Interest of in-depth investigation for studying the relation between speed and accident risk

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Abstract

In-depth accident investigation offers many advantages for the analysis and comprehension of crash mechanisms. IFSTTAR makes such investigations since 1992 without interruption. The corresponding database contains more than 1200 accident case studies. Currently, in-depth accident investigation is one of the best ways to determine the speed or cars involved in accidents. This paper first presents the methods used for accident investigation and for accident kinematic reconstruction. Then, in order to illustrate the interest and possible applications of such accident data, it shows some results from a recent study based on the IFSTTAR in-depth accident study programme (IDAS) and dealing with the link between travelling speed and accident risk.

INTRODUCTION

The interest of in-depth accident investigation is well described and proved for many years by road safety research [1]. A recent European project, DACOTA, funded by the European Commission, presents a state of the art on in-depth accident investigation programmes in Europe and a description of what would be the benefit if such studies were extended to nearly all European countries [2].

Such programmes offer many advantages for the analysis and comprehension of crash mechanisms. In particular, by offering the ability to determine the speed of crashed cars, they represent an interesting tool to carry out research work on the role of speed in road safety.

Various publications provide thorough states of the art on the relation between speed and road safety, such as for example the Actes Inrets n°105 [3] or, at the international level, a report from OECD/ECMT [4].

More precisely, the scientific literature and accident research usually suggest that the risk of being involved in a road accident increase with the travelling speed. For example, research work published by Nilsson in 1982 deals with the analysis of the accident data according to the average speed of the traffic before and after modification of speed limits [5]. Others studies are rather based on the comparison between the speeds of vehicles involved in the accidents and the current driving speeds. In particular, matched case-control studies were carried out in Australia. On various types of network in rural areas [6] and in urban areas [7,8], they compare the speed of each vehicle involved in an accident (case) with the speed of vehicles circulating at the same place (controls).

The in-depth accident investigation programme performed at IFSTTAR is named IDAS, which stands for In-Depth Accident Study (in French EDA: Etude Détaillée d'Accidents [1]). This paper first presents the methods used in this programme for accident investigation and for

accident kinematic reconstruction. Then, in order to illustrate the interest of such accident data for evaluating the link between travelling speed and accident risk, it shows some results from recent research work using speed data issued from the IDAS programme [9]. This work makes comparisons between the speed of the crash-involved car (obtained through kinematic accident reconstruction) and laser speed measurements made on the accident spot for other vehicles, and then use a matched case-control study design in order to fit and compare different statistical models.

MATERIAL AND METHODS

In-Depth Accident Study (IDAS)

The in-depth accident data used in this paper are collected through the IDAS programme, which was built up and is carried out at IFSTTAR Laboratory of accident mechanism analysis [1]. It should be noted that the first objective of this database is to be illustrative of the diversity of accidents but not necessary statistically representative of all the accidents occurred in France. So we could say that the aim of the IDAS programme is more to build up an accident cases library than a statistical database.

The principle of IFSTTAR IDAS is to collect in real time as many information as possible on the three components of the driver-vehicle-environment system. The investigation area is about 20 km around the town of Salon de Provence in the south of France. A multidisciplinary team of investigators (a technician and a psychologist) is automatically alerted and takes action at the same time as the emergency service, on the scene of the accident. It makes its own collection (material clues, statements of the involved persons and witnesses) focused on the processes leading to the crash and on the accident circumstances. The collected data cover the involved protagonists, the vehicles, the roads and the environment.

On the scene of the accident the priority is, for the technician, to take pictures and films of the final positions of the vehicles, the tracks on the ground, the vehicles deformations and any other relevant elements that can help to understand the accident. A careful examination of the involved vehicles is made to collect the positions of the gear lever, the weight of a possible loading, the presence of a mobile phone, etc. The technician also takes pictures and films of the area of the accident. At the same time, the psychologist interviews all the peoples directly involved in the accident (driver, rider, cyclist, pedestrian) to collect their accident understandings. If necessary others car occupants or witnesses are also interviewed.

