. People showing impairment in sensorimotor and cognitive abilities constantly should not take part in traffic by themselves at all. However, overall failures in these abilities can occur suddenly (medical condition) or e.g. after consumption of alcohol and/or falling asleep. People commonly able to take part in traffic as pedestrians face situations when the overall failure occurs and as a consequence are fatally injured in an accident. For the first two scenarios for pedestrians the human role has a main influence, therefore only education, information (take a taxi – don't walk when drunk", use apt lane when no sidewalk present (on-coming traffic side), and wear visible clothing) can be recommended. Also for the third pedestrian scenario the knowledge and behaviour when crossing the street which should have been trained in pre-school age would have helped to avoid the accidents (no risk taking but crossing only on facilities, not crossing on red). As all scenarios show crossing the street as planned task, thus especially the suggestions of separating pedestrians and other traffic by infrastructural and environmental modifications to prevent pedestrian fatalities like done by Retting [8] might apply here as well.

A first set of three prototypical scenarios for fatal pedestrian accidents are possible to propose for the opponents' point of view:
Fatal pedestrian scenario No 1 (Opp: Opponent): A driver is going ahead on a straight road when due to impaired visibility because of other vehicles the driver fails to detect the pedestrian crossing the street.
Fatal pedestrian scenario No 2 (Opp): A driver going ahead on a straight road deliberately decides to violate against safety rules with risk taking behaviour of speeding (at night) when the pedestrian crosses the street.
Fatal pedestrian scenario No 3 (Opp): A driver turns against traffic out of a private drive and fails to detect the pedestrian crossing the street because of focalised acquisition of information due to distraction outside the vehicle or the vehicle design restricting visibility.
The first scenario can be prevented by reduced curb parking density. In addition vehicle systems with better perception sensors compared to humans for detecting earlier also hidden objects could give the missing but necessary information to the driver about pedestrians and other possible obstacles. The second scenario can be overcome by more education, information, law enforcement, and mandatory intelligent speed adaption systems as active safety systems in vehicles, to reduce speeding. In addition as the second scenario occurred mainly at night also night vision would have helped to detect the pedestrian earlier and enable an active speed reduction in time. The third scenario is also based on a detection failure therefore vehicle systems providing information to the driver of the pedestrian being in the way would have helped here as well.
If all suggested prevention measures were not able to avoid the accident in the first then only further structural improvements of the vehicle front (bonnet functions, bumper and front design) might help to at least reduce the injury severity of the pedestrian.
Still, the primary prevention attempts by active and passive safety measures of cars might have helped to avoid a majority of the analysed accidents. According to Molinero [9] the suggested systems range from driver visual aids such as night vision, to autonomous emergency braking systems. Further, some of the more traditional vehicle systems such as brake assist and traction control can also work to reduce braking distances or prevent vehicles from leaving road surfaces, both of which could aid the prevention of an impact with pedestrians.

Limitations:
All fatal pedestrian accidents of which the prosecution files were available for evaluation at LMU Institute for Legal Medicine, within the catchment area in 2004 have been analysed in-depth.

