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Effects of Berlin speed cushions in urban restricted speed zones: a case study in Bari, Italy

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Abstract

The widespread European policy towards urban sustainable mobility requires some engineering-related interventions on the existing urban road network, such as traffic calming measures. There is a substantial amount of research assessing the effects of different traffic calming measures, even if there is no unanimous evidence for some of them, such as speed cushions (in particular Berlin speed cushions). Some research on speed cushions has been conducted, even if different results were achieved, also varying with the country and context of installation. Moreover, some of these studies are old and they need to be updated, given the continuous transformation of urban environments. In agreement with the City of Bari, thanks to ASSET-Puglia Region funds, the Italian Ministry of Infrastructures and Transport has granted permission to install speed cushions on three urban streets located in restricted speed zones (≤30 km/h) in the City of Bari, to test their effects on vehicular traffic. In this context, this article is aimed at assessing the preliminary results obtained, considering the effects on vehicular speeds. The study design is a typical before-and-after study, in which speeds are measured using a laser speed gun on the three selected road segments before and after the implementation of speed cushions (for each segment, the cushion has a different width). Visual observations were also useful to detect the effects of speed cushions on trajectories and speeds of two-wheeled vehicles. The preliminary analysis of speed profiles revealed a consistent decrease in speed for all the three test sites (in particular the operating speed V_{85}, which is reduced by up to approximately 30%). Moreover, it seems that the decrease in speed is more evident as the cushion width decreases.

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Keywords: Traffic calming; speed cushions; experimental site; speed reduction

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1. Introduction

1.1. Traffic calming measures

In the recent past, a great deal of effort has been made to make cities more suitable for pedestrians and cyclists. In this context, the effects of speed reduction from 50 km/h to 30 km/h were assessed in terms of increased urban safety and sustainable development. Safety benefits were deeply investigated by Richards (2010) and the results showed that a vehicle traveling at 50 km/h which impacts a pedestrian, or a cyclist (vulnerable user) causes a mortality rate between 55% and 90%. The same scenario but at a traveling speed of 30 km/h has a mortality rate less than or equal to 10%. According to urban sustainable development, Casanova and Fonseca (2012) compared the travel times on an urban road with a 50 km/h speed-limit and a 30 km/h speed-limit, revealing that the difference is less than 10%. This 10% was quantified by Greenreport (2013) as a time travel increase of at most 5.1 s for a 500 m section traveled at 30 km/h rather than at 50 km/h. This is because greater speeds often involve interrupted traffic flow, with a stop-start effect.

To achieve the aforementioned benefits, it may be necessary to force vehicles to regulate their speed to 30 km/h, hence different interventions are required. Firstly, accurate vertical and horizontal signals need to be installed to avoid surprises and, thus, driver misbehavior. Secondly, infrastructural intervention and space management are required. Hence the introduction of vertical devices (speed humps, speed table, speed cushions, and raised intersections) or horizontal ones (sidewalk enlargement, chicane, roundabouts, road carriageway reduction), preventing maneuvers or creating limited traffic zones (ZTL) are crucial interventions. Among these alternatives, vertical devices are reliable and effective, when correctly designed (Loprencipe et al., 2019; Khorshid et al., 2020), as also shown by Berloco et al. (2018), who conducted surveys by means of low-cost equipment. The vertical devices were found to be the most effective in terms of crash severity reduction: injury crashes are reduced by 44%, fatal and injury crashes are reduced by 35% (Mountain et al., 2005). Given this positive effect of vertical devices, the use of speed cushions, considered to be efficient and versatile, has been thoroughly investigated over the last three decades and they have been found to reduce speed better than other traffic calming devices (Johnson and Nedzesky, 2004), to drastically decrease traffic volume (Chang et al., 2007), up to 48% (Layfield & Parry, 1998), to reduce noise in the case of a preponderance of light vehicles (Layfield & Parry, 1998) and to enhance road safety benefits (Minnema, 2006; Berthod and Leclerc, 2013).

