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Transportation Research Procedia 69 (2023) 504–511

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 3rd International Conference on Transport Infrastructure and Systems (TIS ROMA 2022), 15th-16th September 2022, Rome, Italy

Road users' behaviour in the "30 km/h zones". The case study of Bologna

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Abstract

Excessive vehicle speeds in urban areas have resulted to be a major cause of road accidents involving pedestrians, cyclists, and motorcyclists, identified as "vulnerable road users" (VRU). A possible useful strategy to overcome this problem, both reducing speed and safeguarding vulnerable road users (VRU), is the introduction of "30 km/h zones". As traffic calming measures, they allow a maximum speed for drivers of 30km/h. The purpose of this study is to monitor the behaviour of drivers in the "30 km/h zones" of the centre of Bologna. With the close collaboration of Bologna Municipality, the study has provided for the monitoring of speed and type of transport in specific points within a selected circuit. Data collected showed that, although in most of the selected zones, speeds are below 30 km/h, in the areas where traffic is heavier, drivers exceed the permitted limit.

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

Efforts to improve the protection of vulnerable road users, in particular pedestrians, from injuries and deaths due to accidents have long been considerable worldwide. However, the issue of pedestrian safety is still serious and worrying (Xu et al. (2009)) and far from being resolved. Too high speed of vehicles in urban areas has been found to be a major cause of road accidents involving pedestrians, cyclists and motorcyclists, identified as "vulnerable road

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10.1016/j.trpro.2023.02.201

users" (VRU) (Bassani et al. 2019; Kumar et al. (2021)). In Italy, in 2019, the number of road victims amounted to 3,173 deaths, 46.8% of which were pedestrians, cyclists or motorcyclists (ISTAT, National Institute of Statistics, 2019). Martinelli et al. (2022) demonstrated how inadequate road design associated with high traffic volume, as well as the coexistence of multiple vehicle categories with vulnerable users, and inappropriate driver behaviour (e.g., speeding) are potential causes of collision risk. The massive use of cars has had negative effects not only on traffic volumes but also on air pollution, noise, and the use of public transport. (Pazzini et al. (2021)).

In order to create safer and more comfortable areas for weak users, a speed limit of 30 km/h has been introduced in many urban areas. "Zones 30" are intended to protect pedestrians and cyclists, improve the functionality and safety of the road, and reduce air, noise, and visual pollution. The introduction of "zones 30" within city centers also favors the use of shared vehicles in order to promote sustainable mobility (Pazzini et al. (2022)). Previous studies have shown the significant benefits in terms of road safety resulting from the introduction of the 30 km/h speed limit. Richards (2010) showed that a vehicle that travels at 50 km/h and hits a pedestrian or a cyclist (vulnerable users) causes a mortality rate between 55% and 90%. Conversely, at a driving speed of 30 km/h the mortality rate is less than or equal to 10%. Rosén & Sander (2009) also noted that 50% of pedestrian deaths involved accidents due to contact with a vehicle traveling at a speed ranging between 50 km/h and 80 km/h. Moreover, the risk of death at 50 km/h is more than twice the risk at 40 km/h, and more than five times the risk at 30 km/h. Other studies have found significant reductions in the frequency and severity of accidents on the streets of a certain zone after the installation of speed limit of 30 km/h. (Lindenmann et al. (2005)). Seya et al. (2021) made a comparison between fatal or very serious accidents ("Killed" or "Seriously Injured") within zones with and without speed limit at 30 km/h. Although the total number of accidents in the case of "30km/h zones" was not lower than in the areas without the 30 km/h limit, the results showed a lower number of fatal accidents in the case of "30 km/h zone" presence.

A way to control vehicle speed is to use traffic calming measures which reduce speed and increase safety, resulting in "discomfort" for drivers, especially near road crossings. Possible solutions of traffic calming measures are flat-topped humps, single bumps, and double bumps. Several studies have shown a significant reduction in speeds following the introduction of calming devices (Berloco et al. (2022); Arbogast et al. (2018). After the installation of calming devices, Abdulmawjoud et al. (2021) detected a reduction of 71.6%, 66% and 60% respectively for flat-topped humps, double bumps and single bumps.

