INTERSECTION ROAD ACCIDENT CAUSATION: A EUROPEAN VIEW

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ABSTRACT

Intersections represent 43% of Europe's injury accidents and 21% of fatalities. Although specifically targeted, intersection accident mechanisms merit further investigation.
This study, part of the European TRACE project (Traffic Accident Causation in Europe), analyzes specific intersection accident causation issues from systemic viewpoints (driver, vehicle and environment) and risk factor research angles (visibility problems, speed, manoeuvres, etc.).
Causation analysis uses a three-step methodology. A macroscopic approach highlights the frequency and severity of accidents and determines key scenarios. A microscopic approach, details accident causes. Because the driver plays an important role in the accident process, a dedicated "Human Functional Failure (HFF) analysis" is employed. Finally, risk factors are identified and related to accident configurations.
Project partners and the CARE database supply national and European data. Because CARE does not contain data from all 27 countries, statistical adjustment was necessary.
Partners also provided in-depth databases. The HFF concept is new and necessitated common codification of related data.
Intersection accidents are grouped by common characteristics, such as road layout, driver manoeuvres... Macroscopic analysis identified 3 main scenarios. The "cutting" scenario groups initial perpendicular trajectories and covers 53% of European intersection accidents. The "turn across" scenario combines accidents involving turning manoeuvres on the same road, different direction. Finally the "other" scenarios include rear-end collisions.
In-depth analysis furthered understanding of accident mechanisms and showed mechanisms and countermeasures to be directly linked to right of way rules.
In "cutting" scenarios for example, 60% of drivers without "right of way" failed to look and react before crash, while 70% of opponent drivers braked before impact. Results suggest that the former need help to improve opponent and situational perception while the latter need improved braking and evaluation for earlier avoidance manoeuvres. HFF and related factor identification enable the association of current preventive or curative systems with observed driver needs.

INTRODUCTION

According to the World Health Organization and other sources, the total number of road deaths is estimated at 1.2 million, with a further 50 million injured every year. Two thirds of the casualties occur in developing countries. 70 % of casualties in these countries are vulnerable road users such as pedestrians, cyclists and motorcyclists.
Major studies published by the World Health Organization have identified the growing importance of road crashes as a cause of death, particularly in developing and transitional countries. Murray (1996) showed that in 1990 road crashes as a cause of death or disability were by no means insignificant, lying in ninth place out of a total of over 100 separately identified causes. However, by the year 2020 forecasts suggest that as a cause of death, road crashes will move up to sixth place and in terms of years of life lost (YLL) and 'disability-adjusted life years' (DALYs) will be in second and third place respectively.
These projections show that, between 2000 and 2020, road traffic deaths will decline by about 30% in high-income countries but increase substantially in low and middle-income countries.
The European Community has been trying for many years to promote initiatives through the different Framework Programs in order to contribute to the safety effort. However, without a real target, the progress is difficult to evaluate. This is why, in 2001, the European Commission published its "White Paper" on transport policy (European Commission 2001), in which the main research axes to be improved and quantified targets are determined for road traffic safety.

The short-term strategic objective is to halve the number of fatalities by 2010 compared to 2001. The medium term objective is to cut the number of people killed or severely injured in road accidents by around 75% by 2025, while the long-term vision is to render road transport as safe as all other modes. It is hoped that supporting research addressing human, vehicle and infrastructure environment could achieve this last strategic target. Research should also combine measures and technologies for prevention, mitigation and investigation of road accidents paying special attention to high risk and vulnerable user groups, such as children, handicapped people and the elderly.