Nomenclature

V_{min}	minimum value of the speed distribution obtained for a given cross section
V_{avg}	average value of the speed distribution obtained for a given cross section
V_{max}	maximum value of the speed distribution obtained for a given cross section
V_{15}	value corresponding to the 15th percentile of the speed distribution in the cross section
V_{85}	value corresponding to the 85th percentile of the speed distribution in the cross section
Zone 10	zones in which a 10 km/h speed limit is posted
Zone 30	zones in which a 30 km/h speed limit is posted
Zone 50	zones in which a 50 km/h speed limit is posted

1.2. Speed cushions: state of the art

In the United Kingdom, the Department for Transport (DfT) introduced several Zone 30s in the early 1990s, relying on chicanes, raised intersections, speed humps, and speed cushions. The latter were only used at few points because they were not considered suitable for emergency vehicles (Webster, 2003). Despite this, public transport vehicles were slowed down by common speed humps (Webster, 2003) and so speed cushions were deemed the most suitable for this need. The Department for Transport (1998) analyzed the effect of speed cushions on 34 road segments finding a 27.2 km/h mean speed reduction (V_{85} decreased by 35.2 km/h) and a 60 % crash reduction.

In-depth analyses (DfT 2007) showed a relationship between speed reduction and speed cushion width and the distance between two or more speed cushions. The greater is the width, the greater is the speed decrease, the greater is the distance between cushions, the lower is the speed decrease. Moreover, the effect of speed cushions similarly to narrow speed humps, is negligible for mopeds and motorcycles (Greenreport.it, 2013). Other works also suggested a relationship between comfort, vibration and cushion dimensions (Layfield & Parry, 1998).

Other important experiments were carried out in Italy. The first city to test speed cushion was Tortona (AL), but only recently have dedicated tests been run in Ladispoli, Rome (2017), Turin (2019), and Bari (2020), thanks to the authorization of the Ministry of Infrastructures and Transports (M.I.T.) since the Italian road regulations "Codice della Strada" (C.d.S.) does not allow their presence in road sections, because raised elements are not allowed for portions of the carriageway. These tests in Zone 30 sections were promoted by the local Universities' research groups, to understand the improvement of urban life quality and the applicability of such devices. In Italy, speed cushions are mentioned by the protocol 3698/01 (2001) and they can be used for limited urban road categories (collector and local roads) depending on the traffic volume. However, no specific technical information about dimensions and installation procedures are provided. Hence, International regulations and guidelines should be considered to prevent dangerous situations for ordinary vehicles (like grounding on the speed cushions) and emergency vehicles, as summarized in Table 1. The framework described in Table 1 was defined by comparing the Italian standards, recent studies and research, and international regulations. This comparison was propaedeutic to integrate the Italian framework dedicated to speed cushions, especially their geometric characteristics, to define, as a first instance, an overall Italian regulation on speed cushions design and use.

Table 1. Summary of the characteristics of speed cushions

Italian regulations	- Circular n. 3698/01 (Circ.) - Authorizations released by M.I.T (M.I.T.)			
International studies/regulations considered	- DfT – Department for Transport (UK) - CERTU – Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques - DDT- Delaware Department of Transport (USA) - SN 640213, Swiss regulations (SN-640213)			
Applicability	Local and secondary roads – (corresponding to the "E" and "F" Italian road categories (Circ.))			
Installation procedure	- On the carriageway (DfT) - One for each lane with cross distance (D_t) ≤ 1.2 m (DfT); ≤1.0 m (DDT) - Suggested headway between 30 e 50 m (SN-640213) - For cross distance ≥ 1.2 m insert a median width (DfT); ≥ 1 m insert a third cushion according to the carriageway width (DDT) - Distance from sidewalk ≥ 0,75 m (DfT); 0.8-1.20 m (CERTU); 0,60 m (DDT) - Distance from intersection ≥ 6 m (SN-640213) - The device must comply with the efficiency of the rainwater collection systems for platform water management (DfT)			
Geometric characteristics	Slope (%)	Height (cm)	Width (m)	Length (m)
	Frontal: 15.0 Lateral: 25.0 (M.I.T.)	7.5 cm (M.I.T.)	1.7 m (M.I.T.)	1.70-2.50 m (M.I.T.)
	Frontal ≤ 12.5 Lateral ≤ 25.0 (DfT)	6.5-7.5-8.0 cm (DfT)	≤ 2.0 m (DfT)	1.70-3.50 m (DfT)
	Frontal: ≤ 25.0 – 28.0 (CERTU)	5.0-7.0 cm (CERTU)	≥ 1.7 m (CERTU)	3.00-5.00 m (CERTU)
	Frontal 10.0 Lateral 16.6 (DDT)	18.0 cm (DDT)	1.8-2.1 m (DDT)	3.66 m (DDT)
	Frontal 6.0-12.0 Lateral 10.0-20.0 (SN-640213)	6.0-12.0 cm (SN-640213)	1.7 m (SN-640213)	5.10-9.00 m (SN-640213)
	- In case of great traffic flow of heavy vehicles, the suggested longitudinal slope becomes ≤ 5% (SN-640213)			
Materials	- Similar to speed humps: Anti-slip refinement (Reg. C.d.S.); Plastic or rubber modular elements; Concrete; Concrete paving stones or porphyry			
Signals	- Similar to speed humps (art. 179, c.4 C.d.S.): Hump signal (Art. 85 – C.d.S.) with integrative panel "artificial hump"; Speed limit signal (Art. 116 – C.d.S.); Yellow and black colored (M.I.T.)			

