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Assessing the benefit of the brake assist system for pedestrian injury mitigation through real-world accident investigations

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ABSTRACT

The compulsory fitting of the brake assist system (BAS) for new vehicles in the European Union has been recently established by Regulation (EC) 78/2009 to enhance the protection of pedestrians. This paper describes the main findings of a coordinated study performed by four Spanish Safety Research Centres aimed at assessing the potential influence of the BAS in vehicle–pedestrian collisions through the reconstruction of real-world accidents that occurred in three different cities of Spain. A total of 139 vehicle–pedestrian collisions were investigated in-depth following a common methodology, including on-the-spot data collection, analysis and reconstruction to estimate the collision speed and the pedestrian kinematics. A specific procedure was defined to emulate, through computer simulations, the performance of the BAS acting together with the antilock braking system (ABS). The benefit was assessed in terms of both collision speed and Injury Severity Probability (ISP) by comparing the reduction of their values from the real conditions to the virtual BAS + ABS simulations. The pedestrian ISP was estimated, depending on the collision speed and the head impact point, using a specific application that calculated its value based on the results of headform impact laboratory tests. The ISP values obtained in both conditions were compared. The findings show that while implementing the BAS + ABS would not have prevented the collision in most of the cases, it would have reduced their consequences in terms of the estimated ISP. It was also found that in few cases, a small reduction in the collision speed would increase the head injury severity.

1. Introduction

Pedestrians are the most vulnerable road users, and when involved in traffic accidents, they often suffer severe or fatal injuries. In 2008, a total of 502 pedestrians were killed on Spanish roads; this represents 16.2% of the fatalities in traffic accidents in Spain that year. This high vulnerability has elicited a response from manufacturers and Public Administrations, which have adopted different measures, including driver and pedestrian education, urban planning, vehicles design and equipment to protect these road users.

The technological advances in vehicles, which have been adopted to enhance road users' protection, have been primarily focused on secondary safety (vehicle design and materials, external airbags, pop-up bonnets, and so on); however, there are a number of recent developments aimed at avoiding collisions. Towards this goal, the European Parliament and the Council have enacted Regulation (EC) 78/2009 (European Commission, 2009): "on the type-approval of motor vehicles with regard to the protection of pedestrians and other vulnerable road users…" These regulations bind manufacturers to equip new vehicles sold in the European market with a type-approved brake assist system (BAS). According to the text of the regulation, a brake assist system is a function of the braking system that deduces an emergency braking event from a characteristic of the driver's brake demand and, under such conditions, assists the driver in delivering the maximum achievable braking rate; or braking that is sufficient to cause full cycling of the Anti-lock Braking System (ABS).

The brake assist system was originally introduced to compensate for the insufficient braking rates due to unexpected driver reactions in rear-end collisions. It was found that, despite the ABS, the braking distance in critical situations was not significantly reduced. The reason was that drivers were not pushing the brake pedal strong and quick enough to achieve its full stroke.

The advantages of the BAS as an active safety system were soon seen as a way to avoid collisions and reduce the impact speed when collisions were inevitable. Thus, the European Commission

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decided to mandate the fitting of new vehicles with the BAS; this represents one of the first active safety requirements for type-approval of motor vehicles with regard to pedestrian protection.

The benefit of the BAS for pedestrians involved in frontal accidents was evaluated in this study, which describes an in-depth accident investigation performed by four Spanish Safety Research Centres following a common methodology. Data were collected from 139 frontal vehicle–pedestrian collisions that occurred in the cities of Madrid, Zaragoza and Barcelona between 2002 and 2006. Every case was virtually simulated twice using the PC-Crash® software: the first was a reconstruction of the real accident and the second was a simulation in which the operation of the BAS was emulated by modifying the collision parameters and the potential consequences on the kinematics.

To harmonise the process for all the Research Centres, a common simulation procedure with simplified hypotheses about the driver's reactions and the BAS operation was previously adopted. Collision speeds and pedestrian kinematics were obtained from the reconstructions, which allowed for the estimation of the Injury Severity Probability (ISP) as the parameter considered for assessing the benefit of the BAS in terms of injury mitigation.

Previous studies to assess the benefit of BAS for pedestrians using different methods (Oh et al., 2009; Breuer et al., 2007; Page et al. 2005) have shown that the system can contribute to both injury mitigation and avoidance and that the potential benefit can be further enhanced if coupled with advanced primary safety systems for detection and auto-braking.

