EVALUATION OF THE EFFICIENCY OF TRAFFIC LIGHTS TURNING RED IN CASE OF EXCEEDING SPEED LIMIT WITH PREVIOUS PANELS INDICATING THE SPEED

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ABSTRACT

A usual traffic calming measure (TCM) to reduce vehicle speed in urban areas is the traffic lights that turn red when a vehicle exceeds the speed limit. These traffic lights can detect if an approaching vehicle exceeds the speed limit and, if so, stop it by means of a red light. It is generally employed in interurban roads rather than in big cities, where the presence of traffic lights is common. In a rural road crossing a small village, they are deployed to reduce the risk of accidents to vulnerable road used when vehicles arriving at high speeds tend to conflict with pedestrians attempting to cross the road.

The aim of this paper is to analyze the efficiency of this TCM, preceded by panels indicating the vehicles' speed, by controlling the vehicles' speed in the A-132 road that crosses through the village of Azazeta in the province of Álava/Araba (Spain). Different sequence of the TCMs can be found in each direction approaching the village; in A direction, warning traffic lights, the panel indicating the speed and the traffic light turning red; and in B direction, the panel, the warning traffic lights and the traffic lights turning red.

However, similar results were obtained in both directions for average speeds and percentile 85 of the speed distribution at the traffic lights, and speed was reduced as motorists faced the TCMs. However, although average speed was below speed limit (50 km/h), the percentile 85 was over it, implying that more than 26% of drivers did not respect the red light. Moreover, after the traffic lights turning red, motorist speed up and higher values were measured at the midpoint of the urban segment, the place where pedestrians use to cross from one side of the village to the other one, although no pedestrian crosswalk is available.

1. INTRODUCTION

Traffic calming measures (TCMs) are a usual solution for reducing vehicles' speed in urban areas. TCMs are defined as the combination of mainly physical measures that reduce the negative effect of motor vehicle use, alter driver behaviour and improve conditions for non-motorized street users (Lockwood, 1997). Their main aim is the reduction of vehicles' speed and volumes in an area because speed is directly related to the probability of death for pedestrians involved in a crash, as shown in Table 1 (TRB, 2010; Tefft, 2011) despite the multiple factors that are involved in a highway crash (Llopis-Castelló et al. 2019; Ziolkowski, 2019).

Collision speed (km/h)	80	65	50	32
Chance of pedestrian death (%)	100	80	40	5

Table 1: Chance of pedestrian death if hit by a motor vehicle.

There are a wide variety of possibilities for TCMs but they are generally classified in the following groups (Kveladze and Agerholm, 2018; Gonzalo-Orden et al. 2016; Ziolkowski, 2018; Pérez-Acebo et al. 2020a):

- Vertical deflection: Speed hump, speed bump, speed cushion, rumble strip, raised intersection, raised crosswalk, road lump and table.
- Horizontal deflection: Curb-extension, chicane, gateway, traffic circle, raised median island.
- Physical obstruction: Semi and diagonal diverter, right-in and right-out island, raised median through intersections, street closure
- Signs and pavement markings.

In urban areas, calmed road segments are achieved due to the succession of traffic calming measures in the area. Nevertheless, an important problem is observed in the transition from and interurban area to an urban area, i.e. at the beginning of the urban area (Gonzalo-Orden et al. 2018; Pérez-Acebo et al. 2021a). The problem is increased in rural roads crossing small villages that are not bypassed. When drivers arrive to a short urban area, as the ones that can be found in rural roads crossing small villages, they do not usually reduce their speed conveniently, maintaining high speeds allowed in the interurban area and, hence, increasing the risk for pedestrians in the village (Table 1).With the aim of reducing the speed of the vehicles during the short segments of these villages, traffic calming measures are placed at the entrance to indicate that drivers are entering an urban area, even for a short period of time, and, to force them to speed down. Typical solutions at the border between non-urban and urban areas are raised crosswalks, signs with speed limits, panels displaying vehicle speed, radars (which could fine if drivers exceed speed limit), etc., and their efficiency is being analyzed (Gonzalo-Orden et al. 2018; Daniels et al. 2019).

