EFFECTS OF SPEED TABLE, CHICANE AND ROAD NARROWING ON VEHICLE SPEEDS IN URBAN AREAS

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Abstract. Objectives: The aim is to evaluate the effectiveness, in order to speed reduction, of three traffic calming measures: 1) speed table, 2) chicane, 3) road narrowing. Prior Work: Many researches show the effectiveness in reducing the speed of the traffic calming measures. To this effect, field measurements were made on street sections with different traffic calming measures. In addition, driving simulators and microsimulation-based technique are used. Approach: The speed analyses regard a series of traffic calming measures located in Italian urban contexts. In order to study the variation of the cinematic characteristics of the vehicles, have been chosen various speed measurement sections. Subsequently, the following were calculated: 1) the average speed on all the sections; 2) the 85\textsuperscript{th} percentile speed. Results: The presence of traffic calming measures analyzed in this study results in a significant reduction in speeds. This reduction occurs within the following ranges: 40-50\% for speed tables, 40-50\% for chicane and 35-40\% for road narrowing. Value: It has been demonstrated the concrete possibility of “forcing” drivers to reduce speed. If the traffic calming measures were implemented systematically in urban areas, it could be obtained, with little investments, a result of great importance for the road safety.

Key words: Traffic calming, Road safety, Experimental survey.

1. INTRODUCTION

The concept of traffic calming is fundamentally concerned with reducing the adverse impact of motor vehicles on built up areas. This usually involves reducing vehicle speeds, providing more space for pedestrians and cyclists, and improving the local environment.

Traffic calming schemes generally incorporate a wide range of measures designed to complement each other in both speed reduction and environmental terms. Engineering options are more diverse and employ one or more of the following techniques: 1) narrowing 2) vertical deflection, 3) horizontal deflection, 4) restrictions.

Engineered options are designed to increase the complexity and cognitive load of driving, making the driver naturally slow down, or to create discomfort above certain speeds.

Many researches show the effectiveness in reducing the speed of the traffic calming measures. To this effect, field measurements were made on street sections with different types of traffic calming measures, in different places. These measurements were compared with other ones located on other street sections of similar characteristics but without traffic calming measures (Gonzalo-Orden et al., 2016; Chen et al., 2013; Ewing et al., 2013; Rahman et al., 2009). Given the strong relationship between speed and crash experience,
safety performance can be related to speed. Consequently, speed can be used indirectly as a surrogate safety measure in the absence of crash and speed data (Moreno and García, 2013).

In addition to experimental studies the effectiveness of calming traffic measures is assessed by using driving simulators and microsimulation-based techniques. In this regard, Jamson et al. (2010) highlight how driving simulators can be used to overcome the methodological constraint that do not allow you to evaluate different ranges of interventions with comparable metrics.

However, most studies focus on assessing the effectiveness of a typology or a few types of traffic calming interventions, such as types of signage, perceptual countermeasures or physical traffic calming.

Mahdy (2012) focuses on vertical deflections in road alignment to study the influence of their physical and geometric characteristics on traffic performance, in terms of speed profile. Rokade et al. (2017) also deal with the assessment of the effectiveness of vertical deflection devices that include speed bump, plastic speed bump, raised crosswalk, rumble strips and sinusoidal hump. Jateikiene et al. (2016) also present research methodology and analysis of results of vertical traffic calming measures (speed bumps, speed humps, raised crosswalks), safety islands and speed cameras influence to the road safety on Lithuanian roads. The raised island greatly reduces distractions in the behavior of the gaze and is very effective element for speed reduction (-7.24 km/h), being very visible (Lantieri et al., 2015).

