Description of pedestrian crashes in accordance with characteristics of Active Safety Systems

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Abstract Primary safety systems have been developed for vehicles in order to detect a pedestrian and to avoid or mitigate an impact autonomously. This work aims to estimate the safety potential of six Active Pedestrian Safety Systems (APSS) from a sample of 100 real vehicle/pedestrian crashes provided by in-depth crash investigation. The accident cases were first reconstructed by emulating the kinematics of the vehicle and the pedestrian. These simulations provided a comprehensive set of data describing the interaction between the vehicle and the pedestrian over a crash sequence. Then, four particular pre-crash events on the timeline were selected as fields of interest with respect to performance characteristics of APSS. They correspond respectively to 2.5s before the impact, the instant when the pedestrian is visible (pedestrian steps into the field of view of the sensor), the last moment for the vehicle to brake in order to stop before impact and one second before the impact. For each of these instants and for each of the six selected APSS, it was evaluated if the systems could detect the pedestrian according to the different attributes of these systems. Results allow describing the required performance of an APSS and understanding the issues and challenges in pedestrian safety.

Keywords Pedestrian active safety, Primary safety systems, Pedestrian crashes, Crash reconstruction, Crash modeling

I. INTRODUCTION

Pedestrian accidents still remain an important issue in road safety. Each year, more than 270,000 pedestrians are injured or killed around the world due to impact against a vehicle [1]. Several studies focused on pedestrian accidents highlight that most of these accidents occur because the driver of the vehicle has not seen the pedestrian or has detected him too late to react properly [2-3].

Primary safety systems have been developed for vehicles in order to autonomously detect a pedestrian and to avoid or mitigate the impact. The global functioning of these systems is based on analyzing the forward path of the vehicle in real time in order to try to identify a pedestrian on the road. If it is determined that the pedestrian trajectory is across the forward path of the vehicle, as a countermeasure to avoid an imminent crash, these systems employ emergency braking and some may potentially employ emergency steering [4-6].

These Active Pedestrian Safety Systems (APSS) are installed on board vehicles and have quite different attributes. For detection, different types of sensors can be incorporated into the vehicle such as cameras, radar, scanners or infra-red systems. The different characteristics of these sensors can be classified according to their procedure to analyze the scene which can involve not only image processing which operates in visible light or Near, Mid and Far Infrared radiation (NIR, MIR, FAR) but also “time-of-flight” sensors such as RADARs and LIDARs. These detection sensors have their strengths and weaknesses [7]. Moreover, these systems may be affected due to constraints concerning the environmental conditions. To compensate for their limited performance, sensors are often combined in order to improve the detection rate by merging the data [8].

Consequently, one of the main issues concerning these APSS is their validation and their efficiency because they have different attributes from image processing to decision-making strategies. These attributes operate at different levels along the sequence of events preceding a crash. Several researchers are trying to develop

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standard test protocols using typical accident scenarios involving car-to-pedestrian front crashes [9-10], but these evaluations are incomplete because they are based on a limited number of scenarios. Therefore, it appears quite relevant to analyze their effect in real accident configurations because they vary in terms of vehicle speeds, pedestrian trajectory, weather conditions, road configuration, etc.

The objective of this study is to analyze a sample of real crash data involving pedestrians in order to estimate the safety impact of different active systems. In addition, this research implicitly highlights the issues and the challenges for these technologies regarding pedestrian safety.

II. METHODS

Accident database

This study is based on real world crashes involving pedestrians. A sample of 100 in-depth accident cases was gathered from two sources: 40 crashes provided by the French institute IFSTTAR-LMA (the Laboratory of accident mechanism analysis of the French institute of science and technology for transport, development and networks) and 60 crashes provided by CASR (Centre for Automotive Safety Research, University of Adelaide). These two research centers follow a common methodology in in-depth investigations. The multidisciplinary team attending crash scenes gathers sufficient evidence to reconstruct and analyze the crashes [11-12].

The data were organized into sub-models representing the different components of a crash: vehicle, pedestrian and crash environment. All the studied cases were recorded in a database classified in files including the following information:

- Photographs and videos of the crash scene and vehicles involved;
- Details of the road environment such as the weather condition at the time of the crash;
- Details of the involved vehicles with the measurement of the impact points (bonnet, windscreen, etc.);
- Statements of people involved in the crash, witnesses and police;
- Details of any injuries on the basis of the medical records;
- A site diagram of the accident drawn to scale including the final resting positions of the vehicles involved, the marks observed at the scene (skid, debris, etc.), the estimated impact location and the estimated trajectories of the different subjects involved in the crash.

The crash data from IFSTTAR-LMA cover a wide period, 1995-2011; the crashes occurred in the township of Salon-de-Provence (~42000 inhabitants) and surrounding areas and also in the town of Aix-en-Provence (~140000 inhabitants) since 2000. The CASR cases occurred in the Adelaide metropolitan area (~1.2 million inhabitants) in the period April 2002 to October 2005.