A common solution in Spain is traffic lights turning red if the speed limit is exceeded. The traffic lights detect an approaching vehicle, measure its speed and, if it is higher than the speed limit, they try to stop it by turning red immediately. Consequently, in theory, drivers speed down in front of a red light and, when speed is reduced below the limit, the lights turn yellow again. Few studies can be found in the literature about this type of TCM. Generally, papers are focused on traffic offenses involving red lights and how red light cameras can be efficient on crashes (Llau et al. 2015; Baratian-Ghorghi et al. 2016). Pérez-Acebo et al. (2021a) analyzed the efficiency of traffic lights turning red in case of exceeding speed limit and they showed that better results were obtained if the traffic lights were combined with a crosswalk.

The aim of this paper is to measure the efficiency of traffic lights turning red in rural roads crossing villages with a short urban segment, preceded by panels indicating the speed. The case study took place at the A-132 road and at the village of Azazeta, in the province of Álava/Araba (Spain). The traffic lights were placed at the entrance of the village on both directions and before them panels indicating the instantaneous speed of each vehicle were also posted. It was aimed to observe the speed reduction achieved combining both TCMs (the traffic lights and the panels) at the centre of the village.

2. METHODOLOGY AND CASE STUDY

As explained before, the village of Azazeta and the A-132 running trough it were selected as a case study for analyzing the efficiency of traffic lights turning red in case of exceeding speed with previous panels indicating the drivers' speed. The A-132 road belongs to the Regional Government of Álava/Araba, one of the 3 provinces of the Basque Country. Due to the special legal status of the Basque Country, all the roads in each of the provinces belong to the regional government of the province, even those connecting to other regions and countries. Consequently, the Spanish Government does not manage any road in the Basque Country (Pérez-Acebo et al. 2020b; 2021b).

The A-132 road is included in the Basic Network (orange network), which is the second level of importance in the province. Table 2 shows all the road network categories in which the road network of the province is divided (DFA/AFA, 1990; Hernández et al. 2021). The A-132 road goes from Vitoria-Gasteiz (the capital of the province of Álava/Araba) to Estella, in the Region of Navarre.

When entering in the Region of Navarre, as that stretch from the border to Estella belongs to the Regional Government of Navarre, the road changes its name to NA-132-A. In the segment in the province of Álava/Araba, there is the mountain pass of Azazeta, and at the bottom of it, after crossing it coming from Vitoria-Gasteiz, the village of Azazeta is located.

Road Network level	Lenght (km)
Preferential interest network (red)	145.7
Basic network (orange)	146.42
Provincial network (green)	200.91
Local network (yellow)	534.23
Neighborhood network (grey)	373.02

Table 2: Length (km) of the road network in the province of Álava/Araba.

At the mountain pass, there is a permanent counting station, measuring passing vehicles continuously and, hence, provided values are real. The obtained values, shown in Table 3, represent the traffic flow for a 17.5 km-long segment, including the entire mountain pass and the village of Azazeta.

Table 3 shows the values of the Average Annual Daily Traffic (AADT), the percentage of heavy vehicles and the Average Annual Daily Traffic of Heavy Vehicles (AADTHV), in both directions. In Spain, a vehicle needs to weight more than 3,500 kg to be considered as a heavy vehicle (MFOM, 2003; Pérez-Acebo et al. 2020b). As seen, the total traffic volume and the percentage of heavy vehicles increase each year.

Years	AADT (vehicle/day)	% of heavy vehicles	AADTHV (heavy vehicle/day)
2019	3510	8.6	302
2018	3453	5.1	280
2017	3411	6.2	213
2016	3352	6.0	221
2015	3239	5.9	192
2014	3202	5.8	187

Table 3: Traffic volume values at the permanent counting station of Azazeta (190) for the last years.

The A-124 crosses the village of Azazeta, in a segment of approximately 240 m, dividing the urban area in two approximately similar parts (Figure 1).

There is not any pedestrian crosswalk between the two parts. Nevertheless, the Regional Government of Álava/Araba wanted to reduce the speed of vehicles crossing the village because inhabitants cross the road to access the other part of the village.