Agerholm et al. (2017) have studied the effects on speed reduction following the establishment of sinus speed humps of height 10 cm and length 950 cm and chicanes with a free carriageway width of 5.30 cm and a length between the 0.5 m wide obstacles of 18 m. Abdi et al. (2017) show that the traffic calming devices, including speed humps, should be placed at appropriate distances (from 200 to 400 m) to each other to achieve balancing speed and road safety benefits against capacity. It was found that 85th percentile speeds at long distances from calming devices were 45-55 km/h for horizontally deflected streets and 40-45 km/h for vertically deflected streets (Daniel et al., 2011).

The design speeds of two common speed tables in the city of Tehran have been examined, with a length of 6.5 m and 8.5 m respectively (Falamarzi and Rahmat, 2014). For 6.5 m speed table, design speed is calculated at 41.5 km/h and for 8.5 m speed table, design speed is calculated 47.5 km/h. Also, it was found that the speed reduction due to the speed tables depends mainly on the separation between traffic-calming devices, whereas the speed over the speed tables depends crucially on the entrance-ramp slope, the speed table length, and the distance from the previous traffic control device (Moreno et al., 2011). Lee et al. (2013) evaluate the effectiveness of four traffic calming measures (two types of speed humps, speed tables, and chicanes). The results show that chicane is better than the other types of traffic calming measures considered.

Yousif et al. (2013) investigate the relationship between road narrowing spacing from a priority junction and the "major-to-major movement" driver's delay for different flow levels using a microsimulation model. The findings show that for a minor arm with two-way flow level of up to 500 veh/h, the road narrowing spacing should be at least 30 m. Once the flow level reaches 700 veh/h, the spacing should be at least 50 m, whereas for flow levels of 800 veh/h, the spacing should be at least 100 meters. Hadayeghi et al. (2006) have measured the effectiveness of a coloured slurry seal traffic calming treatment, used to "narrow" lanes of a road, in reducing driving speeds and traffic volume on residential streets.
Finally, it should be noted how many studies have considered the effect of traffic calming devices on the production of atmospheric pollutants and noise. In general, it can be stated that horizontal deflections, narrowing and restrictions result in lower production of pollutants. Vertical deflections (e.g. bumps) often result in increases in the production of atmospheric pollutants and higher noise production (Casanova and Fonseca, 2012; Daham et al., 2005; Distefano and Leonardi, 2015; Ghafghazi and Hatzopoulou, 2015; Kaffure et al., 2013; Watts, 2007).

In this paper, we will study the effectiveness, in order to speed reduction, of three types of traffic calming measures: 1) speed table, 2) chicane, 3) road narrowing. The speed analyses regard a series of traffic calming measures located in urban contexts of Catania Province (Italy). The effectiveness of such measures, highlighted by results exposed in the following paragraphs, should encourage greater spread in urban contexts.

2. METHODS

The methods for determining speed profiles in sites where the traffic calming measures described in this study are present will be dealt with in detail for each type of device.

2.1. First traffic calming measure: speed table

The investigation context is represented from the residential area that is developed around to the road called Lungo Mare Pantano street, in Riposto city (CT). In particular, on this road are two speed tables, placed to a distance between one and the other of 40 meters, realized in bituminous conglomerate and opportunely premarked (Fig. 1).

![Figure 1. Speed tables in Lungo Mare Pantano street (Riposto)](image)

In order to adequately study the variation of the cinematic characteristics of the vehicles, for effect of the speed tables presence, have been chosen the five speed measurement sections: 1) the section indicated with “A” letter, located 30 meters before the first traffic calming measure; 2) the “B” section is placed 10 m before the first speed table; 3) the section “C” is equidistant between the 2 speed tables; 4) the “D” section is located 10 m after the second speed table; 5) the “E” section is placed 30 meters after the second traffic...
calming measure. The distance described from the sequence of sections A, B, C, D and E, is
downhill, with longitudinal slope of 2%.

For speed measurement, it has been used the Autovelox 104/C2, realized from the
"Sodi Scientifica", based on the emission and the reception of a pair of laser beams that cross
the road perpendicularly. The survey operations have been completed in 10 days.

