WHY IS NECESSARY TO REDUCE THE SPEED IN URBAN AREAS TO 30 KM/H?

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ABSTRACT

In Spain, on November 2020, a new law imposed that the generic speed limit on single carriageway two-lane roads is reduced from 50 km/h to 30 km/h.

The changes in the general rules of traffic, proposed by the Spanish government, are a sample of the evolution, in the use of the shared space of the streets, and at the same time shows its sensitivity towards road safety. Traditionally, the objective of the regulation was to attend to the growing increase in the use of motor vehicles (mainly cars), and for this reason, it was the protagonist in most of the articles of the General Traffic Regulations. Today, in many cities, the car is no longer the protagonist and shares the space on the streets, not only with other motor vehicles as buses or motorcycles, but also with pedestrians, bicycles, electric pedal-assisted cycles (EPAC), personal mobility vehicle (PMV), …

Pedestrian mobility is becoming more and more important every day but the number of pedestrians that died inside Spanish urban areas in road accidents is almost 50% of total urban areas road fatalities. In this sense, the mobility and road safety policies developed by local administrations have to focus on the objective of the reduction of accidents and their severity involving pedestrians and other vulnerable users in urban areas.

This article collects studies and experiences in other countries that show the effects of reducing the speed of motor vehicles in urban areas in order to reduce accidents and/or their severity if they occur. It also analyzes other options that reinforce this measure and that could help reduce this problem.

1. INTRODUCTION

Several articles of the General Traffic Regulations were modified in Spain, on November 11, 2020. The changes that affect article 50, which deals with speed limits on urban roads, stand out (BOE, 2020). The generic speed limits on urban roads/streets now are established as follows:

- 20 Km/h on roads with a single-carriageway one-lane road. 30 Km/h on single-carriageway two-lane roads.
- 50 Km/h on carriageways with two or more lanes per direction.

In this paper, we will focus on the new speed limit for urban streets with a unique carriageway and two-lanes, one per direction. Before this change in the regulation, the usual maximum speed of these streets was 50 Km/h.

Speed has been identified as a key risk factor in road traffic injuries, influencing both, the risk of a road crash as well as the severity of the injuries that result from crashes. Therefore, a reduction in the speed would improve road safety (Gonzalo-Orden et al, 2016, 2018).

Over the world, road safety is one of the major problems (Llopis-Castelló and Findley, 2019). In 2013, there were 1.25 million fatalities in collisions. Fatalities among pedestrians, cyclists, and motorcyclists are painfully high and represent more than 48% of the total. If we focus on pedestrians, the average value over the world is 22%, 26% in Europe and as higher as 39% in Africa (WHO, 2015).

In the European Union, during 2019, almost 23,000 people died in crashes, which is 21 hundred less than in 2018, and 135,000 were seriously injured. The yearly cost of road crashes in the EU has been estimated to be around EUR 280 billion, equivalent to about 2% of Gross domestic product (GDP) (EC, 2020a; EC, 2020b).

The road fatalities in Spain have been decreasing in the last decades. The peak number of fatalities reached a maximum of 9,344 in 1989. This situation changed reaching the lowest annual total in 2013 with 1,680 people died in road accidents. The last official data, related to 2019, indicates that there were 1,755 fatalities, 8,613 people seriously injured and 130,745 injured. On interurban roads, 1,236 people died, 4,303 people were seriously injured and 51,407 were injured. On urban roads, 519 people died, 4,310 people were seriously injured and 79,338 were injured. (DGT, 2020).

If we look back 10 years, in 2009, 2130 people died outside urban roads and 584 inside urban areas. As the reduction outside urban areas shows a great improvement (42%), inside urban areas the improvements are smaller (11%) (DGT, 2020).

If we focus on pedestrians in urban roads, 247 pedestrians died during 2019 and 269 during 2009. For these vulnerable users, the reduction was only 8%.

	Non-Urban. Total fatalities	Non-Urban. Pedestrian fatalities	Urban. Total fatalities	Urban. Pedestrian fatalities
2019	1236	134	519	247
2009	2130	201	584	269
% reduction	42%	33%	11%	8%

Table 1: Urban/non-urban total/pedestrian traffic road deaths in Spain 2009-2019.