In addition to infrastructure solutions for speed reduction, including vertical and horizontal signs and other traffic calming solutions, appropriate educational and information campaigns should be developed both for drivers and pedestrians (Gonzalo-Orden et al. (2021); Pazzini et al. (2022)). Awareness campaigns for users are aimed at directly involving citizens, residents, and schools in order to share key information about road safety and compliance with the speed limit of the "Zone 30". Zhang et al. (2013) have carried out a real educational campaign for improving pedestrian safety and the results have shown that pedestrians, bicyclists and drivers have different perceptions on driver yielding behaviour towards pedestrians and cyclists.

The aim of the present work is to monitor speeds within a "30 km/h zone" along six roads within the Municipality of Bologna (Italy), with different infrastructural characteristics. Moreover, three different vehicle classes have been considered, namely motorcycles, cars and buses or heavy vehicles, in order to assess the different variation of speeds and compliance with the limit provided for by the legislation.

2. Case study and methods

The historic centre of the city of Bologna is a "30 km/h zone" divided into neighbourhoods with the aim of protecting pedestrians and cyclists, improving functionality and safety of the roads and reducing air, noise and visual pollution.

The area under study is the Porto – Saragozza District. Southwest of the city, it includes Porta Saragozza and Porta Sant'Isaia, two of the twelve ancient gates surrounding the historic centre of Bologna. This residential area is characterized by the presence of several "sensitive" and "strategic" buildings such as kindergartens, nursery schools, primary schools and health facilities. Access is regulated by a ZTL (Limited Traffic Zone) passage from 07:00 a.m. to 8:00 p.m. except for public transport, state bodies, residents, motorcycles and vehicles authorized by permits.

In June 2021 the Municipality of Bologna carried out an analysis of the speeds within this district monitoring six different roads, with different characteristics (Fig.1):

Fig. 1: Roads analysed within the "zone 30" of the city centre of Bologna in the Porto-Saragozza district

In particular, the following streets have been analysed (Table 1):

- Via Sant'Isaia: a two-way street, with a fast lane to the west (out of town), usually very busy due to the presence of two secondary schools and a health facility. This street is one of the roads connecting the city centre with the peripheral area. Along the road, in the direction of the centre, there are parking spaces marked by special blue horizontal stripes.
- Via Frassinago: one-way street, southwest direction. In the first section, up to the junction with Via Cà Selvatica, on the left side of the road, runs a one-direction cycle path separated from the road by protection poles. There are also some parking spaces for motorcycles. On the right side there are parking areas for vehicles marked with special blue stripes. After the junction with Via Cà Selvatica the road narrows and only parking spaces on the right are present.
- Via Nosadella: one-way road to the north; only 4.5 metres wide, vehicles are not allowed to stop along this road. A kindergarten and a nursery school are also present along the road.
- Via Ca' Selvatica: one-way road to the west, flanked by a pedestrian path separated from the road by protection poles. A nursery school and a primary school are present along the road
- Via Santa Caterina: one-way road northwards, connecting Via Saragozza and Via Cà Selvatica;
- Via Saragozza: a two-way street, usually very busy as it is the connection of the city centre with the suburbs. There is a secondary school here. In both directions a one-direction cycle path is marked with a special white continuous stripe. Along the lane to Porta Saragozza there are properly marked parking spaces.

Table 1. Geometric features of the roads analysed

Roads analyzed	Length	N lane	Lane width (m)
1 Via Sant'Isaia_direz. Malpighi	650	2	3.00
2 Via Frassinago	410	1	3.60
3 Via Nosadella	340	1	3.00
4 Via Ca' Selvatica	240	1	3.00
5 Via Saragozza (direz_centro)	650	2	3.50

6 Via Santa Caterina	270	1	3.50

In the analysis of speed measurement within the "30 km/ h zone", the route shown in Fig.2 was taken into consideration, excluding Viale Carlo Pepoli (red dashed line). Monitoring sections were identified for each road. When choosing the sections to survey on each road, criterion followed was to focus on the sections where drivers were expected to outrun the maximum speed along the road. Therefore, these points never include the beginning or the end of the road and are not located near schools or pedestrian crossings. In this way, vehicles were free to take speed along the road and the collected data are consequently as realistic as possible.