All the accidents have been reconstructed from a kinematic point of view. Firstly, the accident was graphically represented including the final resting position of the vehicle and the pedestrian, skid marks, potential obstacles which could hide the pedestrian, etc. The approximate trajectories of the vehicle and the pedestrian were then extracted from the scaled accident diagram provided from the in-depth investigation. Obstacles that mask the pedestrian were also located using the diagram. A temporal reconstruction was set up to emulate the kinematics of both the vehicle and the pedestrian from a pre-defined initial state until the impact. The initial conditions of the car and pedestrian were defined. As the pedestrian walking speed is often missing in the in-depth accident databases, it was estimated from the speed of the 50th percentile based on the age of the pedestrian [13]. The pedestrians were defined to have a constant motion. Similarly, the vehicle travel speed was also considered as constant over the chain of the pre-crash events in order to “rewind” and retrieve the position of the vehicle at the beginning of the simulation. This vehicle speed was given in the in-depth database and it was calculated or estimated using crash reconstruction methods [14-15]. Finally, realistic crash scenarios were reconstructed displaying the interaction between the three different components of the accident: vehicle, pedestrian and crash environment. Hence, all the spatial-temporal dimensions of the accidents were considered in this work.

Active safety system modeling

Six different pedestrian active systems have been considered in this study. This choice was made due to the knowledge of their characteristics and their descriptions are based on existing information in the literature. Each of them is briefly described below and references are given for more details on the APSS.

S1. CWAB-PD® is a pedestrian detection system developed by Volvo Cars and launched in the Volvo S60 MY2011. This third-generation system is composed of a Forward-Looking Camera (FLC) mounted near the rear-view mirror and a Forward-Looking Radar (FLR) mounted in the vehicle grille [6].
S2. The Artificial Vision and Intelligent Systems Laboratory (VisLab), University of Parma has developed a system based on a laser scanner and a near-IR camera for night-time capabilities [4].
S3. The EyeSight® 2.0 system designed by Subaru uses a stereo camera: twin overlapping lenses mounted on the top edge of the windscreen [16].
S4. The system developed by Continental A.G. within the project Proreta 3 also uses a stereo camera or pedestrian detection but the lenses have a wide field of view [9].
S5. The PRE-SAFE® system developed by Daimler uses a near-IR camera located near the rear-view mirror in addition to a stereo camera [17].
S6. Toyota Motors preferred to fit to the new Lexus models a system using a stereo vision based on twin near-IR cameras [18].

The main technical characteristics of these systems in terms of Field of View (FoV) and range are given in Table I.

The scope of this study is to estimate the benefits of the aforementioned systems in enhancing pedestrian safety. To evaluate their effectiveness, each system was applied to the 100 reconstructed accident scenarios through computational simulations. The systems were modeled by their field of view as summarized in Table I and illustrated in Figure 1.

TABLE I
CHARACTERISTICS OF PEDESTRIAN DETECTION SYSTEMS

System		Sensor (Detection)		
		Type	FOV	Range (m)
S1	Volvocars (CWAB-PD®)	Radar (FLR)	15°	200
		Mono camera (FLC)	48°	60
S2	University of Parma	Laser Scanner	100°	100
		NIR camera	25°	30
S3	Subaru (EyeSight®)	Stereo camera	25°	50
S4	Continental (ContiGuard®)	Laser Scanner	22,5°	200
		Stereo camera	44°	60
S5	Daimler Chrysler (PRE-SAFE®)	Stereo camera	45°	50
		NIR/FIR camera	20°	160
		Mid-Range Radar	60°	60
		Short Range Radar	80°	30
S6	Toyota Motors (Lexus)	NIR Stereo camera	30°	25
		Radar	60°	200

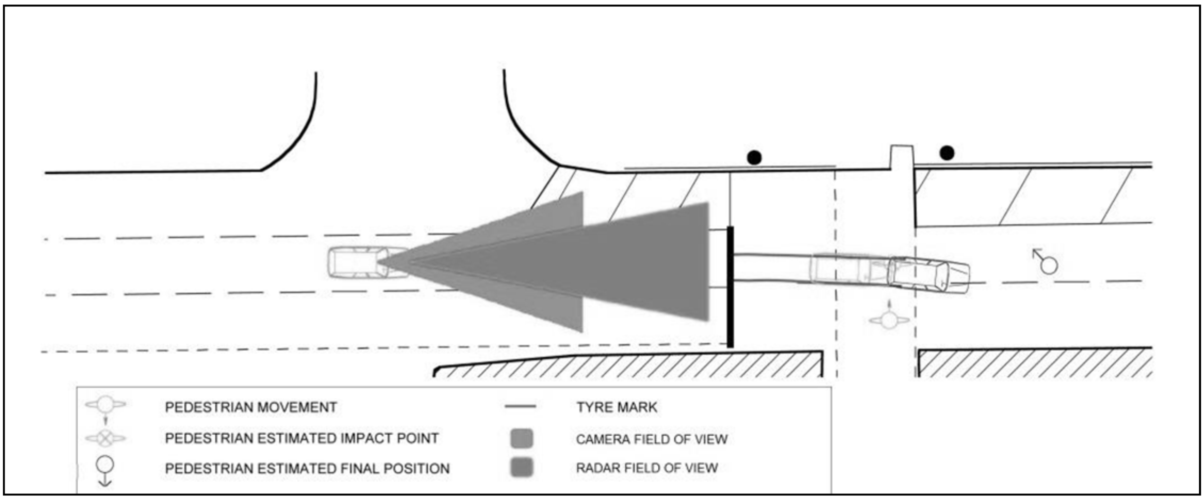

Fig. 1. Scheme illustrating a crash representation including an active system
(e.g. composed by a camera and radar)