The reduction achieved outside urban areas has been much higher than the small decrease that has been accomplished within them.

In urban areas, apart from the 247 pedestrians who died, we find other users who, in the event of an accident with a motor vehicle with 4 or more wheels, have a high probability of suffering serious injuries or death. We can highlight that, in 2019, in Spain in urban areas, 32 cyclists, 22 moped users, and 126 motorcyclists also died in traffic accidents.

In the following sections of the article, we will see the effects of speed on urban road safety.

2. THE REDUCTION OF SPEED AND ITS EFFECT ON VISIBILITY AND IN THE STOPPING DISTANCE

One of the most important aspects to reduce the probability of an accident when the trajectory of two street users intersect is to increase the visibility distance at which they begin to see each other. For example, if the driver of a car sees a pedestrian approaching a crosswalk from further away than another driver, he/she will have more time to react and adapt his/her speed or even stop than the driver who sees the pedestrian later.

In this section, we will see how to calculate the Stopping Sight Distance (SSD) and how it varies depending on the traveling speed of the car at the moment the driver decides to stop. The SSD is necessary to provide the drivers the ability to see far enough in front of them to be able to stop before hitting a hazard that is in their path in the roadway. Also, we will need to define the Sight Distance (SD) as the distance a driver can see ahead at any specific time. To avoid an accident, the Stopping Sight Distance must always be less than the Sight Distance.

As indicated in the Spanish Standard of I.C. 3.1. related to the Design of Roads (BOE, 2016) the Stopping Sight Distances is composed of two distances:

- dpr: Distance traveled during perception and reaction time.
- db: Distance required to physically stop the vehicle.

$$SSD = (V \cdot t_{pr})/3.6 + V^2/(254 \cdot (f_l + i)) \quad (1)$$

where:

- SSD = Stopping Sight Distance (m)
- V = Initial traveling speed of the car at the moment the driver decides to stop (km/h)
- tpr = Brake perception and reaction time (s)
- fl = Longitudinal friction coefficient mobilized wheel-pavement
- i = Longitudinal grade (m/m)

The perception and reaction time assumed in the Spanish standard (2.0 s) is lower than the one assumed in the USA, where the value is 2.5 s (AASHTO, 2018). The braking action is based on the driver's ability to decelerate the vehicle while staying within the travel lane and maintaining steering control during the braking maneuver. For the values of t_{pr} of 2.0 s and 2.5 s and i=0 %, the d_{pr}, d_b, and SSD are calculated and presented in table 2.

V (km/h)	t_{pr} (s)	f_l	d_{pr} (m)	d_b (m)	SSD (m)
50	2,0 - 2,5	0,411	27,78 -34,72	23,95	51,73 - 58,67
40		0,432	22,22-27,78	14,58	36,80 - 42,36
30		0,453	16,67-20,83	7,82	24,49 -28,66

Table 2: Stopping Sight Distance, dpr, and db in a road with i=0.

The values used for the longitudinal friction coefficients (f_l) provide comfortable vehicle decelerations for the user who must stop, in a controlled manner, the vehicle before reaching an obstacle that is in his path in the roadway.

These calculated SSD distances make us see the first problem. In our cities, we find numerous examples where the design of the pedestrian crossings is not adequate. The design does not allow enough sight distance between the pedestrian and the driver of the motorized vehicle.

Figure 1: Example of crosswalk before and after improvement.

The left and center photos in Figure 1 show how the garbage containers do not allow drivers to see, with enough time (or distance), the pedestrians who want to cross.

As a partial improvement, in the right photo, the sidewalk has been widened, narrowing the lane of the street, and improving mutual visibility between the pedestrian and the driver. Other more effective solutions are removing parking spaces (Figure 2 right) or switching parking spaces for bicycle and motorcycle parking. The same problem is reproduced when we have close to the crosswalk provisional works areas (Figure 3 center), rail barriers (Figure 3 left), urban furniture, a bus stop (Figure 3 right), vegetation, etc. In other cases, we find that the difficulties in the design of the crosswalk are related to problems of sun glare or dark-lighted conditions.