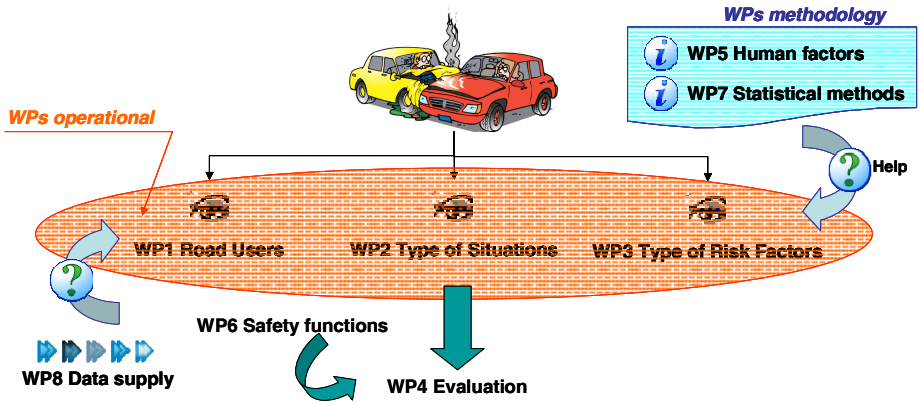


Figure 1. TRACE organisation

Within this context, the European project, TRACE (TRaffic Accident Causation in Europe), was set up to reduce or avoid road accidents in Europe by identifying and continuously up-dating the causes of accidents under three different but complementary research angles: types of road users, types of situations and types of factors. The identification and the assessment (in terms of saved lives and avoided accidents), of the most promising technology-based safety functions that can assist the driver or other road users in a normal or emergency situation or, as a last resort, mitigate the violence of crashes and protect vehicle occupants, riders and pedestrians in the event of a crash.

OBJECTIVES

The general objective of the TRACE project was to provide the scientific community, the stakeholders, the suppliers, the vehicle industry and other Integrated Safety program participants with an overview of the road accident causation issues in Europe, based on the analysis of any current available databases which include accident, injury, insurance, medical and exposure data (including driver behaviour in normal driving conditions). The idea was to identify, characterise and quantify the nature of risk factors, groups at risk, specific conflict driving situations and accident situations and to estimate the safety benefits of a selection of technology-based safety functions.

To carry out these objectives, TRACE was broken down into three series of Work packages (See Figure 1):

The operational work packages
The methodology work packages
The data supply work package

The aim of TRACE was to improve knowledge on accident causations. To reach this goal, TRACE analyzed road accidents according to several points of view (road users, road user situation and accident factors).

The purpose of this publication is to highlight the situation point of view. A situation is defined as a pre-accidental event to which the driver or the rider is confronted in normal driving conditions just before it turns into an accident[1] . It is assumed that there are specific accident causation factors related to these situations that deserve to be studied. The types of situation can include one or more accident scenarios[2] which contributed to the accident.

Four specific groups of situations, which correspond either to normal driving situations with no specific driver solicitation, or to driving manoeuvres where driver intervention is specifically required, have been identified:

Stabilized Traffic Scenarios (no specific manoeuvre), Intersection Scenarios, Specific Manoeuvre Scenarios (such as overtaking) and Degraded Scenarios (where atmospheric conditions lead to a degradation of the visibility or surface friction).

[1] A situation is linked to a vehicle. One accident with two vehicles count two situations

[2] A scenario clusters several similar situations according to predefined criteria.

INTERSECTION ACCIDENTS

Accidents at intersections represent 43% of road injury accidents in EU27. This result is largely due to countries such as UK, Czech Republic, Italy, Denmark and Netherlands with the rate varying between 47% and 59%. Several reasons explain these differences such as the intrinsic definition of the criteria. In UK for example, intersection includes the point where the roads cross plus the 20 m on either side which means that accidents occurring close to intersections are also counted as intersection accidents.

Although intersection accidents account for around the half the total number of accidents in EU27, they are at the origin of only 21% of fatalities and 32% of fatalities and serious injuries.

Method

The methodology proposed in TRACE and common to all operational work packages, is divided into three steps:

Descriptive analysis - uses macro-accidentology (use of extensive databases) to identify the main scenarios associated with each pre-defined situation type and their respective frequency and severity.in order to rank them.

In-depth analysis - details the main scenarios to provide information on the accident mechanisms, the main causes, through relevant indicators, specific to the scenario (such as precipitating event, contributing factors, driver functional failures, etc.). This analysis requires the use of in-depth databases.

Risk analysis - identifies the likelihood of being involved in an accident taking into account the results obtained from the 'in-depth' level.

An intersection is an area formed by the connection of two or more roadways. An intersection situation concerns all situations directly related to an intersection location.