2. Research questions

The research questions of this paper are the following:

1. Verifying the speed cushion effects on speeds in Zone 30. Are they effective at reducing speeds to 10 km/h, in the proximity of pedestrian areas?
2. Verifying the effect of speed cushions placed 8.0 m before the critical point;
3. Verifying the speed cushion length effect on speed reductions;
4. Verifying the user behavior (vehicle, moped, and motorcycle users) before and after the installation;
5. Verifying the trajectory of vehicles and the behavior due to the speed cushion installation.

3. Methods

The experimental sites are located in the city center of Bari in three different areas. The sites are designated Zone 30, becoming Zone 10 at the intersection with a pedestrian area, Via Sparano. Moreover, the sites did not present lateral parking lots, thanks to the presence of lane narrowing. The choice of the sites was in accordance with the M.I.T. directives. The speed cushions installed at these test sites are modular and compact, made of vulcanized rubber. The width of the devices was 1.70 m as suggested by SN, M.I.T., and CERTU; but the length varied, within the regulatory boundaries, for each site to add another layer to the research questions, that is inquiring into the relationship between device length and driver behavior.

Table 2. Speed cushion dimensions according to the installation site.

Site name	Length (m)	Width (m)
Via Calefati	3.20	1.70
Via Nicolai	2.70	1.70
Via Putignani	2.20	1.70

The speed of the vehicles at these sites was measured by accurately positioning a Laser Speed Gun device (LaserTech TruSpeed®) placed on a tripod and manipulated by an operator. The measurements were run after some on-site tests propaedeutic to testing the device and to letting vehicle users be comfortable and get used to the presence of the operator with the device. During this phase it was noticed that the presence of parking lots, greenery and pedestrians result in almost completely hiding the operator to the drivers. In fact, the operator was clearly visible only from the middle of the pedestrian area, so when the effect of the speed cushion was already dispatched. In this way, experimental observations were collected independently on the presence of the operator.

After this recognition period, the measurements were influenced by two variables: time and space. In the first case, the vehicles should have traveled at almost free-flow speeds, without start-stop phenomena to detect precisely and reliably their speed close to the cushions. Since the selected road segments intersect with the pedestrian area, the traffic flow regime depends on the pedestrian flow. The time spots during which run the measurements were selected after surveys of both pedestrian and vehicular traffic. The pedestrian flow crossing the site roads was considered significant but not disturbing for the regular vehicular flow when it was lower than 350 pedestrians/hour. At the same time, the vehicles travelling should have been more than 100 vehicles/hour to have a significant sample for undisturbed traffic flow. Considering these two prerequisites and also the consequences of COVID-19 pandemic rules, the following three-time intervals were chosen for the test: from 7 a.m. to 8 a.m., from 2 p.m. to 3 p.m., from 9 p.m. to 10 p.m.