In all these cases, we have limitations on the mutual visibility of the driver and the pedestrian.

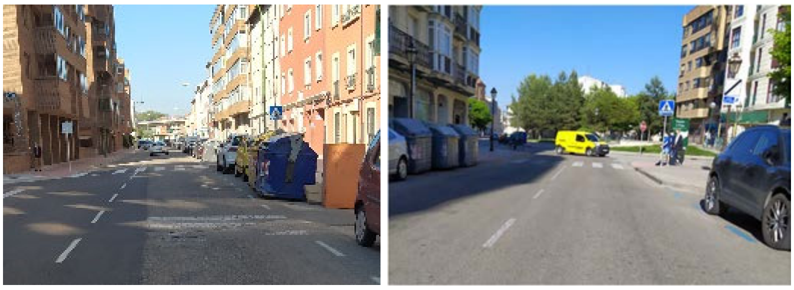

Figure 2: Examples of crosswalks with limited visibility by car parking (left) and improved by sidewalk widening (right).

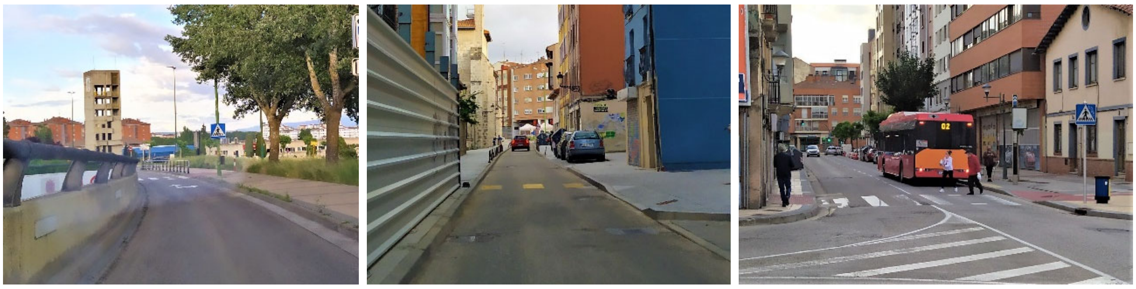

Figure 3: Other examples of crosswalks with limited visibility.

Figure 4: Blinker pedestrian sign with a real-time warning when pedestrians are in or about to enter an approaching crosswalk.

Finally, we can also find traffic signs with presence sensors that turn on a warning light when pedestrians are in or about to enter an approaching crosswalk. (Figure 4) or traffic light that activates the change to red of the traffic light for the driver.

In a few years, it will be normal to find that this information will be sent not only to the traffic lights or signs but also to the approaching vehicles.

We see that a first problem appears in many of the pedestrian crosswalks where the Sight Distance (SD) is less than the Stopping Sight Distance (SSD). In case of need, the driver can perform emergency braking, reducing d_b by more than 34% (DfT, 2007). Even so, of the 61,177 accidents where pedestrians were involved, recorded in Spain during the years 2016, 2017, 2018, and 2019, in more than 42% of the collisions, the pedestrian was crossing properly (Febres et al, 2021).

In addition to increasing the Sight Distance (SD) by changing the street design and reducing the braking distance (d_b) we can try to reduce the distance traveled during the perception and reaction time (d_{pr}). Although this objective has traditionally depended on the driver (attention, reaction time, age, fatigue ...), in the coming years it will also depend on the vehicle. Little by little, the vehicles are incorporating automatic emergency braking systems that will allow us to reduce those almost 17 m traveled at 30 km / h due to d_{pr} or the almost 28 m, traveled while we perceive and react, when we are driving at 50 km/h.

Although new vehicles with advanced emergency braking systems (AEBS) are arriving, the public space should be reorganized. The sidewalk should always be extended over the parking lane and narrowing the roadway. Furthermore, in streets where the maximum speed is 30 km/h, at the pedestrian crossings, at least the two previous parallel parking spaces (10 meters) should be replaced by an obstacle-free zone that facilitates the vision between pedestrians and drivers (or the intelligent vision systems that vehicles have incorporated). If the maximum speed is 50 km / h, it would be necessary to think about clearing a larger area and/or installing a traffic light.