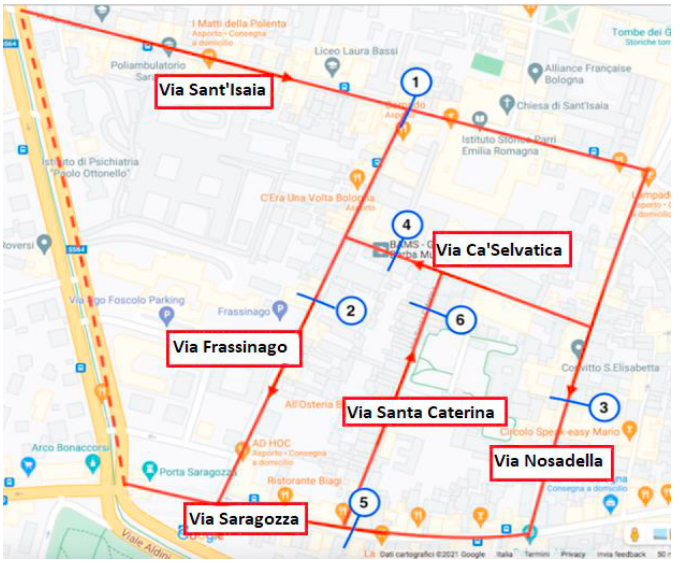

Fig. 2. Monitoring sections

A portable radar equipment has been used for temporary surveys of traffic along two-lane roads. The equipment has been placed on the vertical signs on the side of the road with an inclination of about 45 degrees from the road (Fig.3). No vehicles should be parked in front of the equipment to allow a correct detection of vehicles passing through the selected road section. For this reason, points were chosen where parking was not allowed, without signalling the presence of the radar equipment so as not to affect drivers and adjust speed accordingly.

(a) (b)

Fig. 3. (a) radar equipment used for speed monitoring (b) installation of the equipment to vertical signs

Once the device has been installed and the basic road parameters have been entered, the equipment performs a self-calibration minimizing significant errors. Measurements were carried out for four days with a 24-hour operation. On

two-way traffic roads, both directions were taken into account. The data provided by the instrument at the end of the survey are date and time of measurement, speed, vehicle class according to length, and direction.

3. Results

In a first phase of the analysis of data obtained, a classification was made into three-type classes, based on the length (L) of the vehicles: motorcycle, car, bus or heavy vehicle.

- Motorcycle: $L \leq 2{,}5$ m;
- Car: $2{,}5\ \text{m} < L \leq 6{,}0$ m;
- Bus or Heavy Vehicle: $L > 9{,}0$ m.

Table 2 shows the values obtained by monitoring the speeds at the six identified sections. Sections 1 (Via Sant'Isaia) and 5 (Via Saragozza) are the only two-way roads for which both directions have been evaluated. First, the V85 operating speed was calculated. This speed is defined in literature as a speed not exceeded by 85% of the only cars running through a homogeneous element or trunk of the infrastructure in free flow conditions, that is, without mutually influencing one's driving behaviour and being able to freely choose the speeds to be adopted. Only in sections 4 and 6 the speed limit of 30 km/h is respected while, in the remaining roads, this limit is exceeded by more than 10 km/h. Via Sant'Isaia (1) and Via Saragozza (5) are the two roads where speeds over 50km/h are reached in both directions of travel. Since these roads connect the city centre with the suburbs, they are far busier than the other roads, as the number of vehicles detected clearly shows. On the contrary, via Ca' Selvatica (4) and Via Santa Caterina (6) are internal roads, usually travelled by residents, by people going to school or to reach Via Frassinago (2) from Via Saragozza (5). This first phase of analysis provided basic information on the general characteristics of vehicle flows and user behaviour. Conditioning coming from the surrounding environment and traffic due to the passage of buses or heavy vehicles were not taken into consideration.