Autopsies might be requested primarily for unclear situations raising legal interest The sample might be biased towards fatal pedestrian accidents where death happened on site and where information about the accident circumstances are lacking on a first view so that the police orders a legal investigation. The advantage of this selection can be seen in the fact that focus is laid on traffic accidents where tertiary prevention might not influence the outcome. Death might have occurred to the pedestrians independent of time and mode of first aid, transport, intensive medical treatment and factors like age and co-morbidities. Despite this estimated selection bias the urban accidents which are assumed to happen at lower velocities with a higher chance for surviving at least up to 30 days are over-represented. However, the results are comparable to published facts concerning pedestrian accidents. Opponents and age distribution is comparable to a German study on pedestrian accidents [10]. The pedestrians are primarily of older age and by taking the total number of fatalities in traffic for females into account, the higher risk for females is also found in the CARE- database for the EU [2]. The number for Germany is also given with 47% of pedestrian fatalities being in the age group of 65+ [9].
The method was not developed for fatal accidents, as no interview can be performed with a fatally injured traffic accident victim. Thus, a lack of information in the files used has to be accepted for this study. Especially for the Human Functional Failures and the contributing factors the lack of information is striking. For the HFF of the opponents most often also eye-witness reports had to be taken into account in addition to their own statements towards the police and the prosecution. As from the pedestrian no information can be expected, the opponents might be tempted to lying or refrain from statements at all, in order not to be convicted. Especially confessing to having been in thoughts, being in a hurry, or being sleepy might be easily avoided, as no objective proof afterwards is possible. In contrast the speed driven or alcohol limit can still be assessed afterwards by expertises.
The evaluation scheme is primarily focusing on vehicle accidents and their drivers. Tasks and conflicts sometimes lack possibilities for coding apt items. In addition three times trams had been involved, where tasks are also not meant to be applied to. In general the method allows defining new items for each variable. A suggestion for new categories within the tasks would e.g. comprise: - "walking on pavement", - "standing beside the traffic lane (banquette)", - "pedestrian crossing at a pedestrian crossing with pedestrian lights".
The case number of 45 is too low to give general statements on prototypical scenarios consisting of typical failure*task*conflict*involvement*contributing factors combinations. But, first hints for typical scenarios out of a multitude of single events were possible to detect. More analysis of this type would be necessary to show if the most often occurring scenarios in this sample will hold the highest shares also in larger samples. This is necessary for giving useful advice concerning efficient countermeasures.
Although psychological interviews on site would be preferable this study shows that the method can nevertheless add new insights also to fatal pedestrian accidents.

CONCLUSION

Applying the human functional failure analysis method as developed by van Elslande [1,11] on fatal pedestrian accidents was successfully performed on the database of fatal pedestrian accidents in 2004 of the Institute of Legal Medicine, Munich. Some emerging prototypical scenarios were possible to derive for pedestrians and opponents. The combination of drunken pedestrians and reduced visibility conditions for opponent drivers shows up as a typical deadly mixture. Corresponding countermeasures for prevention can be suggested comprising educational, infrastructural, and vehicle measures.

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Appendix: all annexes derived from vanElslande, 2007 [1] and 2008 [11] and Naing, 2007 [4]

Annex 1: Human Functional Failures

Failure type	HFF-label	HFF- sub-type
Perception	Perception - P	P1 Failure to detect in visibility constraints
		P2 Focalised acquisition of information
		P3 Cursory information acquisition
		P4 Interruption in information acquisition
		P5 Neglecting information acquisition demands
Diagnosis	Translation - T	T1 Incorrect evaluation of a road difficulty
		T2 Incorrect evaluation of a gap
		T3 Incorrect understanding of how site functions
		T4 Incorrect understanding of manoeuvre undertaken by another user
Prognosis		T5 Not expecting (by default) manoeuvre by another user
		T6 Expecting adjustment by another user
		T7 Expecting no perturbation ahead
Decision	Decision - D	D1 Directed violation
		D2 Deliberate violation
		D3 Violation-error
Action	Effect - E	E1 Poor control of a difficulty
		E2 Guidance problem
Overall	General - G	G1 Loss of psycho-physiological ability
		G2 Impairment of sensorimotor and cognitive abilities
		G3 Exceeding cognitive abilities