Simulation process

In order to evaluate the six selected APSS, their functioning was numerically simulated during the sequence of the reconstructed accidents. Because the simulation tool supplies a comprehensive set of data describing the interaction between the vehicle and the pedestrian over a crash sequence, it is possible to estimate the efficiency of the APSS at different Time-To-Collision (TTC). It involves detection issues followed by the challenge in decision making and reacting. Regarding these issues, a comparison was conducted between the characteristics of the different systems presented previously. Because the scope of this analysis is built on describing the evolution of the pedestrian location relative to the vehicle, four specific events have been considered.

The first is 2.5s before the impact (TTC=2.5s). This moment has been chosen because it appears to be sufficient to simulate the emergency maneuver. Indeed, it was observed during the accident reconstruction that it is not necessary to consider the situation before this time.

The second event is the moment when pedestrians are visible to the sensors; i.e. pedestrians are located entirely within the field of view of the different sensors. The objective here is to determine the maximum detection rate. If the pedestrian is detected by the APSS on all the 100 cases, this ratio reaches 100%.

The third event concerns the position of the vehicle at the last moment to brake to stop before impact. This moment in the crash sequence is called “the Last Time-To-Brake” (LTTB) and is retrieved by determining the corresponding braking distance with the following equation:

$$d_{stop} = \frac{V + V\sqrt{L}}{2} * t_{tr} + \frac{V^2\sqrt{L}^2}{2 * |a|} + d_{offset} \quad , \qquad (1)$$

where V is the vehicle travelling speed (m/s), t_{tr} is the delay to reach a full braking (assumed to be equal to 0.2s), L corresponds to loss of kinetic energy from start to full brake (chosen at 0.8 according to Reed and Keskin [19]), a is the deceleration that fluctuates depending on the road conditions of the reconstructed accidents (m/s²), d_{offset} is the vehicle clearance from pedestrians set at 0.3m.

This model of braking is similar to the model used in the crash reconstruction, yet it takes into account the intervention of the Brake Assist that improves the actuation phase. At this sequence of the crash, an estimation of the avoidance rate of collisions is established for each system. It is calculated by verifying if the pedestrian is visible at time LTTB and by considering that autonomous braking is applied at this time.

Finally, the last specific event is one second before impact (TTC=1s). This time interval is assumed to be appropriate for a system to respond in order to reduce the risk of false interventions [6][9].

III. RESULTS

Accident database

One hundred real pedestrian accident cases were reconstructed in this work and each crash scenario was analyzed taking into account its specific configuration (vehicle and pedestrian speeds, weather conditions, driver reaction, etc.).

For all accidents, the travel speed of the vehicles ranged from 20 to 60 km/h with an average value around 40 km/h (S.D. 20.2 km/h). In 33% of cases, drivers perceived the hazard and braked. This reaction reduced the average impact speed to 32 km/h.

The reaction of drivers ranged from 0.5 to 2.5 seconds before the impact occurred. In general, the drivers reacted to walking pedestrians whose average speed was about 5 km/h. For some cases (N=28), drivers' reaction may have been affected by the road environment. In addition, lighting and weather conditions may also have affected the performance of the active safety systems.

The majority of the cases happened during the day (83%). However, some of these aforementioned cases were classified as awkward conditions for the detection sensors due to heavy rain (4%) and dazzling light (7%). In the simulation of the cases with these constraining factors, pedestrians were assumed to be undetected by imaging sensors, unless a Radar or a Laser scanner was part of the detection system.

Furthermore, it is presumably challenging for a system to detect a pedestrian while the vehicle is turning (18%).

Finally, obstacles located at the crash scenes were taken into account (22%) since this could have led to a late detection of the pedestrian and time and space limitations affecting the reaction of the system. These obstacles were mainly parked vehicles and those stopped due to traffic.

Detection issue: position of the pedestrian 2.5s before the impact

The reconstructed crash scenarios were reproduced over a timeline of 2.5 seconds. At this initial stage of the crashes, a map of the location of the pedestrians relative to the corresponding vehicles is drawn in Figure 2. Not all the cases are represented in this figure since it is zooming on the pedestrians located within 40m ahead of the involved vehicles.

At 2.5s before impact, it can be observed that all pedestrians masked by obstacles were located at a distance greater than 12m ahead of the vehicles. Additionally, night time cases representing 17% of all cases were also located at a distance greater than 12m.