Table 2. Results obtained from speed analysis

Monitoring Sections	N veichle	N moto	N cars	N bus/heavy vehicle	Median	V_{85}	V_m	SD
1 Via Sant'Isaia_direz. Malpighi	24043	9206	13661	1176	39.0	63	38.6	14.5
1.2 Via Sant'Isaia_direz. porta	5649	2696	1804	1149	36.0	52	37.5	14.8
2 Via Frassinago	3819	1387	2260	172	31.0	42	30.9	11.3
3 Via Nosadella	10626	3708	6542	376	30.0	41	30.7	10
4 Via Ca' Selvatica	1973	1321	612	40	18.0	25	18.6	6.8
5 Via Saragozza (direz_centro)	8907	2574	5431	902	35.0	51	35.7	14.4
5.2 Via Saragozza (direz. Porta)	16256	3550	11511	1195	46	53	42.7	11.7
6 Via Santa Caterina	2344	1371	939	34	19	27	19.9	7.7

By analysing the values of average speed (V_m) and standard deviation (SD) for each section monitored, the speed limit of 30 km/h was exceeded in most of the sections under consideration. Average speed and standard deviation are higher and more dispersed in sections 1 and 5, but there are no significant variations compared to other roads. Thiessen et al., (2017) and Dinh et al. (2013) showed that this variation may be related to the lane width. An increase of 1 m in the width of the lane results into an increase of the average speed along the road. This is realistic since drivers might consider wider roads safer, thus increasing driving speed. Moreover, the urban context analysed is located within the historic city centre, where the road is flanked by car parks and cycle lanes reducing the space available for traffic. As demonstrated by J. Edquist et al. (2012) speed variability increases along with environmental complexity. When there are no parking spaces on the side of the road, the speed is significantly less variable than the condition in which there are parking spaces on the side of the roadway. In the latter case speeds are much more variable than in the first situation.

The variation in the standard speed deviation is higher on the sections of the two-way road with two lanes. Contrary of what demonstrated by Martinelli et al. (2022), the presence of painted median did not result in a decrease in the standard deviation. In fact, the analysis has shown that, on single-lane roads, such as sections 2,3,4 and 6, speed variability is lower.

The second phase of the study focused on the analysis of speed variation along the sections analysed in relation to the three types of vehicles. From the data collected, the sections analysed can be divided according to the common characteristics of the roads and the results obtained.

In Via Ca' Selvatica (4) and Via Santa Caterina (6) (Fig.4) speed variation is not significant for any of the three types of vehicles. The speed values for motorcycles, cars and buses and/or heavy vehicles are around the average, but in most cases, they are below the limit value of 30 km/h. This may be due to the street design, which, being within a district of the old town and flanked by parking areas, bike paths and residential buildings creating a "canyon effect", causes users to proceed along the road at moderate speeds.

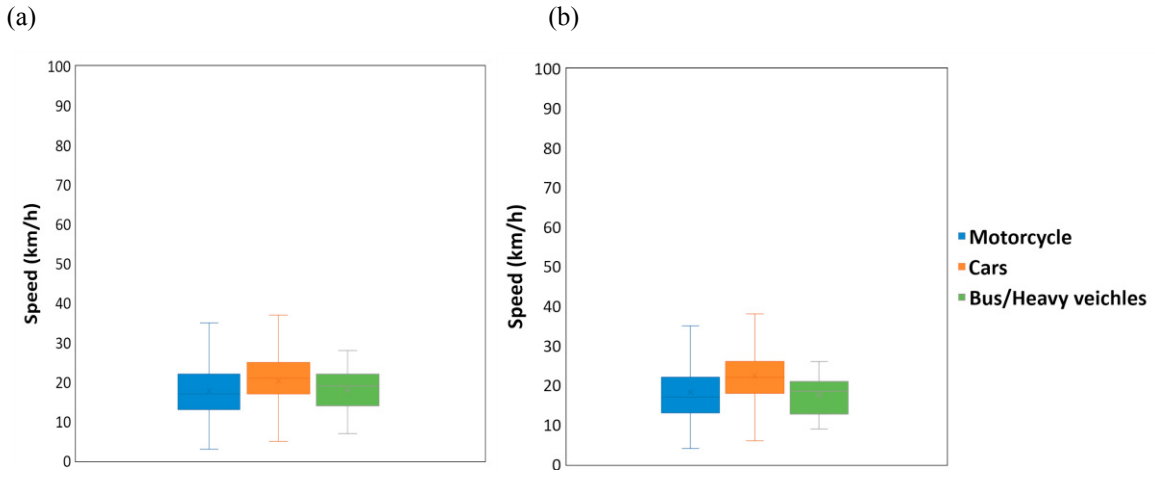

Fig. 4. (a) speed variation depending on the type of vehicle in Via Ca' Selvatica (4) (b) speed variation depending on the type of vehicle in Via Santa Caterina (6)