A second data collection is done within a few days after the accident. The psychologist performs a second interview, more detailed and more focused on the state and experience of the protagonists. The medical files concerning the victims (anthropometric measures, statements on lesions, etc.) are also colligated in the emergency service of the hospital in Salon de Provence. On the site of the accident, the technician makes road measurements to perform an accident map. He/she also does speed measurements with a laser speed gun (figure 1) for vehicles passing the site in the same condition as the car involved in the accident: same direction, type of day, hour, luminosity and traffic conditions (free-flow), etc.

Figure 1 Laser speed gun Laser Tech® Ultra Lyte LTI 20

Speed measurements are made on the zone of approach (Figure 2), for around 10-15 vehicles (for each crash-involved vehicle). The speed measurements are taken at around 80-100m ahead the impact location. These measures are implemented in the database.
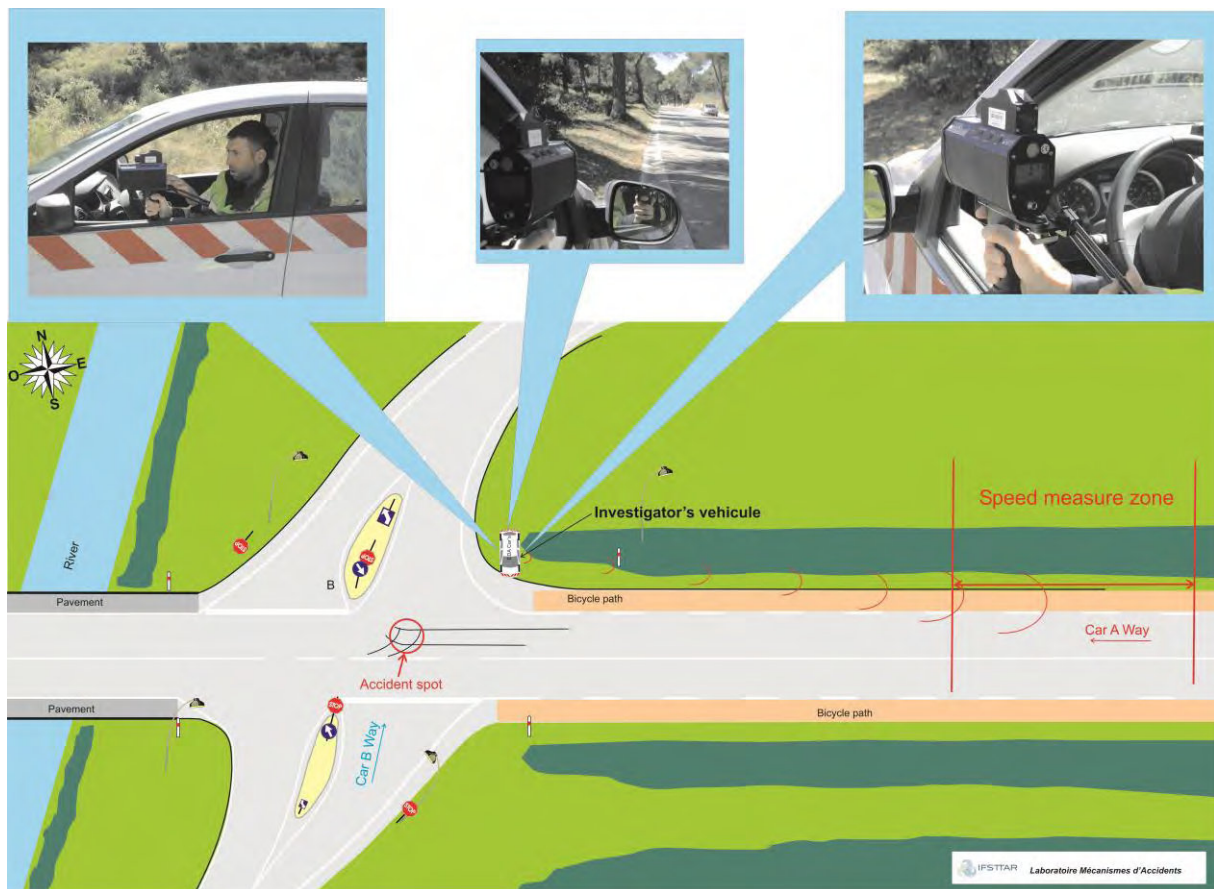