Therefore, we have seen in this section that we should try to increase the SD and reduce the SSD. To increase the SD, we must consider a new design of the crossing areas, eliminating obstacles that reduce visibility or, with the incorporation of sensors in those areas, detect sooner the people approaching these crossings. In order to decrease the SSD we have seen that an instant measure is to reduce the circulation speed. Additionally, as a slower implementation action, it is necessary to accelerate the incorporation of AEBS in all the new vehicles that are sold.

3. THE REDUCTION OF SPEED FROM 50 KM/H TO 30 KM/H AND ITS EFFECT ON THE SEVERITY OF THE ACCIDENTS

Speed has been identified as a key factor in traffic fatalities crashes influencing both the probability of an accident and its severity (Aarts and van Schagen, 2006; Anderson et al, 1997; Davis, 2001; Elvik, 2004; Elvik 2009; Hussain, 2019; Kong and Yang, 2010; Kroyer et al, 2014; Kroyer, 2015; Rosen and Sander 2009; Rosen et al 2010; Telf, 2013).

Analyzing different studies, we realize the difficulty of directly relating the speed of a vehicle with the probability that a pedestrian will die if hit by that vehicle. In Spain, within the dissemination campaign of the General Directorate of Traffic (DGT) about its star measure of reducing the speed from 50 km/h to 30 km/h, it indicates that in the event of being run over at 30 km/h the probability of dying is 15% and 85% when the speed rises to 50 km/h (DGT, 2021). Older studies such as Bonanomi (1990) offer similar values as indicated in the following table.

Speed of collision (km/h)	60	40	20
Probability of death (%)	85	30	10

Table 3: Relationship between the speed of the vehicle and the probability of death of the pedestrian involved in an accident (Bonanomi, 1990).

The probability of survival and the severity of the injuries not only depend on the speed of the vehicle. Other recurrent factors, that we found in the different studies, are the age of the pedestrian, the response time of emergency assistance, or the type of the vehicle (Ballesteros et al 2004; Desapriya et al 2010; Henary et al, 2006; Hussain, 2019; Kröyer, 2015; Lefler and Gabler 2004; Rosén, 2009; Sze, and Wong, 2007). For example, for pedestrian older than 15 years, Rosén (2009), proposed the following pedestrian fatality risk function (P) (Eq. 2) where P is the probability of death of the pedestrian of age “A” in years that is hit by a motorized vehicle that circulated at a speed of “V” Km/h.

$$P(V, A) = 1/(1 - \exp(\,9.1 - 0.095 \cdot V - 0.040 \cdot A)) \qquad (2)$$

In addition to the age of the pedestrian, within the urban environment, other variables have also been analyzed, such as height, weight, sex, or Body mass index (BMI) (Telf, 2013). Basem (et al, 2006) highlighted that the irrespective of impact speed, vehicle body type, and pedestrian weight, height, and gender, senior pedestrian victims are at higher risk of morbidity and mortality than adult victims. Tefft (2013) showed that the average risk of death for a 30-year-old pedestrian struck at a given speed is similar to the risk of death for a 70-year-old pedestrian hit by the same car at a speed 19 km/h slower.

If we focus on the effects of speed reduction on pedestrian fatality risk we see that they are treated in many studies (De Pauw et al., 2014; De Pelsmacker and Janssens, 2007; Elvik, 2009; Fridman, 2020; Heydari et al. al., 2014; Hussain et al, 2019; Rosén, 2009). A reduction in speed limits can help reduce the kinetic energy of the vehicle and therefore, the damage to the pedestrian. Rosen (2009) indicated that the fatality risk at 50 km/h is more than twice higher than the risk at 40 km/h and more than five times higher than the risk at 30 km/h. Analogous values were found by Hussain et al (2019).

Hussain et al (2019), Rosén et al (2009), and Rosén (2011) highlighted that a faster and better emergency assistant and a medical care system will help to reduce the fatality risk.