With this aim, various traffic calming were introduced to speed down the traffic. Moreover, in the direction from Vitoria-Gasteiz to Estella, vehicles have just gone down the mountain pass and their speed tends to be high. Consequently, the TCMs were necessary to calm down the urban area of this short road segment.

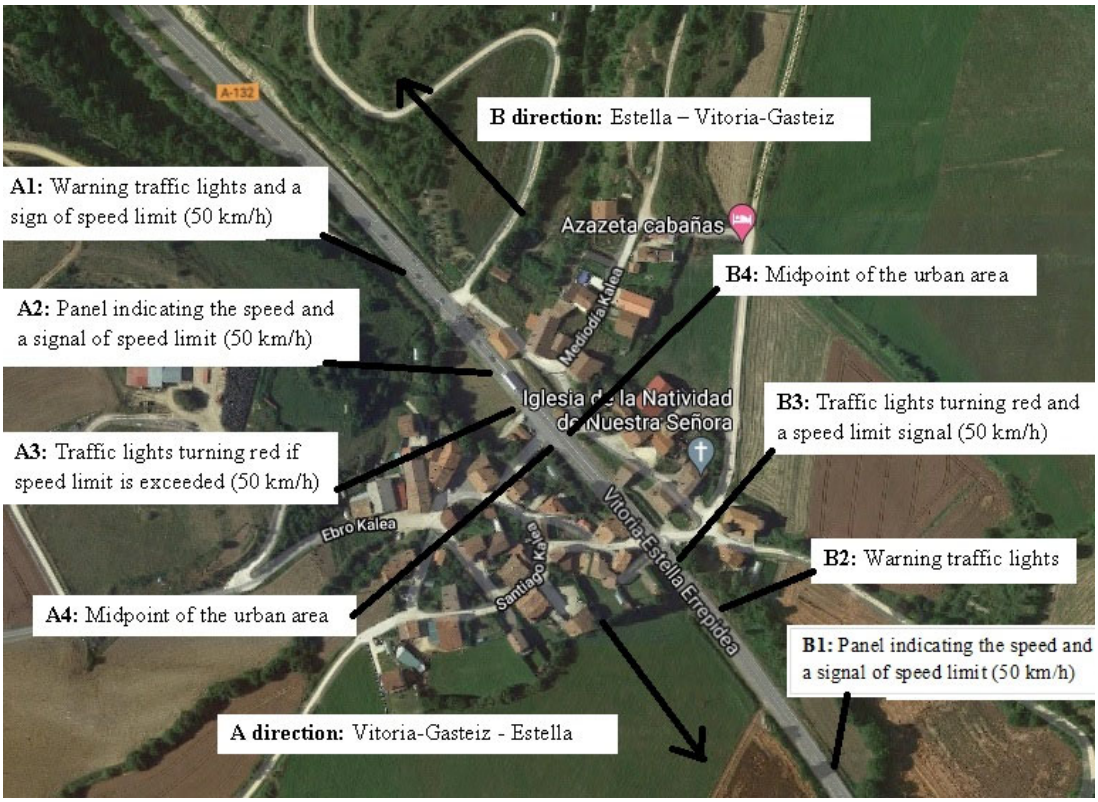

Figure 1: Aerial photo of the village of Azazeta and locations of the TCMs.

Traffic lights turning red if speed is exceeded and some previous panels indicating the speed of each vehicle were placed in both directions. In each direction, the sequence of the TCMs is as follows:

Vitoria-Gasteiz – Estella direction (north – south) (Figure 2):

- Point A1: Traffic lights warning about the presence of traffic lights and a signal with a speed limit of 50 km/h.
- Point A2: A panel indicating the speed of each vehicle (with a speed limit of 50 km/h).
- Point A3: Traffic lights turning red if speed limit is exceeded.
- Point A4: Mid-point of the urban segment, where pedestrian cross the road.