Figure 2. Speed measurement method on accident spot

A kinematic reconstruction is performed with specific in-house software (ANAC®) based on final and impact positions, skid marks, angle of the impact, impact locations on the vehicles, involved persons accounts, victim's injuries, etc. The objective of the reconstruction is to build a spatiotemporal description of the processes leading to the collision, consistent with the whole data (Figure 3). The used method requires knowledge in kinematics [10] and is based on the estimation of some parameters such as the energy spent in the vehicle deformation, the decrease in speed of the vehicle depending on the tyre marks on road, etc. The trajectories of the vehicles involved are determined according to data collected on the scene of the accident: final positions, marks, estimated positions at impact point, and arrival directions of each vehicle. In general, it is necessary to go back in time and on the trajectory

of each involved vehicle, with the calculation of simple kinematics sequences (each sequence is associated to a simple kinematics model). The post-crash phase is first modelled by a constant speed movement or by a uniformly accelerated movement. Then the analysis of the collision consists in applying simple mechanical laws: conservation of momentum (two axles) and conservation of energy (kinetic energy and energy of deformation). The global objective is thus to balance these three simultaneous equations. Finally, the study of the pre-crash phase uses exactly the same principles of calculation than the post-crash ones.

Figure 3. Results of the kinematics reconstruction, spatiotemporal description of its proceedings

Lastly, both investigators write together a case summary presenting the whole analyse: the story of the accident. The whole data collected is structured in check-lists and coded in a database. Likewise, all raw data, such as videos, photos, interviews are also introduced in the numerical database.

The influence of travelling speed on the risk of injury, a specific study based on IDAS data

This research is presented as an example to illustrate the interest of in-depth investigation in this field. A comprehensive account of this work has been published in a recent article [9]. Data from the IDAS programme have been used to study the relation between the travelling speed and the risk of being involved in an injury accident, following the method described below [9].

First, a subsample of accident cases was selected based on restrictive criteria:
- Vehicle type: only cars were considered.
- Driving situation: cars involved in particular manoeuvres before the accident (such as overtaking, slowing or accelerating for turning or merging, starting from a Stop or Yield line, manoeuvring for parking, etc.) have been excluded. Moreover, only cars traveling in free flow traffic conditions before the accident were considered. These criteria were introduced in order to obtain speed-risk relationship which corresponds to the most simple and common driving situation, and to be sure that the control vehicles can be matched to the case vehicle without ambiguity.

- Light and weather conditions: cars involved in accidents occurred during the night-time or in wet weather or wet pavement conditions have been excluded. These criteria were added for practical reasons. For accidents occurred in wet weather or wet pavement conditions, the measurement of the speeds of control vehicles cannot be made in conditions exactly comparable to the conditions prevailing at the time of the accident. Moreover, during the night hours, for some accident sites on minor roads, there are too few vehicles passing the site and thus it is not possible to obtain a sufficient number of control vehicles within a reasonable period, corresponding to the time of the accident.

- Sufficient information for kinematic reconstruction: the vehicles considered were only cars involved in accidents for which the data gathered by the IDAS investigators allowed them to carry out a kinematic reconstruction leading to an estimate of the speed of the car before the accident.

Finally 52 vehicles issued from 49 accident analyses were retained in the IDAS Database for years 2003 to 2012. The method used is a matched case-control study design, where controls are individually matched to each case. So each crash-involved car considered (case vehicle) is associated with a set of matched control vehicles. The corresponding controls are other cars passing the same road site as the case, in the same conditions (same direction, same time of the day, etc.). For each case, speed measurements were made for around 16 control vehicles, on average. Overall, 52 cases and 817 controls are used. The speeds are obtained from kinematic reconstructions for the crash-involved cars, and using a laser speed gun for the controls. The statistical models were fitted using conditional logistic regression, which is the method usually applied for matched case-control studies in the field of epidemiology (as regards the statistical aspects of this study, the reader is invited to refer to reference [9]).