Because in Europe, 85 to 90% of intersection accidents involve at least one passenger car we focused our analysis on this configuration. As such, the scenarios were defined on the basis of the involvement of at least one passenger car,. In-depth analysis showed that the right of way attributes of protagonists provided the most pertinent conclusions, as opposed to relative trajectories (the opponent coming from the left or the right) or vehicle type,. Scenarios were therefore grouped according to vehicle priorityb:

"Yield" drivers without Right Of Way

"Priority" drivers with Right Of Way

Literature review

TRACE builds on the findings of the PReVENT-INTERSAFE project which carried out an intersection accident analysis in the United Kingdom, Germany, and in France using available accident data (Simon et al 2006). The magnitude of intersection accidents and the most relevant accident situations were defined according to pre-accident manoeuvres. This distribution was predominantly based on the French National data.

The study provided a list of 50 accident situations including 20 intersection situations, from which. the top five were selected. Roundabout accidents were intentionally excluded from this analysis.

The top five situations include 4 turn onto/cross scenarios and 1 turn off scenario and represent 60-70 % of intersection injury accidents depending on the country. This classification was useful to launch the TRACE approach.

Numerous surveys have broadly described intersection problems, mainly from infrastructure layout, traffic flow, and traffic regulation standpoints.

Traffic flow. The traffic flows seem to have a great effect on accident frequency, in particular the traffic flow on minor roads which is directly proportional to the accident rate.

Sight distance. A poor sight distance increases the accident rate in particular when it concerns the sight distance from the minor road. In fact, sight distance threshold depends on the road layout, the V85 of the main road (speed of 85% of the drivers), the stopping time (in relation to the speed on the main road), the crossing time (in relation to the speed on the main and secondary roads).On the other hand, a survey highlighted that a visual restriction can result in decrease of approach speeds at rural intersection and a reduction in accident severity by limiting driver anticipatory decision-making.

Road Layout. Intersections are laid out with different devices such as road signs, road lighting, turn left or right lanes, central separator, traffic regulation.

It emerges from all the literature that the "channelization"[3] of the space reduces vulnerable user accident rate (and the overall intersection accident rate) by inviting the user to follow a dedicated lane and thus reducing the conflicts between different categories of road users.

The number of lanes combined with the intersection layout on the whole show a great influence on the accident rate. So, if we classify intersection layout in term of increasing accident rate, the literature shows that the best results are to be found at T intersections then Y intersections and offset 4-arm intersections. The worst results are attributed to the conventional 4-arm intersection. Once again, this information is related to traffic flow, the skew angle

[3] Channelization : is the separation of conflicting traffic movements into defined paths of travel to facilitate the safe and orderly movement of vehicles, pedestrians, and bicycles.

of the lanes (the rate increases with the increasing skew angle) and obviously with the regulation type (increasing effectiveness from intersections with no regulation (except conventional right of way) to roundabouts and finally traffic lights).
In addition accident rate is linked to layout and level of the intersection. At-grade intersections experience more accidents than grade-separated intersections.
Although we can consider the roundabout as a safe intersection layout notably for vulnerable users, the literature shows that there is no effect for car occupants. Moreover, the efficiency will depend on approach speed.

Traffic regulation. At last, traffic regulation plays a role by managing and regulating the traffic flows. The literature shows that traffic light intersections experience fewer accidents than 4-arm intersection with no traffic control. Accidents are less severe when STOP or Give way signal are replaced by traffic lights. The same trend appears with roundabouts.

User type. Intersection accidents are linked to the road layout, the traffic flow and regulation but the literature also shows that the type of user plays a great role. Vulnerable users (such as pedestrians) and elderly users are well documented.
Pedestrian accidents for example occurred more often (85% source Herms) on the marked pedestrian crossings
The number of pedestrians using them is smaller (77% source Herms).
The risk goes up as traffic volume rises.
The youngest and oldest groups of drivers were found to be over-represented in junction accidents. The young drivers had particular problems turning onto major roads and are more likely to violate such red lights.
The oldest drivers are more involved at intersection than anywhere else. More than half fatal accidents with drivers of 80 years and older occurred at intersections (25% for the drivers up to age 45 source Hauer). More over, 37% of all fatalities and 60% (source Hauer) of injuries experienced by the older drivers occurred at intersections. These data show the high frequency and severity of intersection accidents for older drivers. Many reasons can explain this involvement and their severity.
Why are older drivers more involved at intersections than in other configurations? The literature recalls the deficits in vision (acuity, contrast, spatial functions). These deficits express a bad perception of movement as well as this function taking longer (in particular at constant speed) when compared to younger drivers. Moreover older drivers are less able to manage sudden changes in situations which are often the case at intersections. Physically, older drivers show an age-related decline in head and neck mobility. So, older drivers present more difficulties in making left or right turns and in negotiating traffic signals.
One important factor is the interaction between older and younger road users. No differences appear in attention behaviour between the age groups but different acceleration habits and thus different turning times are reported. The outcome of the turning manoeuvre was dependent on age. The time gaps to the vehicles on the main road were shortest when an old driver was turning and a young driver approached on the main road.
Gender of the driver also seems to have an effect on accident occurrence. So, women were more likely than men to stop before turning; they tended to have their collisions with other women and they were under-represented as drivers of the non-turning vehicle.