Estella - Vitoria-Gasteiz (south - north) (Figure 2):

- Point B1: A panel indicating the speed of each vehicle (with a speed limit of 50 km/h)..
- Point B2: Traffic lights warning about the presence of traffic lights.
- Point B3: Traffic light turning red if speed limit is exceeded and a signal reminding the speed limit (50 km/h) some meters before.
- Point B4: Mid-point of the urban segment, where pedestrian cross the road.

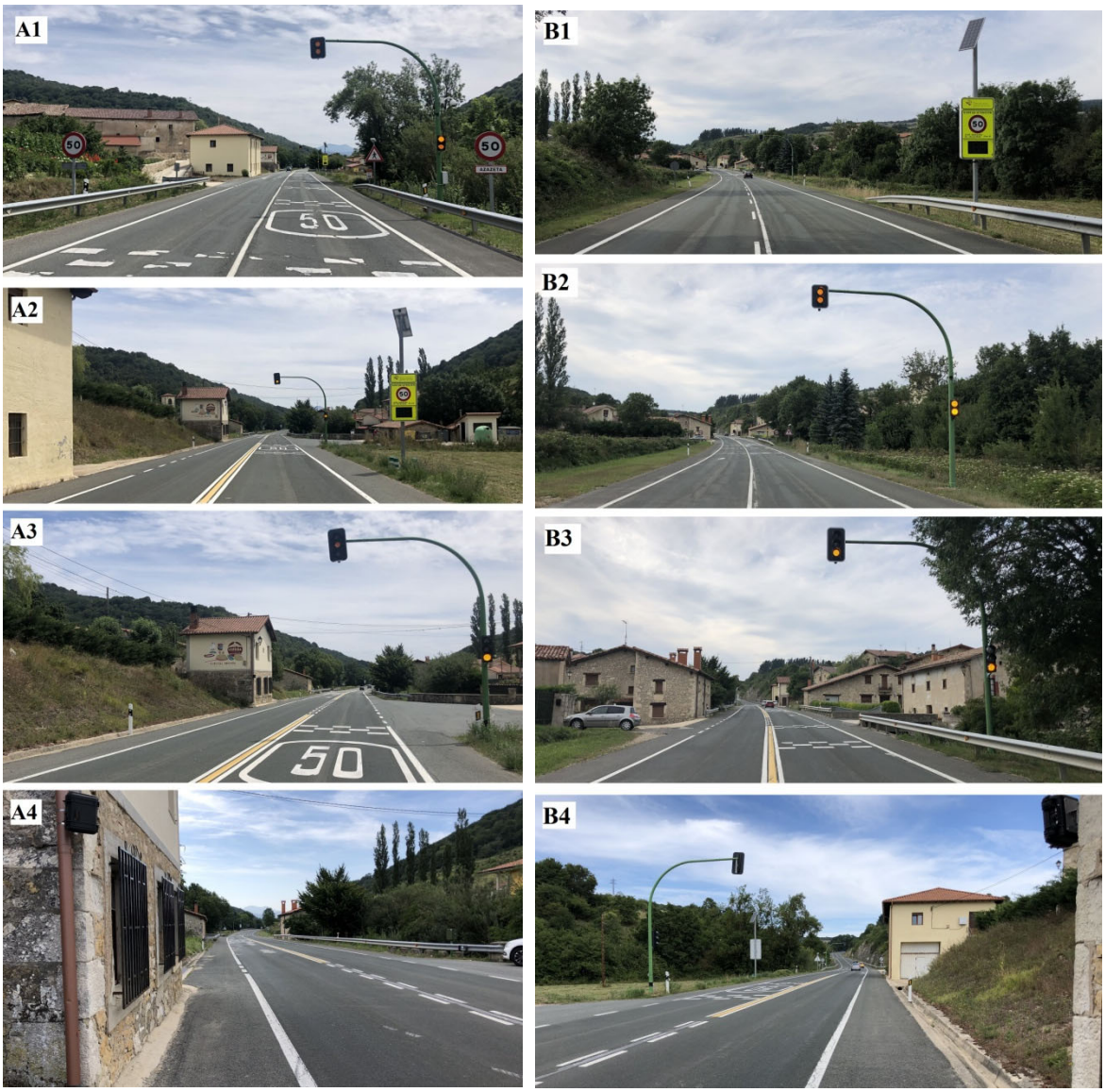

Figure 2: Traffic calming measures in direction A (points A1, A2, A3, and A4) and in direction B (points B1, B2, B3, and B4).