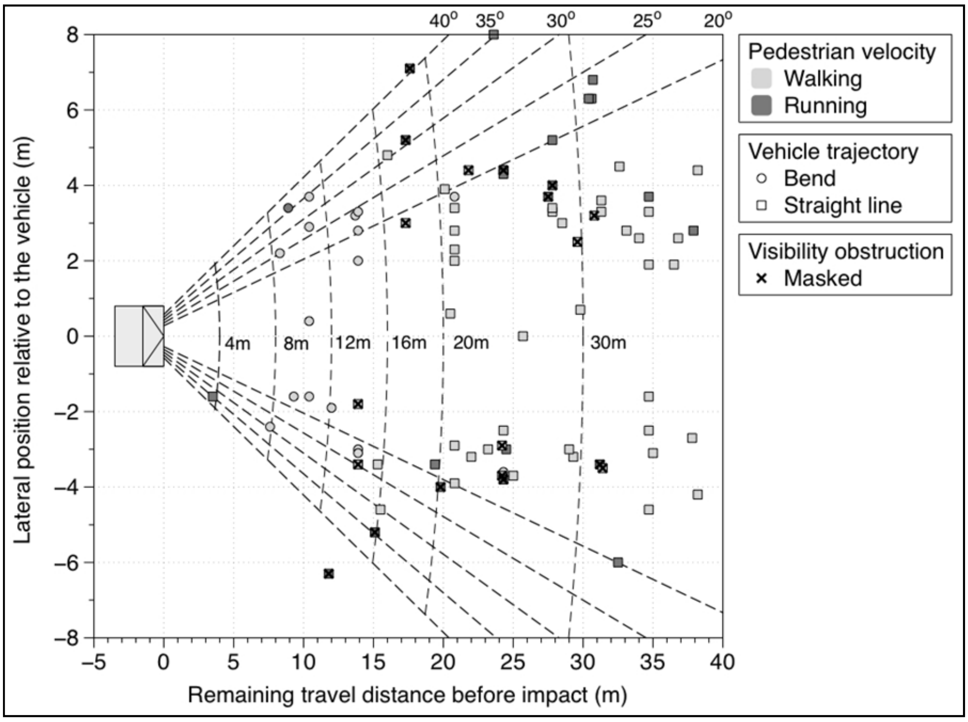

Fig. 2. Pedestrian location at 2.5s before impact

Accordingly, it is possible to evaluate the number of pedestrians located in the field of view of the six different APSS. Table II below gives each detection rate for each system. Globally, it can be observed that 2.5s before the impact, approximately half of the pedestrians were identified by most of the systems.

TABLE II
DETECTION RATE AT 2.5 SEC BEFORE IMPACT

Systems	Sensors (FOV)	Detected pedestrians	Not detected pedestrians Light condition	Obstacle	Out of the FOV	Total
S1	Radar (60°)	69	0	17	14	100
	Camera (48°)	43	26	17	14	100
	Fusion	69	0	17	14	100
S2	LIDAR (100°)	55	0	15	30	100
	NIR cam. (25°)	47	8	15	30	100
	Fusion	55	0	15	30	100
S3	Stereo (25°)	36	20	14	30	100
S4	LIDAR (22,5°)	52	0	16	32	100
	Stereo (44°)	41	24	17	18	100
	Fusion	60	0	17	23	100
S5	Stereo (45°)	41	25	17	17	100
	NIR cam. (20°)	45	7	14	34	100
	SRR (80°)	66	0	17	17	100
	Fusion	66	0	17	17	100
S6	NIR ster. (30°)	50	8	16	26	100
	Radar (60°)	58	0	16	26	100
	Fusion	58	0	16	26	100

Detection issue: Maximum detection rate

According to the scenario of the accidents, the probability that each system could detect the pedestrian before the impact was evaluated. The objective was to determine the maximum detection rate of each system. Table III gives the ratio for each APSS. Due to the accident configurations (obstacles, road curvature, etc.), it can be observed that the pedestrian could not be detected in all the 100 cases. Nevertheless, three systems reached high rates, above 90%.

TABLE III
MAXIMUM DETECTION RATE

Systems	Sensors (FOV)	Detected pedestrians	Not detected pedestrians Light condition	Out of the FOV	Total
S1	Radar (60°)	94	0	6	100
	Camera (48°)	66	28	6	100
	Fusion	94	0	6	100
S2	LIDAR (100°)	84	0	16	100
	NIR c. (25°)	73	11	16	100
	Fusion	84	0	16	100
S3	Stereo (25°)	54	28	18	100
S4	LIDAR (22,5°)	76	0	24	100
	Stereo (44°)	65	28	7	100
	Fusion	90	0	10	100
S5	Stereo (45°)	65	28	7	100
	NIR c. (20°)	72	11	17	100
	SRR (80°)	93	0	7	100
	Fusion	93	0	7	100
S6	NIR st. (30°)	76	11	13	100
	Radar (60°)	87	0	13	100
	Fusion	87	0	13	100

Avoidance issue at LTTB

Based on the 100 accident reconstructions, the average Last-Time-To-Brake was approximately 0.97s (S.D. 0.42s). This value has been calculated considering the last moment to brake to stop before impact. The corresponding longitudinal distance at the LTTB can also provide information about the vehicle speed. In particular, pedestrians located within 2m in front of the vehicle correspond to cases with very low speed (e.g. vehicle just starting at an intersection). According to [20], these impacts at low speed will generate minor injuries.