User behaviour. While user type, gender and age are shown above to have a great effect on accident occurrence, the opponent driver manoeuvre plays a role in the driving strategy too. So, usually the driver would give way less to the opponent driving on the main road (right of way) in 3-arm intersection (60 to 69% source Björklund) than coming from his right in a 4-arm intersection (75 to 78% source Björklund).The expectation is based on what the drivers think is the rule in force (priority rule or road design).
It was also shown that the drivers' behaviour was more dependent on the other driver's behaviour (approach speed) than on road width (priority to the wider road is commonly admitted) and that the priority to the right rule was equally as important as the other driver's behaviour.
So driver strategy is linked to the transversal traffic and the intersection layout. When there is traffic visible on the other intersection arms, despite the fact that they have right of way, drivers regulate their speed. But when there is no traffic on the other intersection arms, driver strategies depended on intersection and approach characteristics.

Emergency reaction. When accidents occur, the drivers instinctively try to avoid each other by braking, swerving or accelerating. But this emergency manoeuvre is only possible if the intersection layout provides sufficient space. The literature shows that widening the approach allows a decrease in the accident rate whereas widening the whole road may increase the accident rate.

RESULTS

The main issues related to intersection accidents - the frame of the in-depth analysis.

Most of the intersection accidents involved at least one passenger car.
65% to 76% of drivers involved in intersection accidents involving at least one passenger car are male.

9% to 15% of intersection accidents are pedestrian accidents. Pedestrian accidents occurred mainly inside urban area and at intersections with traffic regulation. Older pedestrian are overrepresented (12% to 41% of the pedestrians involved at intersection).
64% to 73% of intersection accidents occurred inside urban area. Moreover 73% to 85% of intersection accidents with at least one passenger car occurred in urban area and 45% to 68% of intersection accidents occurred at intersection with traffic regulation.
65% to 74% of intersection accidents (with at least one car) occurred in daylight.
82% to 90% of all intersection accidents occurred while the weather was normal. Moreover, 68% to 88% of all intersection accidents occurred while the road surface was dry.
According to the above information, intersection accidents occurred particularly within urban area, during daylight, with good visibility conditions and involved passenger cars driven by male drivers.

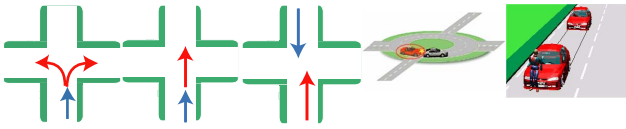
Identification of the most relevant intersection scenarios.

In order to identify the parameters linked to the intersection, accidents occurring at intersection have been split into scenarios. We have based our selection on the available parameters in the extensive databases [4] such as the pre-accident manoeuvre, the relative direction, the right of way, the vehicle type.
Each scenario was characterized with the frequency (number of accidents in this scenario compared to all intersection accidents, either in national database or in European databases). The second criterion is the KSI or "Killed and Seriously Injured" rate (number of fatalities and serious injuries compared to all injuries in the related sample).
Obviously, we were confronted to the problem of data compatibility. Each European partner had to adapt the data to suit the scenario request. We decided to group scenarios into six main common European scenarios. They represent 97% of all intersection accidents in Europe.
The "cutting scenario" where vehicles crossed the roads and/or the trajectory of the opponent vehicle (the drivers turned left or right or continued straight) is more frequent and the most severe .

53% of all intersection accidents and 59% of the fatalities and serious injuries at intersection belong to the "cutting scenario" class.

[4] BAAC, France; STATS19, UK; DGT, Spain; ODV, Czech Republic; OGPAS, Germany.

The remaining 47% of intersection accidents belong to the following scenarios.



The in-depth analysis related to the most relevant scenarios.