As seen, the sequence is not identical in both directions. While in north-south direction, there are traffic lights warning about the presence of more traffic lights and then the panel indicating the speed appears, in the other direction the panel is placed before the warning traffic lights. Additionally, Point A4 and B4 represents the same point, the midpoint of the urban area and the different name for it means the direction of the measured traffic volume.

Speed measurements were taken on August 6, in 2019. This type of small villages has a higher population in summer because many people spend their holidays in these small villages, leaving the big cities. A fixed radar was placed in point A4/B4 to measure the speed at the midpoint of the urban area, where inhabitants tend to use to cross the road in spite of the lack of an adequate pedestrian crosswalk. Moreover, warning signals (triangular) indicating that pedestrian could eventually cross the road are placed between A1 and A2 and between B2 and B3.

Therefore, this point represents the place where the effect of the traffic calming measures must take place in case pedestrians want to cross the road. Furthermore, at this place, vehicles coming from any of the two urban areas access to the main road, the A-132.

Additionally, from 11:00 am to 2:00 pm, a gun radar was employed to measure the speed of vehicles in points A1 and A3 from a hidden place, not to disturb vehicles' speed. Speeds shown to the vehicles in the panel of point A2 were also recorded and, hence, a complete speed profile of the vehicle was possible to obtain. Similarly, from 3:30 p.m. to 6:30 p.m., the same gun radar was used to measure the speed of vehicles in point B2 and B3 from a hidden place and the speed indicated in the panel in B1 was also registered.

The aim of this study was to show how the speed is reduced at the traffic lights turning red in the case of exceeding speed limit in two different configurations (with the panel indicating the speed nearer or further from the traffic light), know the speed profile of the vehicles approaching the traffic lights and how the reduced speed is maintained after the traffic lights, at the place where pedestrian would cross the road.

3. METHODOLOGY AND CASE STUDY

More than 1700 vehicles were controlled at the midpoint of the urban area (A4/B4) in both directions, and 334 vehicles in direction A and 257 in direction B. Table 4 presents the average speed of the vehicles, V_{ave}, the percentile 85th of the speed, V_{85} (which is the speed not reached by 85% of vehicles or, from another point of view, the speed achieved or exceeded by 15% of the vehicles), the maximum speed V_{max}; and the minimum speed, V_{min}. Moreover, Table 4 also includes the number of vehicles exceeding the speed limit (50 km/h), and the percentage of vehicles exceeding this limit from the total of measured vehicles.

Direction	Vitoria-Gasteiz – Estella				Estella – Vitoria-Gasteiz			
Points	A1	A2	A3	A4	B1	B2	B3	B4
V_{min} (km/h)	27	27	19	7	35	26	10	4
V_{ave} (km/h)	56.33	49.9	46.2	53.4	68.7	59.0	46.5	55.0
V_{85} (km/h)	67	59	55	65	83	72	56	66
V_{max} (km/h)	105	92	79	99	103	95	84	103
Total number	334	334	334	361	257	257	257	807
Vehicles V>50 km/h (units)	216	122	88	588	231	180	79	569
Vehicles V>50 km/h (%)	64.7	36.5	26.3	61.2	89.9	70.0	30.7	70.5

Table 4: Measured values of selected variables at control points in both directions.

As observed, in the Vitoria-Gasteiz – Estella direction, the average speed at A3 (the point of the traffic light turning red) was 46.2 km/h, and the V_{85} is 55 km/h, implying that 26.3 % of the vehicles did not respect the speed limit and the red light, and continued their way. Fortunately, a decrease on the speed can be seen from point A1 to point A3 (Figure 3a).