As far as the space variable is concerned, the tripod had to be located in order to overcome the detection error due to the laser incidence angle with the traffic direction and to detect the vehicles approaching and leaving the speed cushion. The characteristics of the instrument were considered to set the longitudinal distance. The maximum range of detection of the tele-laser is 650 m, the minimum detected distance is 15 m. The accuracy of the measurement is approximately 0.2 m for distance and 2 km/h for speed. Considering these details, the instrument with the tripod was placed approximately 30 meters from the center of the speed cushion (Fig. 1). The distance from the start of the pedestrian area was also considered, in order to allow undisturbed flow traffic on the cushion. The center of the speed cushion was placed 10 m from the first LOGES system of the pedestrian area (depending on the site). The

measurements were made by using the continuous recording function of the telelaser, pointing it at each vehicle three times with a time span of 3 seconds between each recording: when the vehicle approached the cushion, passed onto it, and then left it. When the time span between two recordings was greater than 7 seconds, the recordings were attributed to two different vehicles. The recorded data were discretized according to the distance and the time of detection, exploiting a recursive algorithm (in Visual Basic Advanced language) which matched each detection to the following one comparing the recording time and the distance to identify vehicles.
Finally, the speed data were plotted versus distance diagrams (from the furthest detection point to the closest one).

Fig. 1. a) The location of the telelaser (red point) to overcome spacing detection problems, example set up (Via Calefati test site). Note also that the speed cushion axis was always placed 8 m from the beginning of the pedestrian zone so that, on varying the length of the device, its furthest edge from the pedestrian zone is always approximately 10 m from it. b) Via Nicolai speed cushion.

The measurements were made in two different periods: before the installation of the cushions to investigate the "before user behavior" and at least one month after the installation, to let users get used to the novelty and to record an actual "after user behavior". In both phases, the same position of the instrument was used, and the same number of campaigns were carried out, 18 days of measurements. The first one was run in September-October 2020 and the second one during February-March 2021. The average daily traffic measured for the three sites, during the survey was between 52 vehicles/hour and 203 vehicles/hour, highlighting a great variability depending on the day of the week. Despite this variability, the three sites showed comparable traffic flows during the three-time intervals of the on-site measurements. Future studies will analyze the possible relationship between speed cushions and vehicular flows, also during peak hours, when the traffic flows are significantly different at the three sites.

4. Results and discussion

In this section, first results from the experimental survey are presented and discussed. An example of speed data obtained in the case of before-speed cushion detections for the Via Nicolai site is shown in the Figure below. The blue dots represent all the collected data, the yellow, purple, green, and red dots stand for, respectively, the V_{15}, V_{avg}, V_{85}, and V_{max} for each cross section of the investigated road segment. The dispersion of blue dots depends on speed distribution at each detection section and on how the measurements were run. Similar diagrams were obtained for the other test sites and in the "after installation" condition.

The measurements in the before scenario were then compared with the after scenario. In particular, the points representing the before and after V_{15}, V_{avg}, V_{85}, and V_{max} speeds were plotted together, and they were interpolated by 5th-grade polynomial curves (one for each typical speed and each before/after condition), to achieve an optimal fitting.

An example plot is shown in Fig. 3, where each polynomial regression curve is colored in the same color as the dots extracted from the before (Fig. 2) and after graphs.

Apart from the overall speed reduction, it was possible to correlate the speed reduction in terms of ΔV (km/h) and the length of the cushions, which was one of the research questions of this study. In table 3 the ΔV for the typical speeds are reported (by excluding the V_{min} and V_{max} values which poorly represent the overall driving behavior). The speed reductions ΔV are measured at the minimum of the speed profiles in the three test sites, and at the beginning of the pedestrian area.