RESULTS

Example of an accident studied within the framework of the IDAS programme

The accident shown occurred on a crossroads between a large road (A) and two secondary roads (B and C). There are two cars involved (figure 4).
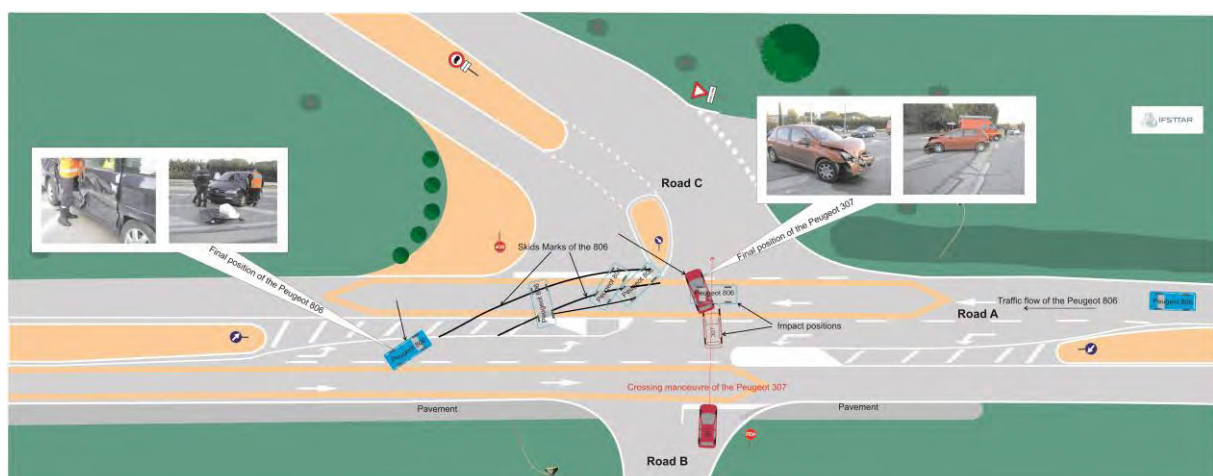

Figure 4. Map of the accident

Summary of the accident

One day in October, by 4:23 pm, in clear weather and on dry road, the driver of a Peugeot 307 stops his vehicle at the stop line on the Road B, in front of a crossroads with the road A. He intends to cross the road A, which is a priority road, to join the opposite road, the road C which leads to the centre of a village. He is familiar to the location. He gives way to some vehicles, coming from his left or right. He takes time to make sure that no vehicles travel on the road A (from both sides), before beginning his crossing. He looks to the right and perceives no vehicles so he begins his crossing. The Peugeot 307 travels 9.5m from the stop line when it collides with the Peugeot 806 coming from the right. The damages on the Peugeot 307 are located on the front left corner while the impact on the Peugeot 806 is on the left side. The driver of the Peugeot 307 never perceives the Peugeot 806 coming from his right before the impact. Both surprised by the shock, none of the drivers try any avoidance manoeuvre. The Peugeot 307 comes to rest across the traffic lane of the Peugeot 806. The Peugeot 806 makes a half turn on the road and stops at about 30 m of the impact point.
The two drivers used seatbelt, only the driver of the Peugeot 806 was slightly injured. The driver of the Peugeot 307 was shocked but uninjured.

Accident reconstitution

Post-collision phase for the Peugeot 806:
There are 31 m of skids marks between the impact and the final position: it is a uniformly decelerated movement of -5m/s².
The speed after the impact is calculated and is equal to 63Km/h.

Pre-collision phase for the Peugeot 307:
The Peugeot 307 starts from the stop and makes 9.5 meters before the impact. The literature [10] gives us an acceleration of 2.3 m/s² for this type of manoeuvre over this distance. The speed of the Peugeot 307, before the impact, is calculated and considered as equal to 24 km/h.