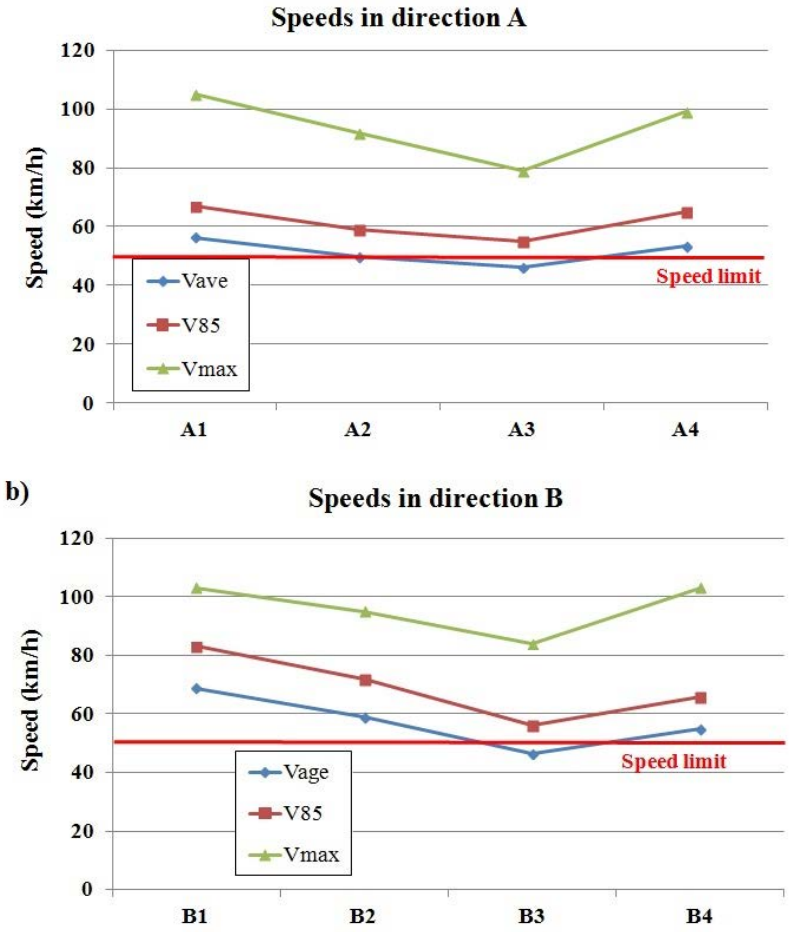

Figure 3: Speeds at each controlled point, a) in direction A; b) in direction B.

It shows that the first traffic lights warning about the presence of traffic lights serves as a first warning but even the average speed is over the speed limit at this point. Motorists speed down at the next point, where the panel indicates their speed, and the V_{ave} is below the speed limit, but not the V_{85} (36.5 % of the vehicles did not respect the limit). Finally, as commented, the better values are obtained at point A3, with the traffic light turning red, as drivers drive more carefully due to the possibility of a fine. Nonetheless, at point A4, the midpoint of the urban area, the place where pedestrian could appear, motorist speed up as they feel they are not controlled. Even the average point at this point (A4) is over the speed limit, with 61.2 % of vehicles faster than allowed (Figure 3a). In Figure 4a, the cumulated distributions of speeds at each point in A direction are shown.

In the other direction, Estella – Vitoria-Gasteiz, similar results were obtained (Table 4, Figure 3b). Speed is reduced from point B1 to B3, reaching the lowest value at B3, where the traffic light that can turn red if speed is over 50 km/h is placed. At B1, where the panel shows the speed to drivers, high speed values were registered despite the speed limit of 50 km/h: the average speed is over 68 km/h and the V_{85} is 83 km/h. Fortunately, lower values were measured in B2 and in B3, the average speed was below the speed limit, 46.5 km/h, and the V_{85} was 56 km/h.

The percentage of drivers not respecting the red light was 30.7 % in B3. Once again, at point B4 motorist speed up and an average speed of 55 km/h was observed, V_{85} was 66 km/h and 70.5% of vehicles did not respect the speed limit. In Figure 4b, the cumulated distributions of speeds at each point in B direction are shown.