Finally, it is necessary to indicate that the designs of the new vehicles take into account the damage they can do to the pedestrian in the event of an accident and to underline that Sport Utility Vehicles (SUVs) and Light Truck vehicles (LTVs) have a higher fatality risk than the passenger cars. (Ballesteros et al 2004; Desapriya et al 2010; Henary et al, 2006; Hussain, 2019; Kröyer, 2015; Lefler and Gabler 2004).

Some lessons that we extracted from these studies is that, in general, they cannot be directly extrapolated to other situations different than the cases studied. Some of the problems that we find, when applying them to other cities, are the following:

- Year of the study. Studies carried out many years ago do not consider improvements in vehicle designs or improvement in the assistance of the injured pedestrian. In these cases, these models will deliver death rates higher than the real ones.
- Distribution of the age of the population. Regions or cities in the same country with an older population will have death rates higher than the country's averages.
- Development of the emergency and medical care system. Countries with less-developed emergency and medical care will present a higher fatality risk.
- Average age of vehicles and Typology of vehicles. Cities with higher percentages of SUVs and lower percentages of passenger cars will present a higher fatality risk. Cities with more modern vehicles will have a lower number and severity of pedestrian collisions.

4. DISCUSSIONS AND PROBLEMS OF THE APPROVED REGULATION

The new article 50 of the General Traffic Regulations (BOE, 2020) that establishes the generic speed limits on urban roads/streets is flexible and allows being more restrictive or less:

- "The established generic speeds may be lowered after specific signaling, by the Municipal Authority."
- "Exceptionally, the Municipal Authority may increase the speed on roads with a single lane in each direction up to a maximum speed of 50 km / h, after specific signaling".

These two degrees of freedom make it possible for some municipalities to abuse the "exceptionally" by preserving most of their streets at 50 km/h and leaving, therefore, this standard unused or almost unapplied.

The "exceptionality" should be applied in streets with few buildings, few pedestrians, and long-distance traffic, and when the main reason is to attract long-distance traffic from other streets with a higher density of buildings and with greater pedestrian traffic.

It is necessary to indicate that, in Spain, at present, the fines for speeding up to 20 km/h, in streets limited between 20 to 50 km/h are only 50 euros if paid before 20 days from receipt. If the speeding is between 21-30 km/h the fine rises to € 150 and in case of exceeding by 31 km/h up to 40 km/h the fine would be € 200.

We see, therefore, that fines for speeding in urban streets should be reconsidered as their punishment is not comparable to the damage caused by this increase in speed in the event of a run-over. In case of maintaining this low level of penalty (low effectiveness), it should be compensated with informative campaigns so that drivers and pedestrians better understand the risks of "seeping" in urban areas and their consequences in the case of a pedestrian run over.

Finally, apart from incorporating changes in the fines for speeding, laws should be modified to improve and reduce street design problems. These laws should prevent numerous obstacles limiting visibility at pedestrian crossings and cycle lane crossings between motor car drivers and vulnerable users.

If we leave it on the hands of the specific training and sensitivity towards road safety of those responsible for our cities, it will take longer to win the battle to reduce these accidents. A State or European regulation for the design of these crossings and intersections between streets, bike lanes, and pedestrian routes would strongly help to reduce this type of accident.

5. CONCLUSIONS

The basic rule that we can deduce from this study is that in order to improve the crossing areas of the paths of pedestrians (and other vulnerable users) and motor vehicles, it is necessary to increase the visibility distance between both so that they have more time to react and make decisions that do not end in a pedestrian run over. We have seen how, at daily traffic speeds in our cities, an accident can lead to serious injuries to pedestrians and, in too many cases, their death.

Therefore, it is recommended:

- Inventory and safety audit of all the existing crossings and those areas where there is a high number of pedestrians who cross badly due to lack of enabled crossings.
- Redesign those that are needed and or install new ones that are required.
- Do not extend the reduction of the speed from 50 km/h to 30 km/h to all streets. A higher speed will help to redirect motor traffic to those areas with less pedestrian traffic and less inhabited.
- Increase fines and reduce the first range of 20 km/h of excess in the first level of infraction. The same fine for going at 31 km/h or for going 49 km/h will not help to maintain the speed limit lawbreaker at speeds closer to 30km / h.