In order to evaluate if the impact could have been avoided using APSS, the pedestrian location was first displayed at this LTTB time (see Figure 3). The most relevant parameter which has to be taken into account is the lateral position of the pedestrian relative to the vehicle trajectory. This position allows evaluating if the pedestrian will cross the vehicle path and if this action will be detected by the APSS. The lateral position of the pedestrian is measured as the perpendicular distance between the pedestrian and the longitudinal vehicle axis. Considering a lateral offset of approximately 0.8m (which corresponds to half of the vehicle width), it can be observed that 26% of the pedestrians were in front of the car (see Figure 3). If this lateral distance is extended by half a meter, the number of cases rises to 39%. When the lateral distance was greater than 1.8m, nearly all the pedestrians were running.

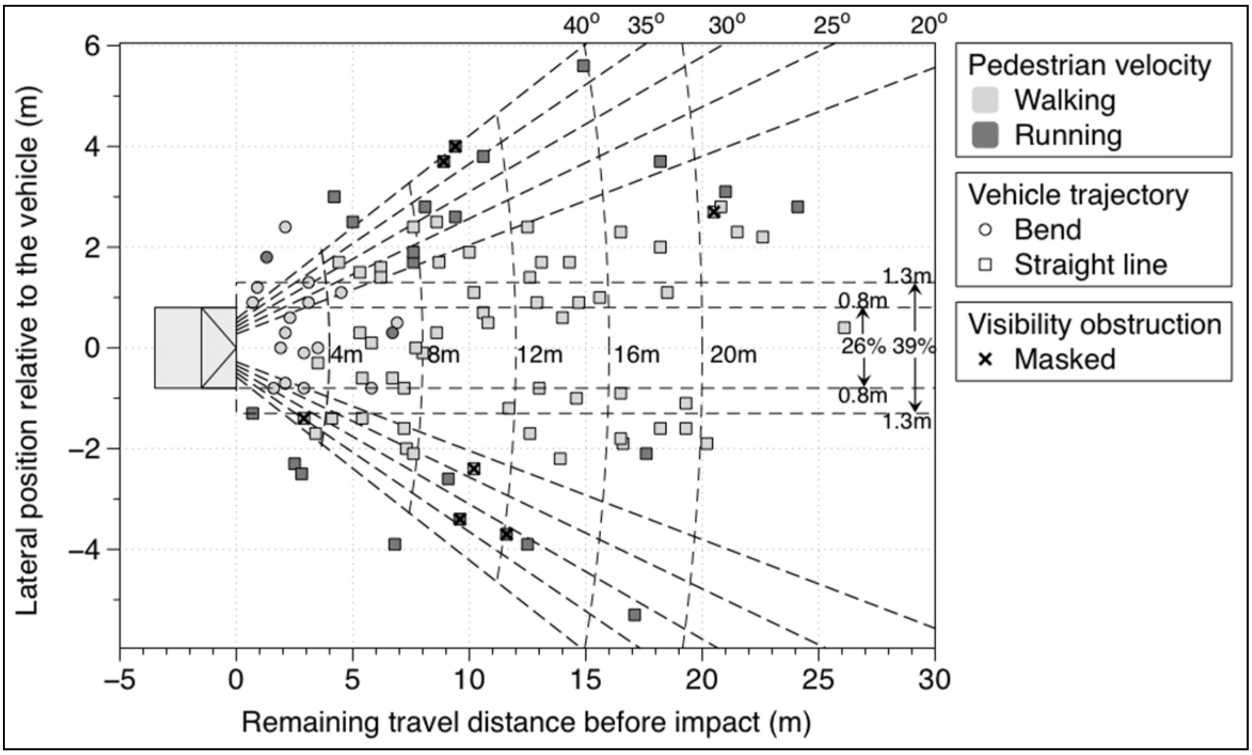

Fig. 3. Pedestrian location at the Last Time-To-Brake

Following this result, it is possible to evaluate how many impacts can be avoided if autonomous braking is activated on a vehicle using one of the six APSS (see Table IV). It can be shown that more than 50% of pedestrian crashes could be avoided, clearly demonstrating the safety potential of APSS.

TABLE IV
DETECTION RATE AT LTTB

Systems	Sensors (FOV)	Detected pedestrians	Not detected pedestrians Light condition	Obstacle	Out of the FOV	Total
S1	Radar (60°)	87	0	1	12	100
	Camera (48°)	54	28	6	12	100
	Fusion	81	0	7	12	100
S2	LIDAR (100°)	61	0	1	38	100
	NIR c. (25°)	50	11	1	38	100
	Fusion	61	0	1	38	100
S3	Stereo (25°)	41	23	1	35	100
S4	LIDAR (22,5°)	49	0	5	13	100
	Stereo (44°)	54	28	1	50	100
	Fusion	72	8	6	14	100
S5	Stereo (45°)	54	28	5	13	100
	NIR c. (20°)	45	8	1	46	100
	SRR (80°)	85	0	1	14	100
	Fusion	80	0	6	14	100
S6	NIR st. (30°)	58	11	2	29	100
	Radar (60°)	69	0	2	29	100
	Fusion	69	0	2	29	100

Avoidance issue at TTC=1s

Relative to the false positive rate issue, the crash set is described at a TTC of 1s. Above this targeted time interval, it should be noted that about a quarter of the drivers did react and triggered the brakes. These driver reactions will not be taken into account here.