The analysis of the pre-accidental events allowed us to identify the accident mechanisms according to:
The "key event" which tips the driving phase over into the rupture phase. It should be remembered that accident occurrence is the result of different related causes which affect the Driver/Vehicle/Environment system. In general, the key event is mainly attributed to the driver who does not have right of way, but sometimes to both drivers.
The "Human Functional Failures" such as perception, diagnostic, prognostic, decision.
The "accident causes" such as the explanatory elements of the Human Functional Failures, the initial speed, the visibility distance, the stopping distance and the emergency reaction.
Through the literature review and our experience, we know that road layout, traffic flow, speed and visibility distances have a great effect on accident occurrence. All accident research teams (LAB included) and institutes mention that speed is a crucial factor in the severity of a crash and obviously in the potential for crash avoidance. The impact of speed differs according to the related moment in time within the sequential phases leading to the accident.
The "driving speed" is the speed during the driving phase or initial speed. The speed can be adapted or inappropriate to the circumstances (according to the difficulties of the situation such as road layout, weather conditions), excessive (higher than the speed limits) or not. The speed at the beginning of the crash phase determines the crash violence.
The speed at the end of the crash phase determines the post collision phase
Because one of the aims of the TRACE project is to define the main causes related to the intersection situations, we focused our analysis on the initial speed to show the effect of this parameter on the genesis of the accident.
According to the relevant criteria, we analyzed:
The initial speed for both drivers according to the right of way and their respective directions.
The visibility distance which is determinant in crossing the main road and depends on the vehicle speed on the main road.
Finally, **the emergency reaction** of both drivers according to the location and the right of way at intersection.

The in-depth analysis sample.

In-depth databases all gather detailed information related to the accident, but can be built using different data collection methods. In the case of in-depth analysis based on police reports, the data are collected by the police teams and analyzed by accident experts. Alternatively, accident experts investigate accidents on the scene and record data concerning the driver, the vehicle and the environment in a detailed database. Experts analyze the information and perform a reconstruction of the accident. On the base of these two approaches, causes, Human Functional Failures and risk factors are identified.
Whatever the data collection method employed, in-depth data help us to accurately identify accident causes and in particular Human Functional Failure HFF. Such, data are not generally available in police reports nor in most in-depth databases. This is therefore a new concept developed within the European project and which gives the survey a new dimension and a new vision of the causes of accidents.
The sample we used in this accurate analysis is composed of seven European in-depth database sources[5]. We took into account accidents occurring from 1997 onwards to analyze the most recent vehicles and situations.

The intersection scenarios.

The intersection scenarios were previously identified (descriptive analysis) on one hand according to driver manoeuvre, the relative direction of the vehicles and the regulation and on the other hand according to the frequency and the KSI severity. In-depth analysis highlights how accidents occurred (accident mechanisms) and their main causes. The following analysis will show that among the relevant parameters, regulation (right of way or not) and direction of the opponent vehicle are the main parameters which differentiate accident causation. This analysis led us to split the results according to right of way. Obviously the related counter-measures we can propose will be adapted to the driver according to his driving tasks and his needs.
In order to propose an accurate analysis and to avoid sample size bias, we have focused the analysis on the 2 main intersection accidents scenarios:
The "Cutting Scenario" covers 53% of all intersection accidents in Europe and 59% of the KSI.

[5] EDA, LAB, France ; EDA, INRETS, France ; OTS, VSRC, UK ; GIDAS, Germany ; RIDER ; ETAC ; EACS.

The "Pedestrian scenario" covers 9 to 15% of the intersection accidents depending on the country. Despite the lack of information concerning pedestrian accidents in the in-depth databases, we intend to analyze the circumstances of such cases and highlight the requirements for further investigation.
We highlighted the "key events" (previously defined), the "Human Functional Failures" and the "related causes".

The "Cutting Scenario"

The "cutting scenario" is a set of several sub-scenarios in which the Opponent Vehicle comes from the left or the right. The Case Vehicle has right of way or not and is going straight or turning.