- Education and dissemination campaigns for drivers and pedestrians.
- Promote the implementation of advanced emergency braking systems (AEBS) and other safety measures in the design of new vehicles that help reduce the number of accidents and the severity if they occur. Encourage the renewal of the fleet of vehicles not only because they are less polluting but also because they include more measures to improve safety.

REFERENCES

AASHTO (2018). A Policy on the Geometric Design of Highways and Streets. 7th ed. American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C. USA.

AARTS, L. AND , VAN SCHAGEN I. (2006). Driving speed and the risk of road crashes: A review. Accident Analysis & Prevention. Volume 38 (2), pp. 215-224.

ANDERSON, R.W.G., MCLEAN, A.J., FARMER, M.J.B., LEE, B.H., BROOKS, C.G. (1997). Vehicle travel speeds and the incidence of fatal pedestrian crashes. Accident Analysis & Prevention. Volume 29, pp. 667-674.

BALLESTEROS, M.F.; DISCHINGER, P.C.; LANGENBERG, P. (2004). Pedestrian injuries and vehicle type in Maryland,1995–1999, Accident Analysis & Prevention. Volume 36, pp. 73-81.

BASEM Y; HENARY, JOHAN IVARSSON; JEFF R. CRANDALL (2006) The Influence of Age on the Morbidity and Mortality of Pedestrian Victims, Traffic Injury Prevention, Volume 7(2), pp. 182-190

BOE, (2003). Real Decreto 1428/2003, de 21 de noviembre, por el que se aprueba el Reglamento General de Circulación. Boletín Oficial del Estado (BOE). Spanish Government. Madrid. Spain. nº 306. pp. 45684-45772.

BOE, (2020). Real Decreto 970/2020, de 10 de noviembre, por el que se modifican el Reglamento General de Circulación. Boletín Oficial del Estado (BOE). Spanish Government. Madrid. Spain. nº 297. pp. 98638-98643.

BONANOMI, L. (1990). Le temps des rues: vers un nouvel aménagement de l’espace rue. Irec-Eple, Lausanne, Switzerland.

DAVIS, G. (2001). Relating severity of pedestrian injury to impact speed in vehicle–pedestrian crashes. Transportation Research Record 1773, 108-113.

DESAPRIYA, E.; SUBZWARI, S.; SASGES, D.; BASIC, A.; ALIDINA, A.; TURCOTTE, K.; PIKE, I. (2010) Do light truck vehicles (LTV) impose greater risk of pedestrian injury than passenger cars? A meta-analysis and systematic review, Traffic Inj.Prev. Volume 11(1), pp. 48-56.

DE PAUW, E., DANIELS, S., THIERIE, M., BRIJS, T. (2014). Safety effects of reducing the speed limit from 90km/h to 70km/h. Accident Analysis & Prevention. Volume 62, pp. 426-431.

DE PELSMACKER, P., JANSSENS, W. (2007). The effect of norms, attitudes and habits on speeding behavior: scale development and model building and estimation. Accident Analysis & Prevention. Volume 39 (1), pp. 6-15.

DfT, (2007). Manual for Streets, Department for Transport (DfT), Thomas Telford, London, UK

DGT, (2020). Anuario estadístico de accidentes 2019. Dirección General de Tráfico (DGT), Ministerio del Interior, Spanish Government. Madrid. Spain

DGT, (2021). A 30 km/h se salvan vidas. Revista Tráfico y Seguridad Vial. Dirección General de Tráfico (DGT), Volume 257, supplement. pp. 1-16.

EC. (2020a). EU Road Safety Policy Framework 2021-2030 - Next steps towards "Vision Zero". European Commission (EC). Publications Office of the European Union. Luxembourg:

EC. (2020b). Road safety key figures 2020. European Commission (EC). Brussels.

ELVIK, R., CHRISTENSEN, P., AMUNDSEN, A. (2004). Speed and Road Accidents. An Evaluation of the Power Model. TOI Report 740/2004. Institute of Transport Economics (TOI), Oslo.