Annex 2: Tasks

Level 1	Level 2
A. Stabilised Situation	
Going ahead	Going ahead on a straight road
	Going ahead on a left bend
	Going ahead on a right bend
B Intersection	
On approach	Approaching a 'give way' intersection
	Approaching a 'stop' intersection
	Approaching a 'traffic signal' intersection
	Approaching intersection where road user has right of way
Stopped	Stopped at a 'give way' intersection
	Stopped at a 'stop' intersection
	Stopped at a 'traffic signal' intersection
	Stopped in road/ turning lane waiting to turn
Going ahead	Going straight on at a 'give-way' intersection
	Going straight on at a 'stop' intersection
	Going straight on at a 'traffic signal' intersection
	Crossing intersection where road user has right of way
	Travelling on roundabout (not turning on/off)
	Travelling on slip-road (not turning on/off)
Turning	Turning across traffic at a 'give-way' intersection
	Turning across traffic at a 'stop' intersection
	Turning across traffic at a 'traffic signal' intersection
	Turning across traffic from main road into side road
	Turning away from traffic at a 'give-way' intersection
	Turning away from traffic at a 'stop' intersection
	Turning away from traffic at a 'traffic signal' intersection
	Turning away from traffic from main road into side road
C. Manoeuvre	
Overtaking	Overtaking stationary vehicle on left
	Overtaking stationary vehicle on right
	Overtaking moving vehicle on left
	Overtaking moving vehicle on right
Changing lane	Moved into lane on left (NOT overtaking)
	Moved into lane on right (NOT overtaking)
Slowing	Stopping (not at junction)
	Parking (roadside)
Starting	Starting (not at junction)
	Leaving parking space (roadside)
Turning (not at intersection)	Turning across traffic from main road into private drive
	Turning away from traffic from main road into private drive
	Turning across traffic out of private drive
	Turning away from traffic out of private drive
Reversing	Reversing
U-turn	U-turn
In wrong direction	Driving in wrong direction (e.g. down a one-way road)
D. Other	
Parked	Parked
Stopped in traffic queue	Stopped in traffic queue
Pedestrian crossing	Approaching pedestrian crossing
	Stopped at pedestrian crossing
Railway crossing	Approaching railway crossing
	Stopped at railway crossing

Annex 3: Conflicts

Level 1	Level 2
None	None
Oncoming vehicle(s)	Oncoming vehicle(s) in correct lane
	Oncoming vehicle(s) in wrong lane
Vehicle ahead (moving in same direction or stationary)	Moving vehicle(s) ahead
	Stationary vehicle(s) ahead (congestion or accident)
	Stationary vehicle(s) ahead (parked)
	Car door open on stationary vehicle
Following vehicle(s)	Following vehicle(s)
Vehicle from side	Vehicle(s) from side road/path
	Vehicle in lateral lane travelling in same direction
Obstacle(s) ahead (non-vehicle)	Moving obstacle(s) ahead
	Stationary obstacle(s) ahead
Pedestrian in road ahead	Pedestrian crossing over
	Pedestrian walking along road
	Pedestrian playing/ running on road

Annex 4: Grid of factors which could lead to Human Functional Failures

Descriptive (user related factors)			
		Generic	**In-depth examples**
A. User State	1. Physical/ Physiological	Medical condition	Heart condition/Epilepsy/Other brain condition/Respiratory condition/Blood condition/Other condition
		Pre-existing impairment	Hearing/Visual/Physical disability/Other impairment
	2. Psycho-physiological condition	Substances taken - alcohol	Above 'legal' limit/Below 'legal' limit
		Substances taken - drugs	Illegal drugs/Correctly used medication/Misused medication
		Emotional	Upset/Angry/Anxious/Happy/Other emotion
		Fatigue	Physical/Mental
		In a hurry	In a hurry
	3. Internal conditioning of performed task	Right of way status	Rigid attachment to the right of way status
		Excessive confidence	Excessive confidence in signs given to others
		Identification of potential risk	Identification of potential risk about only part of the situation
B. Experience	1. Little/None	Driving	Learner/New driver/Infrequent driver/Other
		Route	New route/Road type/New road/Road feature/Driving on the left/Driving on the right/Other
		Vehicle	New vehicle/ Transmission type/ Left hand drive vehicle/ Right hand drive vehicle/ Other vehicle feature
		Environment	Night driving/City driving/Country driving/Driving in snow/Driving in fog/Driving in wet or flood/Driving in ice/Other
	2. Over-Experienced	Driving	Change in driving rules/Other
		Route	Route in general/Road type/New road/Road feature/Other
		Vehicle	New vehicle/ Transmission type/Other vehicle feature
		Environment	Night driving/City driving/Country driving/Driving in snow/Driving in fog/Driving in wet or flood/Driving in ice/other
C. Behaviour	1. Conflicting (Distraction)	Distraction outside vehicle*	Police/Animal in road/ Sunlight or sunset/ People in roadway/ Crash scene/Other perceived danger/Road construction/ Searching for directional information/ Unspecified outside distraction
		Distraction within vehicle*	Adjusting radio/ Adjusting cassette/ Adjusting CD/ Other occupant/ Moving object in vehicle/Using or viewing device integral to vehicle/ Using other device brought into vehicle/Adjusting climate controls/Eating/Drinking/Cell phone/Smoking/Looking inside vehicle/Reaching for object/Unspecified inside distraction
		Distraction within user*	Lost in thought/Medical problem
	2. Risk taking	Speed	Illegal/Legal but inappropriate/Erratic/Other
		Vehicle positioning	In front/Lateral/Other
		Traffic control	Signs disobeyed/Signals disobeyed /Markings disobeyed/Other
		'Eccentric' motives	Testing a vehicle/Thrill-seeking/Competing/'Stunt'/Unspecified eccentric motives