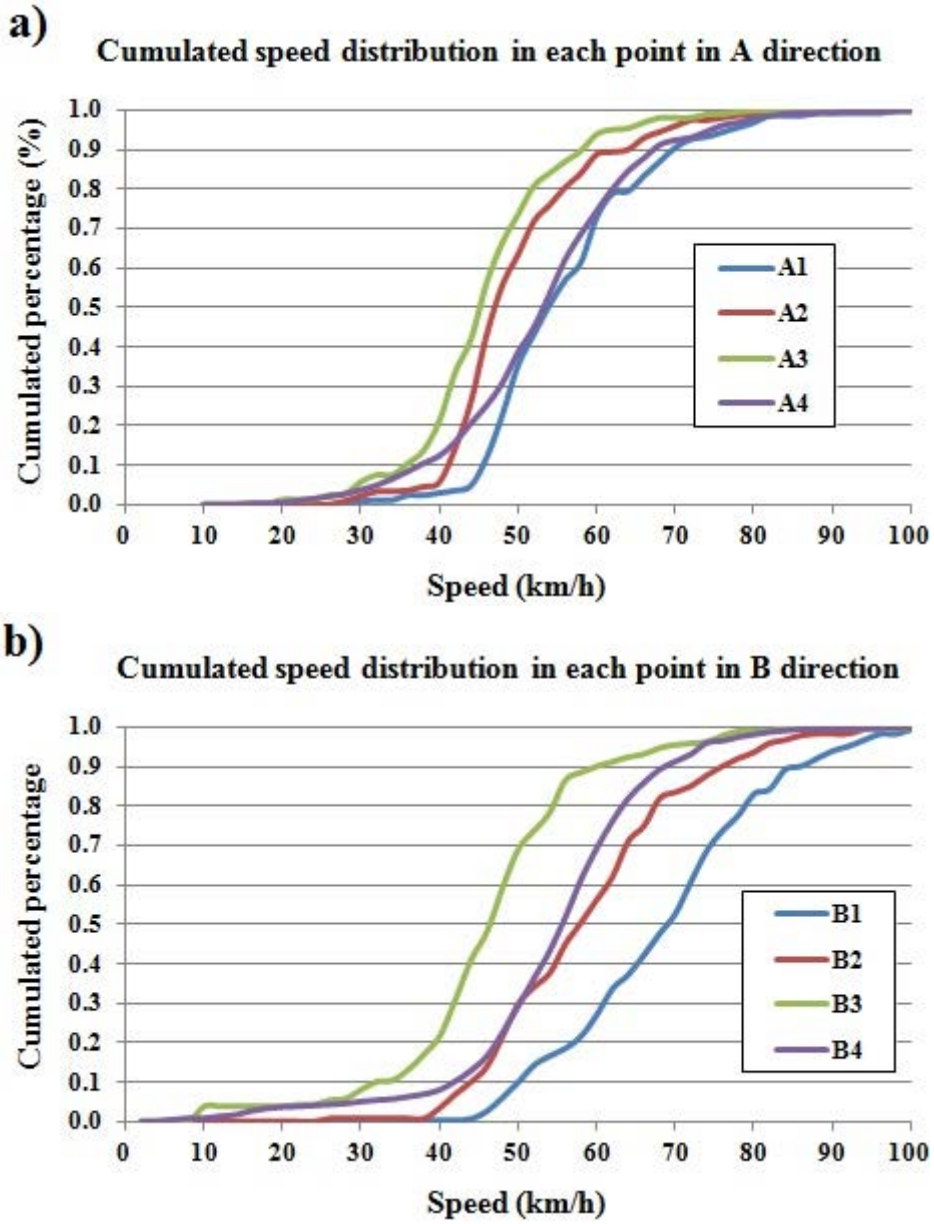

Figure 4: Cumulated speed distribution at each point, a) in A direction, b) in B direction.

If values obtained at the midpoint of the urban area are compared (A4 and B4), similar values are obtained. Average values of 46.2 and 46.5 km/h and V_{85} values of 55 and 56 km/h were measured in direction A and B, respectively. Consequently, the order of the sequence (panel and warning traffic lights or warning traffic lights and panel) obtained similar results at the subsequent traffic light turning red in case of exceeding speed limit and at the midpoint of the urban area.