2. Methodology

The methods presented in this section were developed within the framework of a research project (INSIA, 2008) with a common procedure to be simultaneously adopted by the four Safety Research Centres. The methodology was established to harmonise the different techniques that each team may have been using, unifying them into one optimal procedure to investigate every accident on the spot, to perform reconstructions and simulations, and to analyse the data and the results obtained under the same criteria.

2.1. Accident investigation and reconstruction

To investigate and reconstruct the accidents that occurred in Madrid, Barcelona and Zaragoza, three multidisciplinary teams were created with the support of local police forces, emergency services and hospitals.

On-the-spot accident investigation and data collection was the first step of the process, in which the reaction time was critical. The investigation teams, in collaboration with the police forces, visited the scene to collect all the available information about the scenario, geometry of the roads, visibility, visual evidence such as skid marks and traces, as well as vehicle damages, dents and marks. The aim, when possible, was to save volatile evidence such as the vehicle and pedestrian rest positions.

The information about the pedestrians was then collected from all the available sources paying special attention to the anthropometric parameters. Information about the injuries was obtained from paramedics and hospital data and was used in the analysis phase for determining the injury mechanisms.

The sampling was based on three main criteria: first, according to the road characteristics, the selected accidents occurred in urban areas; the second criterion was about the vehicle type, and accidents in which the striking vehicle was a passenger car, an SUV or a minivan were only considered; the third was related to the accident configuration, and only frontal collisions were considered. No restrictions about pedestrian characteristics such as gender, age, height or weight were imposed.

There was no evidence of drunk driving or any other legal impairment among the drivers included in the sample. This was consistent with the national data, which show that less than 2% of the drivers involved in pedestrian accidents were driving under the influence of alcohol at the time of the accident. The accident circumstances were more related to unawareness, visibility and distraction of both the driver and the pedestrian.

Once the investigation and data compilation phases were completed, the available information was analysed, revised and prepared to be used in the reconstruction.

Fully detailed scene plans were drawn to be used in the reconstruction process. The plans condensed as much information as possible, covering all events that took place before, during and after the collision; the scene plans illustrated positions, distances, marks and the most plausible paths for both the pedestrian and the vehicle. The scaled plans were then used as backgrounds for the computer simulations.

Next, the corresponding vehicles were selected in each case and loaded from the vehicle database available in the computer program; the vehicle's characteristics were set up according to the actual vehicle. The frontal shape was thoroughly refined for the simulation because it had a substantial influence on the pedestrian kinematics, impact points and throwing distances. The frontal shapes of real vehicles were accurately measured for this purpose.

Based on anthropometric studies (Benjumea, 2001; INC, 2008), 50th percentile multi-body pedestrian models were defined, and the models represented an up-to-date Spanish population both for males and females as well as for a wide range of ages. The multi-body models were scaled in each case to the real height and weight of the pedestrian, but in some cases, when the real measures were not available, they were estimated as a function of the pedestrian's age using the 50th percentile.

The influence of friction conditions was also defined individually for the specific characteristics of each case. Friction between both pedestrian and vehicle and pedestrian and road were considered to be linear, but the coefficients of friction were defined separately depending on the clothing material, humidity, weather conditions, pavement and other evidence such as dust and contact marks.

The effect of tyre grip was included and four generic friction models were created to reproduce the dynamic behaviour of a braking vehicle in the most common scenarios found in the accidents investigated within this study. The models were set up using a specific application: TM-easy (Rill, 2006). The parameters were selected depending on the weather conditions, the wear of both the pavement and the tires, and the presence of dust, mud or other components that might modify the grip.

Finally, virtual simulations of the accidents were performed using the reconstruction software. As it has been recently shown (Untaroiu et al., 2010) the initial conditions have a strong influence on the reconstruction kinematics. Many parameters such as approach speed, path, position, pedestrian motion, driver manoeuvres, and sequences were slightly modified and tested in different combinations in an iterative process that led to reliable reconstructions that matched both the impact points and injury locations with the visual evidence, such as dents or marks, and the vehicle and pedestrian rest positions.

To harmonise the process among the three multidisciplinary teams, some simplifying hypotheses were established so that all of the simulations were performed from a common approach. These basic simplifications were: (1) the reaction time of the driver was considered to be one second for all cases; (2) the lag for a conventional brake system was 0.25 s; (3) the Possible Perception Point (PPP) of the driver was the instant in which the pedestrian