Collision:
The EES (Equivalent Energy Speed) for the Peugeot 806 is determined by comparison with crash-test and by analysing the deformation. The EES is estimated at 25km/h.
The EES for the Peugeot 307 is estimated with the same manner at 20km/h.
The calculation of the conservation of momentum and conservation of energy gives the speed of each vehicle at the impact (figure5). The speed of the Peugeot 806 at the impact is considered to be around 70 km/h.
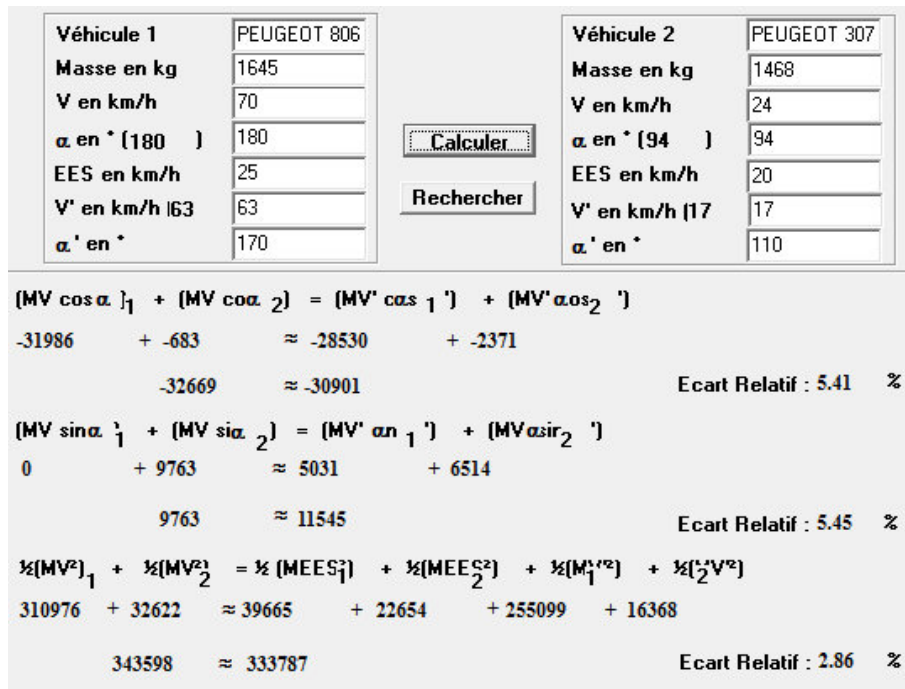
Figure 5. Conservation of momentum and energy, collision equations (ANAC® software)

Pre-collision phase for the Peugeot 806:
There is no perception of the conflict situation by the driver, so the travelling speed of the Peugeot 806 is considered to be equal to the impact speed: 70 km/h (figure 6).

Instant characteristic	Peugeot 806			Time to Impact	Peugeot 307		
	Distance/ Impact point	Speed	Acceleration		Distance/ impact point	Speed	Acceleration
Units	m	km/h	m/s²	s	m	km/h	m/s²
Peugeot 307 Starting	-56	70		-2.88	-9.5	0	
			0				2.4
Peugeot 307 pass on central storage lane	-14	70		-0.72	-4.9	21	
			0				2.4
Impact (input)	0	70		0	0	24	
Impact (output)		63		0		17	
			-5				-3.2
Final position Peugeot 307	20	37		1.48	3.5	0	
			-5				
Final position Peugeot 806	31	0		3.5	3.5	0	

Figure 6. Kinetic reconstruction overview

Finally, the car considered for the study on the relation between risk and travelling speed is only the Peugeot 806 which is in free-flow traffic condition. The Peugeot 307 is performing a specific manoeuvre at the junction so it has been excluded from the sample. For this example, the case is the crash-involved car Peugeot 806, travelling at a speed of about 70 km/h.

Speed measurements of controls

Concerning the approaching speed of the controls, 12 measurements have been made with the laser gun on cars travelling on the same road A (figure 4), on the same lane, in the same direction and in same conditions (figure 7).

Speed of the Peugeot 806: Kinematic reconstruction (CASE)	70
Speed measurement with laser gun on the accident spot (CONTROLS)	71
	66
	67
	69
	59
	56
	63
	66
	69
	63
	58
	67

Figure 7. Speed values for one case (km/h)