Figure 4 shows the position of the pedestrian relative to the vehicle at TTC=1s. In 18% of cases, pedestrians were within the vehicle path. Regarding the pace, walking pedestrians were located laterally up to 2.5m from the vehicle with a mean of 0.6m (SD = 0.69m). The lateral position of running pedestrians relative to the vehicle ranged from 1.6 to 4.5m with a mean of 2.6m (SD = 0.78m).

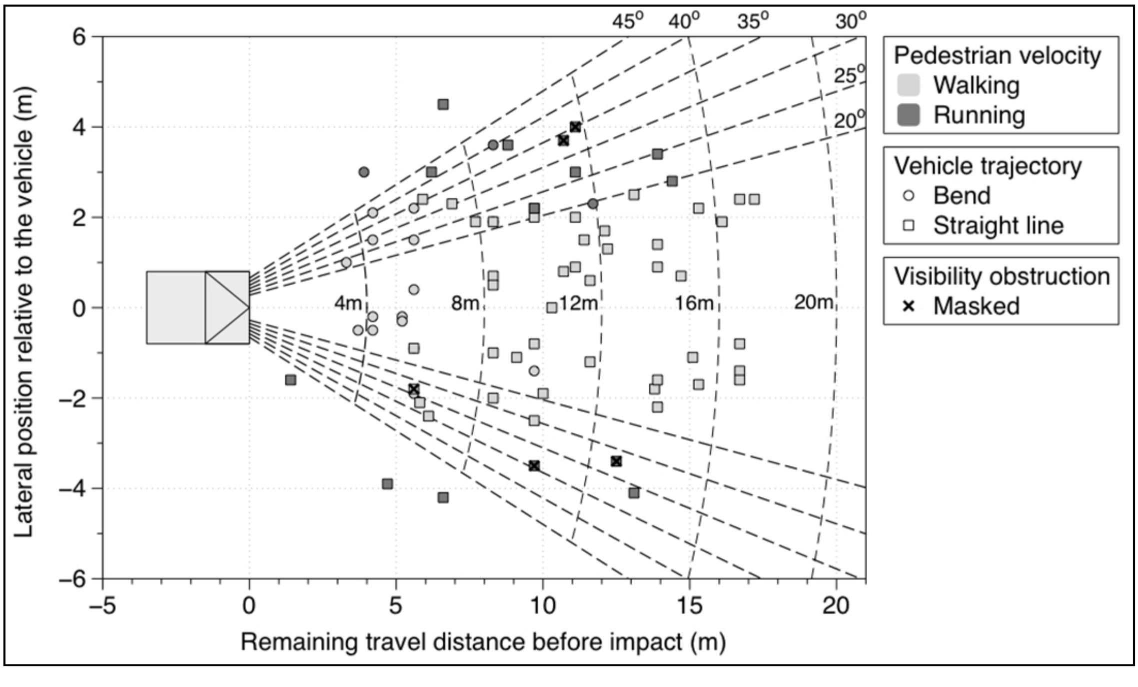

Fig. 4. Pedestrian location at 1s before impact

The corresponding detection rates at TTC=1s for the six APSS are given in Table V.

TABLE V

DETECTION RATE AT 1SEC BEFORE IMPACT

Systems	Sensors (FOV)	Detected pedestrians	Not detected pedestrians Light condition	Obstacle	Out of the FOV	Total
S1	Radar (60°)	82	0	2	16	100
	Camera (48°)	59	23	2	16	100
	Fusion	82	0	2	16	100
S2	LIDAR (100°)	73	0	0	27	100
	NIR c. (25°)	64	9	0	27	100
	Fusion	73	0	0	27	100
S3	Stereo (25°)	48	20	0	27	100
S4	LIDAR (22,5°)	55	0	2	16	100
	Stereo (44°)	59	23	0	45	100
	Fusion	73	9	2	16	100
S5	Stereo (45°)	59	23	2	16	100
	NIR c. (20°)	57	9	0	34	100
	SRR (80°)	82	0	2	16	100
	Fusion	82	0	2	16	100
S6	NIR st. (30°)	66	9	0	25	100
	Radar (60°)	75	0	0	25	100
	Fusion	75	0	0	25	100

In order to evaluate if the remaining distance before the impact was sufficient to stop the vehicle, a relationship between the speed of the vehicle and the remaining distance at 1s before impact was established. Accordingly, at a TTC of 1 second, several crashes could have been avoided if the brakes were fully applied autonomously by the APSS. Table VI below gives the avoided rate for each system.

TABLE VI

AVOIDANCE RATE (FOR TTC=1SEC)

System	Avoidance rate (TTC=1sec)
S1	43
S2	33
S3	15
S4	38
S5	43
S6	35

For autonomous braking systems triggering at 1s before impact (TTC=1s), more than a third of pedestrian crashes could be avoided.

IV. DISCUSSION

Several methods for assessing the potential benefits of active pedestrian safety systems (APSS) have been developed [21-22]. The objective of this study was to present an assessment procedure based on real crash reconstructions and on computational simulation of these safety systems. This method consists of emulating the interaction between the vehicle, the driver, the pedestrian, the road environment and the safety system. Furthermore, it points out constraints that are inherent in these APSS. However, the crash scenario modeling depends on a considerable level of crash data required for the reconstruction. There is inevitably some fuzzy and also missing data to complete the reconstruction of a crash such as the pedestrian velocity.