Descriptive (environment related factors)		
	Generic	**In-depth Examples**
A. Road Condition	Contaminants: Wet/Flood/Snow	Wet/Flood/Snow
	Contaminants: Ice/Frost	Ice/Frost
	Contaminants: Oil/Diesel	Oil/Diesel
	Contaminants: Sand/Gravel/Mud	Sand/Gravel/Mud
	Surface defects	Potholes/Cracks/Bumps
	Surface type	Asphalt/Concrete/Untreated/Cobbles /Brick/Other
B. Road Geometry	Bend(s)	Left/Right/Wide/Tight/Multiple bends
	Slope(s)	Decline/Incline/Multiple slopes
	Road width	Wide/Narrow/Single lane/Multiple lanes/Change in width
	Adverse camber	Left/Right
	Traffic calming	Road hump/Speed table/Throttle/Chicane
	Temporary road layout	Roadworks/Other
	Misleading/complex road layout	Misleading/Complex
	Speed-inciting layout	Bend in road/Straight road/Gradient/Wide road/Continuity effect
C. Traffic Condition	Flow	Smooth/Erratic
	Speed	High/Low/Stationary
	Density	Low/High
	Other road user(s) : Absence of clues to manoeuvre	Absence of clues to manoeuvre
	Other road user(s) : Ambiguity of clues to manoeuvre	Ambiguity of clues to manoeuvre
	Other road user(s) : Atypical manoeuvres	Atypical manoeuvres
	Being drawn into manoeuvre	Passenger/Vehicle ahead/Vehicle behind/Pedestrian/Cyclist
D. Visibility Impaired	Road lighting	Type/Colour/Intensity/No lighting
	Vehicle lighting	Type/Colour/Beam type/No lighting
	Day/night	Daylight/Darkness/Dusk/Dawn
	Sun glare	Direct from sun/Reflection from wet road
	Weather	Rain/Fog or mist/Snow/Hail
	Smoke	Vehicle/Nearby fire/Other
	Terrain profile	Bend/Slope/Side slope(s)/Other
	Other vehicle(s)	High vehicle/Wide vehicle/Parked vehicle/Vehicle stopped in traffic/Other
	Roadside objects	Overhanging tree(s)/ Overhanging shrubbery/Sign(s)/Bridge structures/Barrier(s)/Wall(s)/Boundary fence(s)/Other
E. Traffic Guidance	Traffic signs/signals - Insufficient	Signs present but insuffincient/Signals present but insufficient/Signs absent/Signals absent/Other
	Traffic signs/signals – Maintenance	Signs damaged/Signals damaged/Signs poorly maintained/Signals poorly maintained/Signs positioned incorrectly/Signals positioned incorrectly/Other
	Traffic signs/signals – Unexpected	Signs replaced/Signals replaced/Signs new/Signals new/Other
	Traffic signs/signals – Inappropriate	Signs inappropriate/Signals inappropriate/Signs confusing/Signals confusing /Other
	Road markings (visual/tactile) - Insufficient	Visual markings present but insufficient/Tactile markings present but insufficient/Visual markings absent/Tactile markings absent
	Road markings (visual/tactile) - Maintenance	Visual markings damaged/ Tactile markings damaged/ Visual markings poorly maintained/ Tactile markings poorly maintained/ Visual markings positioned incorrectly/ Tactile markings positioned incorrectly/Other
	Road markings (visual/tactile) – Unexpected	Visual markings replaced/ Tactile markings replaced/ Visual markings new/ Tactile markings new/Other
	Road markings (visual/tactile) - Inappropriate	Visual markings inappropriate/ Tactile markings inappropriate/ Visual markings confusing/ Tactile markings confusing /Other
F. Other Environmental Factors	Earlier collision	Vehicle(s)/Debris/Other
	Pedestrian in road	Adult/Child/Other
	Fire in road/roadside	Car in Road/Car in Roadside/Other in Road/Other in roadside
	Level crossing	Controlled/Uncontrolled
	Animal in road	Dog/Cat/Horse/Cow(s)/Pig(s)/Sheep/ Deer/Rabbit/Badger(s)/Fox(es)/Bird(s)/ Reptile(s)/Other animal(s)
	Other obstacle(s) in road	Vehicle part/Dead animal/Discarded vehicle load/Other
	Road works	Major/Minor/Other
	High wind	Gale force/Storm Force/Hurricane force/Other