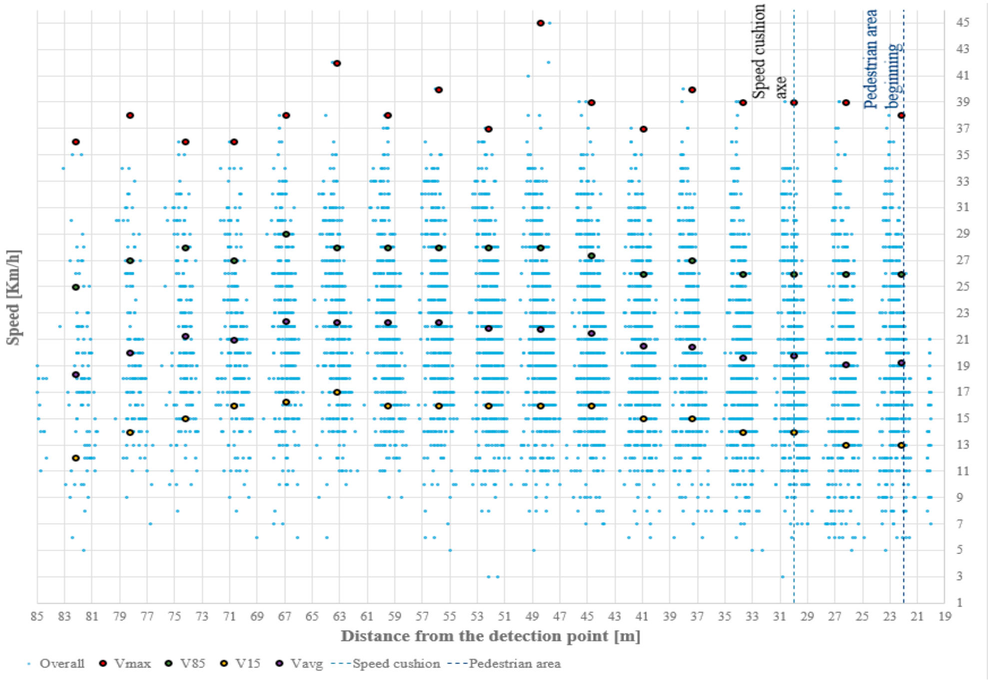

Fig. 2. Measured speed data plotted against the distance from the detection point at the Via Nicolai test site before the implementation.

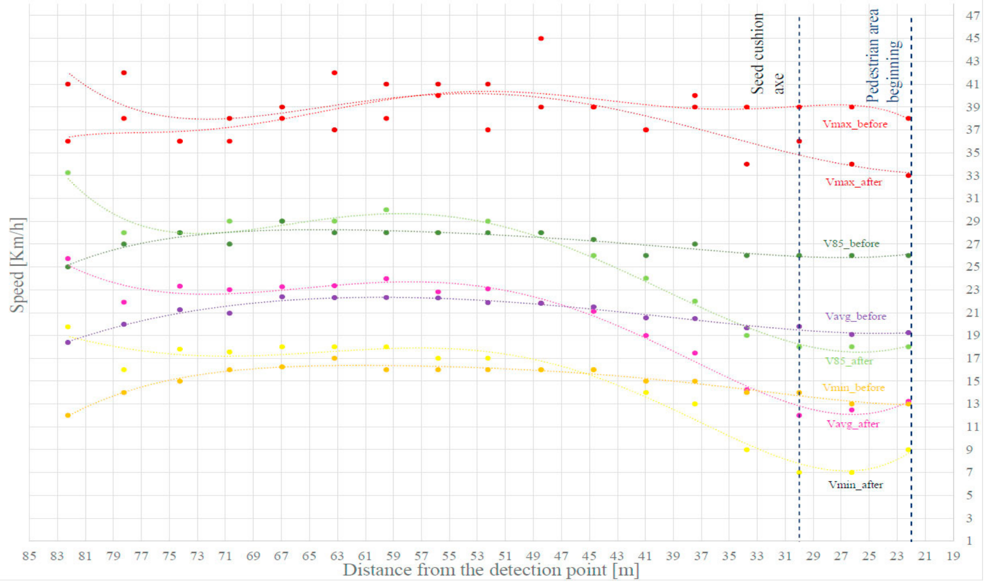

Fig. 3. Speed profiles before and after the implementation of the speed cushions at the Via Nicolai test site.

In previous research (DfT, 2007; Layfield and Parry, 1998) speed cushions were found to be accountable for remarkable speed reductions and a variable traffic volume decrease. The current study has indeed highlighted great speed reductions achieved by use of the cushions (between 30 and 50% depending on the considered speed). This great speed difference can also be explained by the combined effect of lane narrowing at the sites.

Table 3. Speed before/after differences (ΔV) recorded for at the three test sites in correspondence to the beginning of the pedestrian zone and at the beginning of the speed cushion.