In Via Frassinago (2) and Via Nosadella (3) are the two internal roads connecting the two main roads, Via Sant'Isaia (1) and Via Saragozza (2). Here (Fig. 5) the average speeds of motorcycles, cars and buses and/or heavy vehicles are lower or equal to the limit of 30 km/h. Unlike the previous roads, in these two sections speed variation is higher. This variation is evident for motorcycles, which reach the highest speeds, up to 70 km/h. This result may be due to the fact that the roads under consideration are within the ZTL area, where access is not allowed from 07:00 a.m. to 8:00 p.m., except for public transport, state bodies, residents, motorcycles and vehicles authorized by permits. This means that motorcyclists, not influenced by the presence of many vehicles along the road, feel safer, thus increasing speed accordingly.

Finally, analysing the variation of speeds for the three types of vehicles along the two most critical roads, Via Sant'Isaia (1) and Via Saragozza (6), Figure 6 shows that, for all three types of vehicles, the speed limit of 30 km/h is not respected. On the contrary, the average speeds are far above this value and in this case too, a greater variation of speed occurs with motorcycles reaching the maximum speed recorded on both roads. As for cars, buses or heavy vehicles the dispersion of speeds around the average value is lower. Figure 6 shows the graphs obtained in Via Sant'Isaia_direction Malpighi (1) and Via Saragozza_direction Porta (5). The same result was also obtained in the opposite direction.

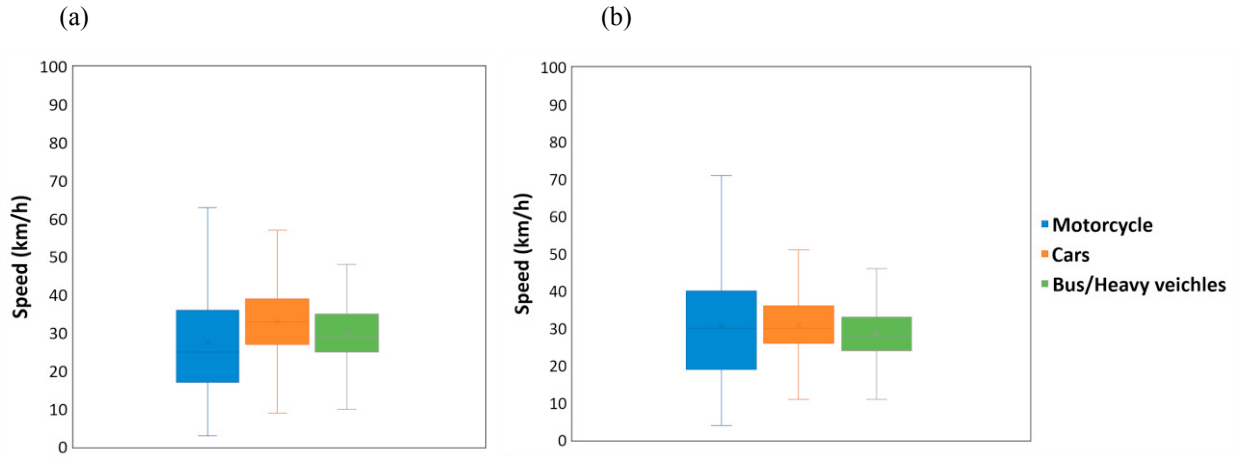

Fig. 5. (a) speed variation depending on the type of vehicle in Via Frassinago (2) (b) speed variation depending on the type of vehicle in Via Nosadella (3)