<u>The drivers having not the right of way- "Yield drivers" – Key events.</u> These drivers are generally driving on secondary roads. Key events that tip the driving phase into the rupture phase are mainly represented by endogenous parameters (i.e. related to the driver) with on the one hand the "internal conditions of the task" and on the other hand "driver behaviour".
The "internal conditions of the task" means all factors related to the driving task such as the manoeuvre (turning, going straight) be it correctly performed or not, the speed and so on. These factors are essential for understanding the accident mechanisms.
The "yield drivers" are more likely to be concerned by incorrect driving manoeuvres or incorrect positioning (2/3 non respect of traffic regulation and 1/3 incorrect decision to perform a manoeuvre according to the information available (visibility or available time gap)).
These drivers also present a poor prognosis (evaluation) of the situation or of the opponents' manoeuvre. "Poor evaluation" means that drivers saw the other vehicle (on the main road) but estimated that they had time to cross.
Finally, the "yield drivers" showed a misinterpretation of the situation. "Misinterpreted the driving situation" includes 1/3 of poor knowledge of the site, 1/3 of misleading infrastructure (the road is not as we think it is!) and 1/3 of miscellaneous factors such as driver state or visibility obstructions.
The "driver behaviour" means all factors directly linked to the drivers' awareness of the situation (attention, distraction for example). Most drivers who did not have the right of way and who presented "driver behaviour" as a key event, "failed to look".
2/3 of "failed to look" causes are exogenous and related to the infrastructure and the environment

(road layout, mask, weather luminosity). Moreover, 1/3 of these drivers had to deal with a problem of geometrical visibility directly linked to the road layout.
1/3 of "failed to look" are endogenous and related to the driver state (age, mood, experience).

The drivers having not the right of way- "Yield drivers" – Human Functional Failures. Half of drivers having not the right of way experience a "perception failure" rather than the other functional failures.
The "perception failure" can be explained by:
a "quick look" (quick look at the environment and the opponent),
"focused attention" (focus on a part of the situation instead of the opponent vehicle),
"did not look" (the driver stopped searching for information and carried out a non-driving task for example),
"no visibility" (the information is not available or there is a geometrical obstruction).
"inattention" (low effort driving task, inattention…).

The drivers having not the right of way- "Yield drivers" – Related causes and discussion.
The emergency reaction
Because, the driver didn't perceive the opponent vehicle correctly, he couldn't anticipate and avoid the crash. Only 1/3 of "yield drivers", with "perception failures", attempted to avoid the crash by braking or accelerating while 2/3 did not react before the crash. Moreover, 20% of these drivers (perception failures) were driving at excessive speeds, thus reducing the chance of avoiding the crash through emergency braking action.

Older drivers. Despite the fact the proportion of older drivers (65+) in the TRACE sample is low (11% of the drivers at intersection), they are more often involved as "driver having not the right of way" than the other categories. It means that older drivers have trouble managing the driving task at intersection and especially when they do not have right of way. Several situations characterize older driver involvement at intersection:
"Perception" issues. They failed to look (looked but didn't see or looked, didn't see anything and decided to cross without checking again)
They have navigation problems (attention focused on finding their route) or mood (irritated),
"Misinterpretation" of the traffic lights in operation,
"Hesitant manoeuvre" or slow manoeuvre (after looking at the traffic, pulled out slowly).
So, older (65+) "yield drivers" had problems related to the perception of the other vehicle but also problems related to the understanding of the situation. Moreover, when they correctly performed the perception and the understanding, their action was too slow.
As a result of these failures, they pulled out or crossed the intersection and most of them did not react. They could not avoid the crash.

The drivers having the right of way- "Priority drivers"– Key events. Although the key-events mostly concern the drivers, who do not have right of way, sometimes both "Priority drivers" and "yield drivers" contributed to tipping the driving phase over into the rupture phase.
"Internal conditions of the task" and "driver behaviour" are the main relevant key events related to the "Priority drivers".
"Internal condition of the task" is split into:
"Incorrect driving manoeuvre" is related to risk taking. The driver sees the other driver, understands the danger but does not anticipate.
"Misinterpreted the driving situation" is related to the driver who misunderstands the intentions of the other driver.
"Excessive speed" is related to the speed limits (above the speed limit) while "inappropriate speed" is related to the driving conditions (weather, road surface, traffic…) even if the speed limit is not reached.
"Inappropriate reaction" concerns drivers who brake to avoid the crash but lock the wheels (sample of accidents with passenger car not equipped with ABS). Moreover, the stopping distance is not long enough to allow correct avoidance of the crash. The "Priority drivers" see the other driver (on the secondary road), but understand his intentions too late.
"Driver behaviour" is mainly "failed to look".
"Failed to look" is related to the "Priority driver" who was attentive to the traffic but didn't see the other vehicle because he didn't look for the information (feeling of priority).