		Speed cushion			Pedestrian area		
Test site	Cushion length (m)	ΔV_{85} (km/h)	ΔV_{avg} (km/h)	ΔV_{15} (km/h)	ΔV_{85} (km/h)	ΔV_{avg} (km/h)	ΔV_{15} (km/h)
Via Calefati	3.2	7.0 (-29.2%)	6.0 (-34.5%)	6.0 (-50.0%)	5.0 (-21.7%)	4.0 (-24.5%)	4.0 (-33.3%)
Via Putignani	2.2	10.0 (-38.5%)	8.7 (-43.9%)	7.1 (-54.2%)	8.0 (-30.8%)	6.0 (-32.9%)	6.5 (-42.9%)
Via Nicolai	2.7	8.0 (-30.8%)	7.8 (-39.3%)	7.0 (-50.0%)	8.0 (-30.8%)	6.0 (-32.9%)	4.0 (-42.8%)

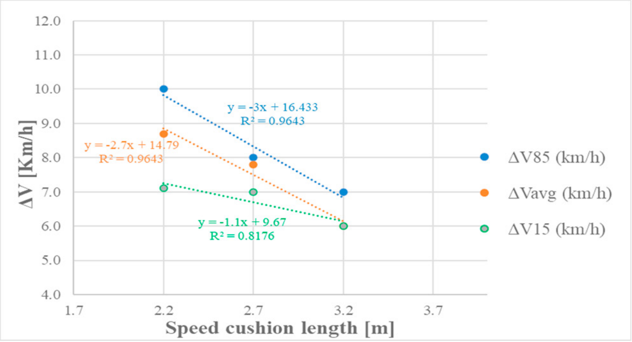

Fig. 4. Speed differences referred to the minimum of the speed profiles plotted against the speed cushion lengths.

The speed difference decreases with an almost linear trend with the increase in the length of the device (Fig. 4). This behavior is in contrast with previous research (Dft, 2007). On the other hand, Layfield and Parry (1998) developed a formulation that linked the cushion dimensions and the speed before the installation of a cushion to determine the speed after the installation. By applying this formula to our case, reductions in the average speeds are achieved only for very short cushions (shorter than 1.20 m) and they increase with the decrease in the cushion length; while for longer cushions, the predicted speed may even increase after the installation, in contrast with the results shown here. Moreover, Johnson and Nedzesky (2004) and Berthold and Leclerc (2013) highlighted that, among all traffic calming devices similar to speed humps and cushions, the shortest ones are the most effective in terms of speed reduction (i.e., speed humps are more effective than long speed cushions). Our study shows that speed differences can be noted for speed cushions of lengths between 2.2 m and 3.2 m, but this is coherent with the other studies which showed that the longer the device is, the lower is the measured speed difference after the installation. This could be explained by driver perception. In fact, when the cushion is longer, its impact on the vehicle could be perceived by the driver as less dangerous in terms of the grounding phenomenon or of damage to the vehicle suspension than a shorter cushion. However, given the different results in previous research, this aspect should be further investigated.

During the surveys visual inspections were also performed. The results indicate that almost the half of the vehicles drove over the cushion appropriately (the variability was 50.0 - 57.5% according to the investigated roads); the other drivers tried to avoid the cushion by passing it laterally. Some users stopped their vehicle just before the device, scared by its presence and stopping all the following cars. During the time slot when there was no pedestrian traffic and the vehicles were almost absent (at around 10 p.m.) the drivers tended to speed up, not considering the device. As far as motorcycles and mopes are concerned (while very few cyclists were noticed), they were not affected by the presence of the cushion except when cars were in a queue before the device and so they had to avoid the stationary cars, then try to sneak between the vehicles, then reduce their speed.

5. Conclusions

The main aim of installing speed cushions is to reduce speeds, especially in areas with limited travel speed, and induce drivers to drive safely with specific regard to the presence of vulnerable road users. In this light, Berlin speed cushions are an *ad hoc* intervention addressed to cars, drastically reducing their speed, while aimed at not modifying the behavior of cyclists, motorcyclists, moped, emergency/public transport vehicles (DfT, 1998; TRL, 2003).

This effect was confirmed in this case study, where the average speeds decreased in a range between approximately

35% and 45% and operating 85th speeds decreased in a range between about 30% and 40% after the cushion installation. Moreover, some of the motorcyclists were indirectly affected by the cushion presence, as well as drivers.