However, it must be noted that higher values were recorded in B1 than in A1, but it could be due to the fact that B1 is further from the urban area than A1, which is very near from the start of the urban area. Although panels show the driving speed to motorist, they understand that they are still far from the urban area and they may think that they have time to speed down.

Moreover, the fact that values obtained in A4 and B4 are similar and higher than in A3 and B4 indicates that drivers tend to accelerate as they feel that they have passed the traffic light turning red and that, despite being in an urban area, the controlled area (at the traffic lights) is finished. Drivers' experience show them that the traffic lights could be the place where the radar of the police could be located (controlling the speed or not violating a red light), but not after passing them. These values also show that although drivers can respect the speed limits at the TCMs but, after them, they forget their effect.

Finally, if we compared the values obtained at the traffic lights of Azazeta with a similar study in Ábalos (Region of La Rioja, Spain) (Pérez-Acebo et al. 2021a) some conclusions can be deduced. In Ábalos, traffic lights turning red in case of exceeding speed limit were placed after warning traffic lights but without panel indicating the speed. However, in one direction the traffic light included a pedestrian crosswalk, and in the other one without pedestrian crosswalk. Table 5 compares the measured speed values in Azazeta and Ábalos.

Location	Azazeta (Álava/Araba)		Ábalos (La Rioja)	
Point	A3	B3	A2	B3
Placed TCM	Traffic lights turning red	Traffic lights turning red	Traffic lights turning red	Traffic lights turning red and pedestrian crosswalk
V_{ave} (km/h)	46.2	46.5	50.5	30.5
V_{85} (km/h)	55	56	60	42
V_{max} (km/h)	79	84	85	80
Total number	334	257	261	1411
Vehicles V>50 km/h (units)	88	79	224	255
Vehicles V>50 km/h (%)	26.3	30.7	58.8	18.1

Table 5: Speed values in traffic lights turning red in Azazeta and in Ábalos (from Pérez-Acebo et al. 2021a).

As seen, the presence of a crosswalk help reducing the vehicles' speed, reinforcing the effect of the traffic light turning red in case of exceeding the speed limit. As seen, the introduction of a panel indicating the speed helps also improving the efficiency of the traffic lights, better if it is located just before the traffic light (as in A3 in Azazeta) and not at the beginning of the sequence as in B3 in Azazeta. Nonetheless, the best effect is achieved if the pedestrian crosswalk is placed with the traffic lights, because drivers would respect more the speed limit.

Apart from the possible fine if the limit is not respected, a pedestrian could appear, wanting to cross the road and that possibility contributes to a higher speed reduction (or a higher percentage of drivers respecting the speed limit).

4. CONCLUSIONS

The study analyzes the efficiency of traffic lights turning red if the speed limit is exceeded preceded by panels indicating the vehicles' speed. Traffic lights that turn red if the approaching vehicle exceed speed limit are a usual traffic calming measure in rural roads crossing short urban segments. The selected village, Azazeta, is crossed by the A-132 road (Vitoria-Gasteiz – Estella), managed by the Regional Government of Álava/Araba, and traffic lights turning red, panels indicating the speed and warning traffic lights in a different sequence. While in A direction (Vitoria-Gasteiz – Estella), the sequence is warning traffic lights, the panel, and the traffic lights turning red, in B direction (Estella – Vitoria-Gasteiz), the sequence is the panel, warning traffic lights and traffic lights turning red. In both directions a speed reduction is observed as drivers pass each traffic calming measure, achieving the lowest speed at the traffic lights turning red, with a similar average speed (slightly over 46 km/h), below the speed limit (50 km/h), but the percentile 85 of the speed distribution is over the speed limit (55 and 56 km/h in A and B direction, respectively), indicating that 26.3% and 30.7% of drivers did not respect the red light. Moreover, after the traffic lights turning red, drivers speed up and higher speeds are measured at the midpoint of the urban segment in both direction. Additionally, obtained results were compared to other traffic lights turning red in Ábalos (La Rioja) and the lowest speeds were obtained when combining the traffic lights with a pedestrian crosswalk.

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