The drivers having the right of way- "Priority drivers"– Human Functional Failures. Drivers having the right of way experience more "prognostic failures" such as anticipation of the opponent driver manoeuvre, prediction of opponent driver presence and "perception failures".
The **"prognostic failures"** can be explained with the fact the "Priority driver**"** is:
"Waiting for the regulation" of the situation by the other driver (sees the other vehicle slowing down up to the intersection and assumes it is going to stop)
"Assuming that the other driver will not manoeuvre" (sees the other driver stopped on the secondary road but does not anticipate his manoeuvre)
"Not predicting obstacle" in his path (unusual or prohibited manoeuvre performed by the other driver).
75% of "prognostic failures" can be explained by endogenous explanatory elements (related to the driver) with a feeling of priority, inappropriate

speed, time constraint, risky driving, misunderstanding the situation.
The **"perception failures"** can be explained by "focused attention" (on the priority rules), "inattention" (lost in thought),
"no visibility" (mobile obstruction to visibility), "no look" (break in information search because of non driving task) and
a "quick look" (feeling of right of way)
75% of "perception failures" are due to endogenous explanatory elements (related to the driver) with feeling of priority, inappropriate speed, non driving task or misunderstanding of the situation.

The drivers having the right of way- "Priority drivers"– Related causes and discussion.

The emergency reaction

In almost nine out of ten "prognostic failures", the drivers with right of way braked before the crash.
However, in the case of "perception failures", only half of drivers with right of way braked before the crash..
"Focused attention" failures led to "no reaction" (as emergency reaction) performed by the "Priority driver" while the other classes (inattention, no look and quick look) led to a braking response.
When the driver with right of way is confronted with a vehicle coming from the left or the right, his emergency manoeuvre is slightly different. When the other vehicle OV comes from the left, the driver with right of way reacts mainly by braking. Whereas, when the other vehicle comes from the right, the driver with right of way reacts with a braking response or a combined braking and evasive steering action. There are more avoidance manoeuvres when the OV comes from the right.

The initial speed of the "Priority drivers"

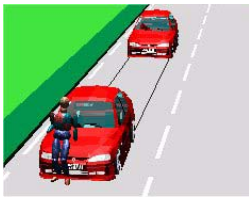
More than a half of the initial speeds, where vehicle braked before the crash, were higher than 80 km/h. 1/4 of the calculated initial speeds were "excessive speed" (over the speed limits).

The stopping distance

More importantly than the initial speed or the driving speed, the "stopping distance" is crucial in determining crash avoidance possibilities. The "stopping distance" is the distance required to stop the vehicle before the crash. It includes the distance travelled during the reaction time and the braking distance.
Despite drivers performing a braking manoeuvre to avoid the crash, the accident happened. If we compare the stopping distance to the available distance (distance to crash used in the reconstruction of the accident to evaluate the initial speed), 66% of the drivers did not have sufficient distance to stop their vehicle and avoid the crash.
So, the "Priority drivers" braking before the crash didn't avoid the accident because:
They did not have the time and the space to perform a manoeuvre
They drove too fast (excessive speed)
The road surface was wet, decreasing the efficiency of the braking
They could not see the other driver

Generic counter-measures. The main generic counter-measures related to the "cutting scenario" drivers are closely linked to the accidents involving older drivers, followed by driver perception problems and finally driver emergency manoeuvre.
Consequently, we need to think about the best way to help older drivers at intersections. The evolution in the population structure (and the driver population structure) means that older drivers are becoming more numerous. Today the best way to help them with the available ITS is through obstacle detection. But when older drivers perceived the other vehicle and performed a manoeuvre such as crossing the main road or turning left into the main road, they were confronted with fast moving traffic which left them insufficient time to perform their manoeuvre. So, the best help is to reduce the approach speed limits on the main road to allow older drivers to perform the manoeuvre safely.
Then drivers "having not the right of way" need to be helped in their perception of the other vehicle, to look properly and to detect the other vehicle. It is necessary to control the available geometric visibility (sight distance), to take remedial actions if necessary or develop new road layouts with appropriate sight distances.
Lastly, the drivers "having the right of way" need to be helped to be more attentive (more concentrated on the driving task) and to anticipate the other driver's manoeuvre. These drivers have a strong feeling of priority. They don't understand the situation as being risky but rather as being safe. They see but don't anticipate or anticipate too late. They need to be informed of the approaching situation with an up-to-date navigation tool that informs the driver of the potential risk situation according to geometry, visibility constraints and referenced "black spots". They also need to be helped during their emergency manoeuvre. EBA can help reduce the braking distances.