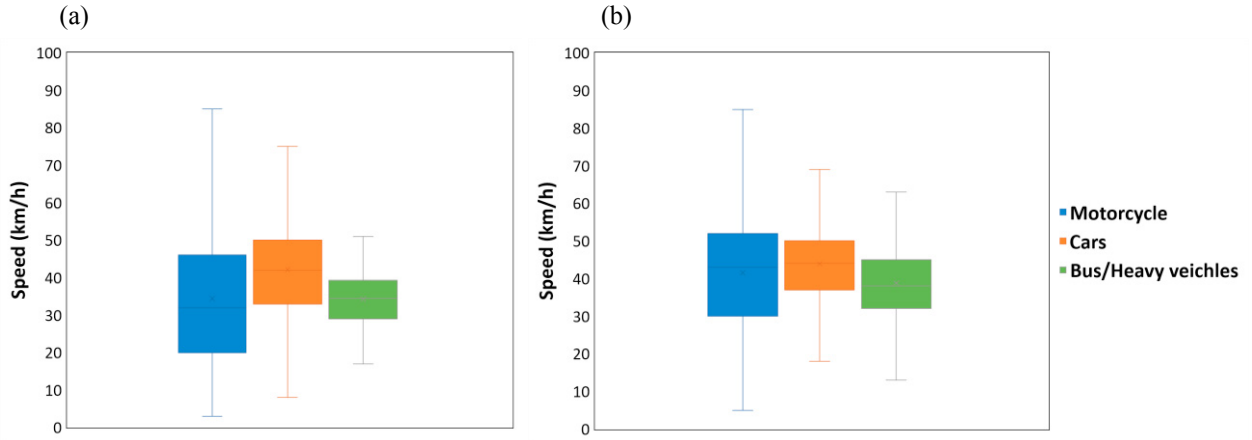

Fig. 6. (a) speed variation depending on the type of vehicle in Via Sant'Isaia_direction Malpighi (1) (b) speed variation depending on the type of vehicle in Via Saragozza_direction Porta (5)

Possible solutions for the reduction of speeds within the considered area have been carefully identified. In the two internal roads, Via Cà Selvatica and Via Santa Caterina, where the registered speeds do not exceed the limit provided for by the legislation, simple installation of special vertical signs highlighting the "Zone 30" may be useful. In the remaining streets, characterized by the presence of schools and/or health facilities, in addition to the insertion of appropriate vertical and horizontal signs at the different gates in order to make the area more visible, a possible traffic calming intervention could be Berlin speed cushion. Bercolo et al. (2022) has shown that the introduction of Berlin cushion within the "30 km/h zones" at pedestrian crossings resulted into a reduction in speed and increased safety for VRUs. In addition, red banners could be placed near the vertical signals with the name of the area, to make clearer to users the urban context they are moving in.

4. Conclusion

Speed is a crucial factor for road safety heavily influencing the occurrence of accidents on urban roads and their severity. Excessive speed of vehicles in urban areas is one of the main causes of road accidents involving pedestrians, cyclists and motorcyclists, identified as "vulnerable road users" (VRU). In this study, in collaboration with the

Municipality of Bologna, speed monitoring was carried out in six different streets within the historic city centre, a "zone 30" whose access is regulated by a limited traffic zone (ZTL) gate from 07:00 a.m. to 8:00 p.m.. Analysis of the V_{85} operating speed showed that, on the busiest roads, the 30 km/h speed limit is not respected, exceeding it by more than 10 km/h. Only in the two secondary streets of the district speeds are below the established threshold. The same result was obtained from the analysis of average speed and standard deviation. The mean and standard deviation values are higher on average and have a greater dispersion in the two main roads, while there are no significant variations along the other roads. Then, the results obtained in the six sections were compared depending on three types of vehicles: motorcycles (L 2.5 m), cars (2.5 m < L 6.0 m) and buses /heavy vehicles (L > 9.0 m). The analysis showed that the greatest variation in speed occurs for motorcycles, which maintain high speeds along most of the road sections analysed. Cars and buses or heavy vehicles do not show great variations in speed, maintaining higher speeds only on the two busiest roads, Via Sant'Isaia and Via Saragozza. The introduction of a Berlin speed cushion inside the "30 km/h zone" at pedestrian crossings and road intersections is one possible solution for reducing vehicle speed and increasing VRU safety. In addition, red banners could be placed near the vertical signals with the name of the area, to make clearer to users the urban context they are moving in.