It should be underlined that this is an exploratory study describing the preliminary results obtained from the before-and-after speed observations. Given all the parameters which may affect drivers' speeds, such as vehicular and pedestrian traffic, hour of the day, cushion length, acquired familiarity with the device, in-depth analyses should be performed to assess the influence of these variables on speed measures and driving behavior. Further studies are planned, to inquire into these aspects in detail.

However, even at this stage, a positive effect of the speed cushions on road safety has already been noticed. It could be also improved with the combined spread of more Zone 30 and Zone 10 sections in the urban context. In this case, safer and more pedestrian and cyclist-friendly cities should become a widespread reality.

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References

Berloco, N., Colonna, P., Intini, P., Masi, G., & Ranieri, V., 2018. Low-cost smartphone-based speed surveying methods in proximity to traffic calming devices. *Procedia computer science*, 134, 415-420.

Berthod, C., Leclerc, C., 2013. Traffic calming in Québec: speed humps and speed cushions. *Journal of Civil Engineering and Architecture*, 7(4), 456.

Casanova J., Fonseca N., 2012. *Environmental assessment of low-speed policies for motor vehicle mobility in city centres*. Universidad Politécnica de Madrid.

CETUR - Centre d'étude des transports urbains (1992) Guide Zone 30. *Méthodologie et recommandations*, CETUR, Bagneux.

Chang, K. N., Nolan, M., & Nihan, N. L., 2007. Developing design standards for speed cushions. *Transportation research record*, 2030(1), 22-28.

Decreto Legislativo n.285 of 30 aprile 1992, *Codice della Strada*.

Decreto Ministeriale n. 6792 of 5 novembre 2001, *Norme Funzionali e Geometriche delle Strade*.

Delaware Department of Transportation (DDT). *Delaware Traffic Calming Design Manual*, 2012 Edition.

Department for Transport (DfT), 1998. *Speed cushion schemes*. Traffic Advisory Leaflet 1/98, February 1998.

Department for Transport (DfT), 1996. *Developing a Strategy for Walking*.

Department for Transport (DfT), 2007. *Traffic calming*. Local Transport Note 1/07.

Greenreport, 2013. Una velocità nuova per la sicurezza: 30 km/h per dimezzare il numero di vittime.

Johnson, L., & Nedzesky, A. J., 2004. A comparative study of speed humps, speed slots and speed cushions. In *ITE Annual Meeting and Exhibit* (Vol. 14).

Khorshid, E., Awada, H., Falah, A. H., & Elkholy, A., 2020. Optimal design of traffic calming devices using computer simulation. International *Journal of Modelling and Simulation*, 40(5), 375-393.

Layfield, R. E., Parry, D. I., 1998. *Traffic Calming-speed cushion schemes*. TRL Report 312.

Loprencipe, G., Moretti, L., Pantuso, A., & Banfi, E., 2019. Raised pedestrian crossings: analysis of their characteristics on a road network and geometric sizing proposal. *Applied Sciences*, 9(14), 2844.

Ministero delle Infrastrutture e dei Trasporti. Registro Ufficiale. U. 0006968, 01-10-2019. *Sperimentazione di dispositivi di moderazione delle velocità denominati "cuscini berlinesi" su strade urbane del Comune di Bari*.

Ministero dei lavori pubblici, prot. N. 3698. Ispettorato generale per la Circolazione e la Sicurezza Stradale. *Linee guida per la redazione dei piani urbani di sicurezza strada*. 2001.

Minnema, R., 2006. *The evaluation of the effectiveness of traffic calming devices in reducing speeds on" local" urban roads in New Zealand*.

Mountain, L. J., Hirst, W. M., & Maher, M. J., 2005. Are speed enforcement cameras more effective than other speed management measures?: The impact of speed management schemes on 30 mph roads. *Accident Analysis & Prevention*, 37(4), 742-754.

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.

Schwizerische Eidgenossenschaft, 2015. VSS SN 640213. *Concepition de l'espace routier. Eléments de moderation du traffic*.

Transport Research Laboratory (TRL), 2003. *Traffic Advisory Leaflet 198*, TRL Report 312, Local Transport Note.

Webster, D., Layfield, R. E., 2003. *Review of 20 mph zones in London Boroughs*. Wokingham, UK: TRL Limited.