"Pedestrian scenarios"



It should be remembered that in Europe, 14% of road fatalities were pedestrians in 2004, 11% in France, and 21% in UK. 67% of pedestrian fatalities occurred inside urban areas, 34% of pedestrian fatalities are aged 65+ and 45% are aged 0 to 24 (CARE 2006).
Despite the lack of information, we know that pedestrians are mostly involved at intersections with neither regulation nor traffic lights. In this

configuration, the youngest and the eldest are overrepresented.

The causation factors. Accident causation factors are mostly related to the "pedestrian" followed by the "internal conditions of the passenger car driver task".

For both pedestrians and passenger cars, "failed to look properly" is the first causation factor. In fact the visibility problem related to this scenario is specific. The visibility is linked to the way the pedestrian crosses the road. Half of intersection accidents involving pedestrian in our sample occurred at night and most of them inside urban area. We suppose that in daylight the problem can be linked to the different traffic flows, the urban environment, and "visual pollution". The literature review highlighted that when volumes are higher than 12 000 vehicles/day, marked pedestrian crossings on multi-lane roads were more prone to crashes than unmarked locations, and the risk goes up as the volume rises. During the night the problem is different. We know that factors such as contrast related to the vehicle colour and lights and to the pedestrians' clothes appear to have an effect on the conspicuity of both users.

Half of the pedestrians cross at intersection with no regulation. But half of them cross at intersection s with traffic lights! The literature indicates that pedestrians look before crossing at both marked and unmarked pedestrian crossings, except at signalized intersections.

The emergency reaction. Although 60% of passenger car drivers did brake before the crash, 40% of them did not react! In fact 9 pedestrian accidents out of 10 were the pedestrians' fault which could explain the lack of reaction. Moreover, all intersection accidents involving a pedestrian occurred when the initial speed of the passenger car was lower than 60 km/h. For half of them, the initial speed was lower than 40 km/h. A passive safety survey (ref LAB) performed on pedestrian accidents showed that when the impact speed is raised from 45 km/h to 55 km/h that is to say "only" 10 km/h, (the risk of sustaining fatal injuries rises from 30% to 50%!

Generic Counter- measures. Generic counter-measures linked to pedestrian intersection accidents are related to the vehicle (passenger car) driver.

In this way, the passenger car driver needs to be helped to perform his emergency manoeuvre. The driver braked most of time (60%) but did not avoid the crash. EBA can be useful to help the drivers.

They also need to be helped to predict the presence of a pedestrian, to see the pedestrian and to anticipate avoidance. Obstacle detection is required when the pedestrian is on the road but when the pedestrian is previously hidden from view, detection is more difficult. Navigation tools can be useful to inform the driver about a potential risk zone (likelihood of pedestrian presence).

CONCLUSIONS

Descriptive analysis based on European national databases led us to identify the main relevant scenarios observed at intersections. The first in terms of frequency and severity is the so called "cutting scenario" grouping crossing trajectories and turning trajectories and representing 53% of intersection accidents. No distinction was possible at European level. The remaining 47% concerned rear end collisions with or without manoeuvres, roundabout scenarios and pedestrian scenarios.

In-depth analysis of the intersection accident scenarios highlighted that we have to consider the scenario as a combination of two situations related to the driver who has "right of way" confronted with the driver who does not. This point of view is very important to infer the best countermeasures related to each requirement.

Endogenous factors, related to the driver are common. They are either related directly to "driver behaviour" through "driving speed" or related to the "conditions of the task" through "poor evaluation" or "poor understanding" of the situation. "Perception failures" are often found in both groups but are overrepresented in the group of the "yield drivers". This functional failure can be explained through factors such as "priority feeling" for the driver with right of way but also in the case of the driver who does not have right of way through the "sight distance". This last result leads to question the intersection design of future roads.

More drivers with right of way performed an emergency reaction to avoid the crash. The countermeasures recommended to these drivers could help the driver perform the emergency manoeuvre earlier and improve vehicle efficiency.

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