In the current study, the assessment method is evaluated through a sample of six APSS. These systems are composed of three main parts: sensors for detection, a unit for processing and actuators for triggering an emergency maneuver. Only sensors have been modeled here by their range and field of view. The other parts are ignored since it is very difficult to get the required characteristics to model them numerically. In addition, many systems are using multiple sensors to improve detection. Data flows from the on-board sensors are merged during the vision processing. Sensors considered as “time-of-flight sensors” are designed to determine the distance between the vehicle and any obstacle. Imaging sensors are mainly used for detecting and tracking pedestrians [7]; hence, it is appropriate to model the detection system with only the camera placed behind the rear-view mirror of the vehicle. This model is even acceptable for stereo cameras since these cameras analyze the forward scene by overlapping the view of both lenses.

The modeling of the detection system and its implementation in the numerical simulation of the crash scenario allow highlighting the issues in pedestrian detection. Obviously, it appears that a sensor with a wide FOV improves the detection rate. However, it has to be noted that our results do not take into account the false detection ratio of the APSS. In fact, our modeling considers that the APSS recognize the pedestrian all the time in the detection process. It is important to keep in mind that in some cases the APSS could not detect the pedestrian as a hazard in the far side location of the pedestrian relative to the vehicle. Moreover, it has to be considered that the decision making of the APSS to trigger an emergency maneuver will never reach the human performance as demonstrated by [23].

Concerning the efficiency of the deployment of an emergency maneuver, our results show that about 40% of accident cases could be avoided if the brake is assumed to trigger at 1 second before the impact. The remaining cases may not be avoidable mainly due to a late appearance of the pedestrians. Indeed, in these cases the pedestrians are mostly struck directly at the front fender of the vehicles. The time-to-collision, therefore, is too short to perform an emergency maneuver, in particular an emergency braking. However, steering maneuvers (which have not been considered in this study) could be beneficial for these cases. Several researchers are developing algorithms to address this topic [5][24].

V. CONCLUSIONS

The purpose of this paper was to highlight issues and challenges in pedestrian active safety through reconstructions of real accident cases involving a vehicle and a pedestrian. This analysis shows the functional requirements for Active Pedestrian Safety Systems concerning the crash avoidance issues. From a general point of view, it appears important to take into account the weather condition, road curvature, obstacles that mask the pedestrian from sight of the detection systems, the travel and impact speed of the vehicle, the pedestrian velocity, etc. According to all these parameters, it has been shown that most of the APSS considered in this study could avoid about 40% of pedestrian accidents. Even if this percentage can be considered as low, it highlights the great interest to implement APSS in vehicles for safety reasons.

This study allowed setting up a general methodology and an accident database which can be used to evaluate current or future APSS. The assessment process is to confront the APSS with real crash configurations and could be evaluated by integrating new cases.

Future research will consider the effects of speed reduction due to the deployment of autonomous emergency braking on the consequences of the impact such as the severity of injuries.

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VII. APPENDIX

The 100 accident cases selected for this research are described below. The first 40 cases are from the database of IFSTTAR-LMA and the remaining from CASR. They are described according to the different components of a crash: the road environment, driver, vehicle and the pedestrian. The description includes the time when the crash occurred (D:Daytime or N:Nighttime), the light condition (BC: bad condition as heavy rain or dazzling), road condition (Wet: wet road), road curvature (LT: Left Turn or RT: Right Turn), obstacles that mask the pedestrian from sight view of the detection systems, the reaction of the driver (B: Brake; S: Steer; B+S: Brake and steer), the travel and impact speed of the vehicle, the pedestrian velocity corresponding to his age and pace (W: Walking; W f.: Walking fast; R: running) and the impact configuration (F: Front or S: Side impact).