Whole sample

The graph in figure 8 shows the whole sample used in the study [9] with, for each case, the speed of the crash-involved vehicle (issued from the kinematic reconstruction), the mean of the speeds of the corresponding controls (measured with the laser speed gun), and the interval defined by the mean plus or minus the standard deviation (of the speed distribution for this group of controls).
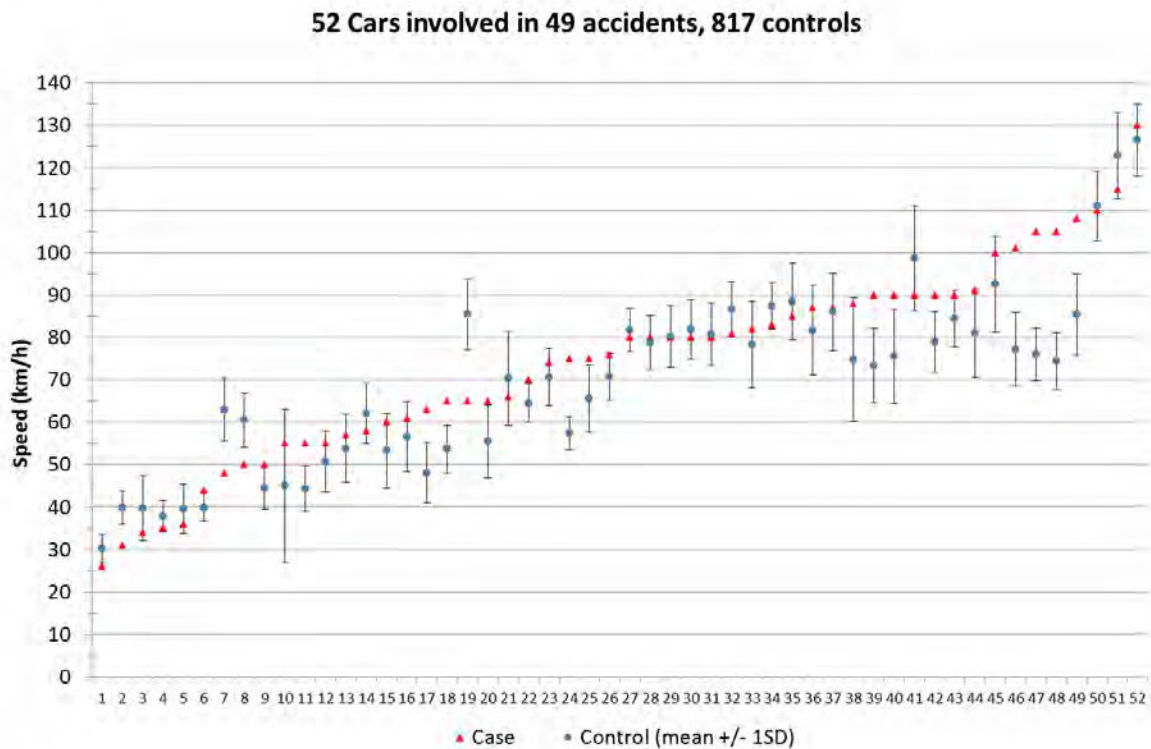

Figure 8. Comparison of the travelling speed of each crash-involved car (case) with the speed distribution for control cars passing the same site (mean speed and interval defined by the mean +/- 1 standard deviation)

Overview of the results of the matched case-control study

A significant positive relationship is found between the individual travelling speed and the risk of injury accident using different types of statistical models. The results show that the relationship between individual speed and accident risk is well described by a power model: the relative risk of being involved in an injury accident at a speed V, compared to a speed V_0, in the same conditions, is equal to $(V / V_0)^{3.41}$. The data are also well fitted by an exponential model but such a model is more difficult to interpret.

Nevertheless, this study has limitations, due to the relatively small number of cases and to the data used, since kinematic reconstructions always involve some degree of interpretation. A detailed account of the statistical method and models and the complete results can be found in reference [9], which is available at www.pp.bme.hu/tr/article/view/7520.

CONCLUSION

In-depth accident investigation programmes are particularly well suited for the thorough analysis of accident causation, which involves complex system interactions between human operators, vehicles, road infrastructures, and environments. However, such programmes also make it possible to acquire an overall knowledge of the factual characteristics and parameters of the accident processes, such as the velocities and paths of the crash-involved vehicles, at the various stages leading to the collision. This is also of interest for the prevention of accidents and injuries. A better knowledge on the paths of vehicles running off the road, for example, may be useful for improving the roadside safety devices and the way they are used. In the same manner, as shown in this paper and in reference [9], the knowledge of the speeds of crash-involved cars allows to study and to better identify the effect of the individual travelling speed on the risk of injury accident, at a given place and time. Such results could be useful within the framework of safety education programmes, for example, or for the improvement of on-board safety systems.

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