Descriptive (vehicle related factors)		
	Generic	**In-depth Examples**
A. Electro-Mechanical	Steering	Partial failure/Total failure
	Brakes	Partial failure/Total failure
	Engine	Partial failure/Total failure
	Suspension	Partial failure/Total failure
	Electrical/electronics	Partial failure/Total failure
B. Maintenance	Windscreen/Glass	Front chipped/ Front cracked/ Front misted/ Front dirty/ Front scratched/ Rear chipped/ Rear cracked/ Rear misted/ Rear dirty/ Rear scratched/ Side chipped/ Side cracked/ Side misted/ Side dirty/ Side scratched/ Other
	Tyre(s)	Incorrect type/Air pressure/ Tread/ Blow-out/Other
	Exterior lights	Headlight type/Headlight bulb needs replacing/Headlight cracked/Headlight broken cover/ Rear light type/ Rear light bulb needs replacing/ Rear light cracked/ Rear light broken cover/ Brake light type/ Brake light bulb needs replacing/ Brake light cracked/ Brake light broken cover/ Indicator type/ Indicator bulb needs replacing/ Indicator cracked/ Indicator broken cover/ Fog light type/ Fog light bulb needs replacing/ Fog light cracked/ Fog light broken cover/Other
	Interior lights	Fuel light/Oil light/Water light/Parking brake light/Other dashboard light/Other interior lighting
C. Design	Visibility	A-pillar(s)/B-pillar(s)/C-pillar(s)/Steering wheel blocking view/Rear view mirror/Wing mirror(s)/Seating/Other
	Auditory	Auditory warnings confusing
	Displays	Colour/Size/Confusing information/Other
	Controls	Colour/Size/Confusing information/Reach/Other
D. Load	Heavy	On vehicle/Within vehicle/Other
	Uneven	On vehicle/Within vehicle/Other
	Visibility obstructed	On vehicle/Within vehicle/Other

Annex 5: Degree of involvement

This variable defines the role played by the pedestrian/opponent in the genesis of the accident. Close to the notion of 'responsibility', it differs from this latter by the reference not to a legal code but by the recourse to a strictly behavioural reference ('code').

- Primary active

This modality designates the pedestrian/opponent who "provoke the disturbance". They have a determining functional involvement in the genesis of the accident: they are directly at the origin of the destabilization of the situation.

- Secondary active

These pedestrians/opponents are not at the origin of the disturbance which precipitates the conflict, but they are however part of the genesis of the accident by not trying to resolve this conflict.

- Non-active

These pedestrians/opponents are confronted with an atypical manoeuvre of others that is hardly predictable, whether it is or not in contradiction with the legislation.

- Passive

These pedestrians/opponents are not involved in the destabilization of the situation but they are nevertheless an integral part of the system. Their only role consists in being present and they cannot be considered as an engaging part in the disturbance.