TABLE A.I

SUMMARY OF THE 100 ACCIDENT CASES

Case	Environment					Driver	Vehicle		Pedestrian			Impact config.
	Day/Night	Light Cond.	Road Cond.	Road curve	Obstacles masking	React.	Travel Speed (km/h)	Impact Speed (km/h)	Age	Pace	Speed (m/s)	
1	D					B + S	45,5	32	52	R	2,83	F
2	N+L*		Wet				50	50	40	W	1,62	F
3	D					B	42,4	10	12	R	1,68	F
4	D					B	117,6	86	66	R	2,47	F
5	N+L					B	75,2	45	79	W	1,07	F
6	D			LT			0	22	17	W	1,65	F
7	N					S	130	130	33	W	1,62	F
8	D			LT			11,1	20	79	W	1,07	S
9	D						53	53	74	W	1,28	F
10	D						55	55	86	W	1,07	F
11	D						50	50	79	W	1,28	F
12	D				Vehicle		35	35	62	W	1,46	F
13	D						30	30	65	W	1,28	S
14	D			LT			2,1	15	76	W	1,28	F
15	D	BC			Tree	B	44,7	40	85	W	1,28	F
16	D				Vehicle	B	39,9	5	27	W	1,62	F
17	N+L					B	33,9	27	69	W	1,28	F
18	N+L						40	40	40	W	1,62	F
19	D	BC	Wet	LT		B	22	8	51	W	1,52	F
20	D			LT			20	20	64	W	1,46	F
21	D+L**				Vehicle	B	43,3	10	21	W	1,62	S
22	D				Vehicle		40	10	15	R	4,2	S
23	D+L	BC	Wet				35	35	17	W	1,65	F
24	D	BC					50	50	69	W	1,28	F
25	D						30	30	77	W	1,28	S
26	D			LT			35	35	60	W	1,46	F
27	N+L					B	38,3	3	82	W	0,5	F
28	D						30	30	70	W	1,28	F
29	D						30	30	73	W	1,28	F
30	D				Vehicle		20	20	60	Stat	0	S
31	D				Bus	B	39,7	17	6	R	3,94	F
32	D			RT			20	20	14	W	1,68	F
33	D				Vehicle	B	34,7	5	5	R	3,94	F
34	N+L					B	55	15	11	R	4,2	F
35	D					B	36,3	11	37	W	1,34	F
36	D						22	22	19	W	1,65	F
37	D	BC					36	36	68	W	1,28	F
38	D						5	5	24	W f.	2,8	S
39	D	BC	Wet	RT	Billboard		30	30	10	R	4,2	F
40	D	BC					30	30	82	W	1,07	F
41	D						35	35	21	W	1,62	S
42	D				Vehicle		45	45	13	R	4,2	F
43	D						55	55	75	W	1,46	S
44	D						40	40	29	R	4,2	F
45	D	BC		RT			20	20	75	W	1,28	F
46	D					B + S	53,4	30	75	W	1,28	F
47	D		Wet			B + S	56,4	44	47	R	2,9	F
48	D				Bus		40	40	13	R	4,2	S
49	N+L						60	60	24	W	1,4	F
50	D		Wet		Vehicle		20	20	18	W	1,65	F

Case	Environment					Driver	Vehicle		Pedestrian			
	Day/Night	Light Cond.	Road Cond.	Road curve	Obstacles masking	React.	Travel Speed (km/h)	Impact Speed (km/h)	Age	Pace	Speed (m/s)	Impact config.
51	D						50	50	47	R	2,9	F
52	D				Bin		35	35	3	R	2,41	F
53	D					B	55,7	30	50	W	1,52	F
54	D		Wet		Vehicle		35	35	14	R	4,2	F
55	D				Vehicle	B	65,5	40	38	W	1,62	F
56	D						47	47	16	W	1,65	S
57	D					B	58,9	14	57	Stat	0	F
58	D			RT			0	43,1	71	W	1,28	F
59	D					B	42,7	29	45	W	1,52	F
60	N+L					S	60	60	17	W	1,65	F
61	D				Bus	B	43,1	36	14	W	1,68	F
62	D				Vehicle	S	25	25	19	W	1,65	F
63	D						60	60	16	W	1,65	S
64	D					B	56,1	22	6	R	3,94	F
65	D				Vehicle		17	17	11	R	4,2	F
66	D						58	58	89	W	1,28	F
67	D						30	30	67	W	1,28	F
68	N+L						43	30	35	R	3,35	S
69	N+L						37	37	35	Stat	0	F
70	N+L						47	47	28	R	3,54	F
71	D					B + S	46,2	36	65	W	1,28	F
72	N+L		Wet				50	50	67	W	1,28	F
73	D					B	50,9	31	18	W	1,46	F
74	D			RT			15	15	65	W	1,28	F
75	N+L		Wet	RT			15	15	24	W	1,62	F
76	N+L				Pole		62	62	44	W	1,62	F
77	D					B + S	48,2	21	76	W	1,28	F
78	D					B	62,6	27	80	W	1,28	F
79	D						60	50	30	W	1,62	F
80	D						35	35	67	R	2,71	F
81	D		Wet			B + S	49,5	5	7	R	3,94	F
82	D	BC	Wet				41,8	41,8	82	W	1,28	F
83	D						55	55	13	W	1,68	F
84	N+L			RT			20	20	53	W	1,52	F
85	D				Vehicle		14,4	25	19	R	4,2	F
86	D	BC		RT			30	30	78	W	1,28	F
87	D				Vehicle	B	27,3	12	20	R	3,54	F
88	D						40	40	23	W	1,62	F
89	D		Wet			B + S	49,1	30	48	R	2,9	F
90	D			LT			15	15	50	W	1,52	S
91	D	BC		LT			15	15	33	W	1,62	F
92	N+L						50	50	39	W	1,62	F
93	D		Wet			S	29,6	20	19	W	1,65	S
94	D						30	20	17	W	1,65	F
95	D				Vehicle	B + S	55,1	20	58	W	1,46	F
96	D					B	35,1	10	30	W	1,62	F
97	D		Wet	RT			20	20	41	W	1,62	F
98	D					B	94,3	49	84	W	1,28	F
99	D					B + S	47,7	30	73	W	1,28	F
100	D			LT			7,9	15	9	R	3,94	S

* Night time with street lights

** Dawn