References

Abdulmawjoud Ayman A,. Jamel Mohammed G, Al-Taei Abdulkhalik A., Traffic flow parameters development modelling at traffic calming measures located on arterial roads, Ain Shams Engineering Journal 12 (2021) 437–444.

Arbogast H., Patao M., Demeter N., Bachman S., Devietti E., Upperman J. S.,d, Burke R. V., The effectiveness of installing a speed hump in reducing motor vehicle accidents involving pedestrians under the age of 21, Journal of Transport & Health 8 (2018) 30–34.

Bassani M., Rossetti L., Catani L., Traffic crash pattern modification as a result of a 30 km/h zone implementation. A case study in Turin (Italy), Transportation Research Procedia 45 (2020) 402–409.

Bercolo N., Coropulis S., Intini P., Ranieri V., Effect of Berlin speed cushions in urban restricted speed zones: a case study in Bari, Italy, Transportation Research Procedia 60 (2022) 180-187.

Dinh D., Kubota H., Profile-speed data-based models to estimate operating speeds for urban residential streets with a 30 km/h speed limit, IATSS Research 36 (2013) 115–122.

Edquist J., Rudin-Brown C. M., Lenné M. G., The effects of on-street parking and road environment visual complexity on travel speed and reaction time, Accident Analysis and Prevention 45 (2012) 759– 765

Gonzalo-Ordena H., Rojo Arcea M., Linares Unamunzagaa A., Apontea N., Pérez-Acebobo H., Why is necessary to reduce the speed in urban areas to 30 Km/h?, Transportation Research Procedia 58 (2021) 209–216.

ISTAT, Istituto nazionale di statistica, (2019)

Kumar A., Nandini D. , Manobi Sairam M, Madhusudan B.P., Development of GPS & GSM based advanced system for tracking vehicle speed violations and accidents, Materials Today (2021).

Lindenmann H.P., The effects on road safety on 30 kilometer-per-hour zone signposting in residential districts, ITE Journal 75 (6) (2005) 50–54.

Martinelli V., Ventura R., Bonera M., Barabino B., Maternini G., Effect of urban road environment on vehicular speed. Evidence from Brescia (Italy), Transportation Research Procedia 60 (2022) 592-599.

Pazzini, M., Lantieri, C., Vignali, V., Simone, A., Dondi, G., Luppino, G., Grasso, D., Case Studies in the Emilia Romagna Region in Support of Intermodality and Accessibility of Public Transport, (2021) Advances in Intelligent Systems and Computing, 1278, pp. 65-74.

Pazzini, M., Cameli, L., Lantieri, C., Vignali, V., Dondi, G., Jonsson, T., New Micromobility Means of Transport: An Analysis of E-Scooter Users' Behaviour in Trondheim, (2022) International Journal of Environmental Research and Public Health, 19 (12), art. no. 7374.

Pazzini, M., Lantieri, C., Vignali, V., Simone, A., Dondi, G., Luppino, G., Grasso, D., Comparison between different territorial policies to support intermodality of public transport (2022) Transportation Research Procedia, 60, pp. 68-75.

Richards, D. C., 2010. Relationship between speed and risk of fatal injury: pedestrians and car occupants. Road Safety Web Publication n. 16, Department for Transport of London.

Rosén E., Sander U., Pedestrian fatality risk as a function of car impact speed, Accident Analysis and Prevention 41 (3) (2009) 536–542.

Seya H., Yoshida K., Inoue S., Verification of Zone-30-policy effect on accident reduction using propensity score matching method for multiple treatments, Case Studies on Transport Policy 9 (2021) 693–702.

Thiessen, A., El-Basyouny, K., & Gargoum, S., 2017. Operating speed models for tangent segments on urban roads. Transportation Research Record, 2618(1), 91-99.

Xu J., Li Y., Lu G., Zhou W., Reconstruction model of vehicle impact speed in pedestrian–vehicle accident, International Journal of Impact Engineering 36 (2009) 783–788.

Zhanga Y., Gawadea M., Linb P. S., McPhersonc T., Educational Campaign for Improving Pedestrian Safety:A University Campus Study, Procedia - Social and Behavioral Sciences 96 (2013) 2756 – 2766