ELVIK, R. (2009). The Power Model of the relationship between speed and road safety Update and new analyses. TOI Report 1034/2009. Institute of Transport Economics (TOI), Oslo.

FEBRES, J.D.; MARISCAL, M.Á.; HERRERA, S.; GARCÍA-HERRERO, S. (2021). Pedestrians' Injury Severity in Traffic Accidents in Spain: A Pedestrian Actions Approach. Sustainability, 13, 6439.

FRIDMAN, L.; LING R, ROTHMAN, L.; CLOUTIER, M.S.; MACARTHUR, C.; HAGEL, B.; HOWARD, A. (2020). Effect of reducing the posted speed limit to 30 km per hour on pedestrian motor vehicle collisions in Toronto, Canada - A quasi experimental, pre-post study. BMC Public Health Volume 20:56.

GONZALO-ORDEN, H.; ROJO ARCE, M.; PÉREZ-ACEBO, H.; LINARES UNAMUNZAGA, A. (2016). Traffic calming measures and their effect on the variation of speed. Transportation Research Procedia, Volume 18, pp. 349-356.

GONZALO-ORDEN, H.; PÉREZ-ACEBO, H.; LINARES UNAMUNZAGA, A.; ROJO ARCE, M. (2018). Effects of traffic calming measures in different urban areas, Transportation Research Procedia, Volume 33, pp. 83-90.

HENARY, B.Y.; IVARSSON, J.; CRANDALL, J.R. (2006). The influence of age on the morbidity and mortality of pedestrian victims, Traffic Inj.Prev. Volume 7(2), pp. 182-190.

HEYDARI, S., MIRANDA-MORENO, L.F., LIPING, F. (2014). Speed limit reduction in urban areas: a before-after study using Bayesian generalized mixed linear models. Accident Analysis & Prevention. Volume 73, pp. 252-261.

HUSSAIN, Q., FENG, H., GRZEBIETA, R., BRIJS, T., OLIVIER, J. (2019). The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: a systematic review and meta-analysis. Accident Analysis & Prevention. Volume 129, pp. 241-249.

KONG, C., YANG, J. (2010). Logistic regression analysis of pedestrian casualty risk in passenger vehicle collisions in China. Accident Analysis & Prevention. Volume 42 (4), pp. 987-993.

KRÖYER, H.R., JONSSON, T., VARHELYI, A. (2014). Relative fatality risk curve to describe the effect of change in the impact speed on fatality risk of pedestrians struck by a motor vehicle. Accident Analysis & Prevention. Volume 62, pp. 143-152.

KRÖYER, H.R. (2015) Is 30km/h a ‘safe’ speed? Injury severity of pedestrians struck by a vehicle and the relation to travel speed and age. IATSS Research, Volume 39, Issue 1, pp. 42-50

LEFLER, D.E.; GABLER, H.C. (2004). The fatality and injury risk of light truck impacts with pedestrians in the United States, Accident Analysis & Prevention. Volume 36, pp. 295-304.

LLOPIS-CASTELLÓ, D.; FINDLEY, D.J. (2019). Influence of calibration factors on crash prediction on rural two-lane two-way roadway segments. Journal of Transportation Engineering, Part A: Systems, 145, 040190241 – 040190249.

ROSEN, E., SANDER, U. (2009). Pedestrian fatality risk as a function of car impact speed. Accident Analysis & Prevention. Volume 41 (3), pp. 536-542.

ROSEN, E., KALLHAMMER, J.E., ERIKSSON, D., NENTWICH, M., FREDRIKSSON, R., SMITH, K. (2010). Pedestrian injury mitigation by autonomous braking. Accident Analysis & Prevention. Volume 42 (6), pp.1949-1957.

SZE, N.N.; WONG, S.C. (2007) Diagnostic analysis of the logistic model for pedestrian injury severity in traffic crashes, Accident Analysis & Prevention. Volume 39, pp. 1267-1278.

TEFFT, B.C., 2013. Impact speed and a pedestrian’s risk of severe injury or death. Accident Analysis & Prevention. Volume 50, 871-878.

WHO, (2015). Global status report on road safety 2015. World Health Organization (WHO). WHO Press. Geneva, Switzerland.