The Lungo Mare Pantano street is a road to service of an exclusively residential zone;
the traffic flows, therefore, are not elevated ever, and the greater part of the vehicles is
isolates. These conditions, evidently, are ideal in order to estimate the intrinsic effectiveness
of any traffic calming measure. The mutual conditionings between the vehicles are
practically null. Therefore, it has not been adopted the traditional criterion of selection of
distinctive hourly bands for the speed measurement; to the contrary, they have been executed
the continuous measures, until obtaining a statistically meaningful number of speeds values
relative to the isolated vehicles.

In particular, after the experimental survey, it has been obtained the speed values of
788 vehicles for the uphill distance (156 for the “A” section, 150 for the “B” section, 168 for
the “C” section, 153 for the “D” section and 161 for the “E” section) and the speed values of
775 vehicles for the downhill distance (148 for the “A” section To, 152 for the “B” section,
156 for the “C” section, 161 for the “D” section and 158 for the “E” section). Subsequently
the following assessments have been executed: A) the calculation of average speed ($S_a$) on
all the speed measurement sections; B) the calculation, for the same sections, of the 85th
percentile speed ($S_{85}$), that is that value of the speed that is not exceeded from 85% of the
road users.

2.2. Second traffic calming measure: chicane

The chicane is located in Anastasi street (road to only direction) in the urban centre of
Catania city, and is realized through two vehicle parking lines disposed alternatively on the
left margin and on the right margin of the road (Fig. 2).

For the experimental survey, six speed measurement sections have been choices: 1) the
section indicated with “F” letter, located 30 meters before the vehicle parking line on the
left margin of the road; 2) the “G” section, placed 5 meters after the beginning of vehicle parking line on the left margin of the road; 3) the “H” section, located 20 meters after the beginning of vehicle parking line on the left margin of the road; 4) the “I” section, placed 5 meters after the beginning of vehicle parking line on the right margin of the road; 5) the “L” section, located 20 meters after the beginning of vehicle parking line on the right margin of the road; 6) the section indicated with “M” letter, located 30 meters after the vehicle parking line on the right margin of the road. The distance described from the sequence of sections F, G, H, I, L, M is almost in plain.

The experimental survey was performed over a two-week period. In order to estimate the real effect of the chicane like a traffic calming measure, it have been selected three hour bands representative of three hours "of soft", that is temporal periods in which the conditionings for the road users derive mostly from the traffic calming measures presence than from the interactions with the other vehicles. The hour intervals for experimental survey, therefore, have been: 10.00-11.00, 15.00-16.00, 16.00-17.00. After the experimental survey, finally, has been obtained the speed values of 969 vehicles (161 for the “F” section, 167 for the “G” section, 171 for the “H” section, 159 for the “I” section, 148 for the “L” section and 163 for the “M” section). Subsequently the following assessments have been executed: A) the calculation of average speed \( S_a \) on all the speed measurement sections; B) the calculation, for the same sections, of the 85\(^{th}\) percentile speed \( S_{85} \).

2.3. Third traffic calming measure: road narrowing

The third measure of traffic calming analyzed is a road narrowing. Such road narrowing has not been realized “voluntarily” but is consequent to urban configuration due to the urbanization conditions and to the territory morphology (presence of substantial rocky formations). The road narrowing is located in Mandrà street (road to only direction) in the urban centre of Catania city (Fig. 3). The road has initially the width of 8 m and subsequently it is shrunk abruptly until the minimal value of 3,10 m (after around 5 meters from the beginning of the narrowing, there is a subsequent narrowing of the road section up to the attainment of the total width of 2,60 m).

Figure 3. Road narrowing in Mandrà street (Catania)

For the experimental survey, three speed measurement sections have been choices: 1) the section indicated with “N” letter, located 30 meters before the beginning of the abrupt narrowing; 2) the “O” section, placed 10 meters before the beginning of the narrowing; 3)
the “P” section, placed 10 meters after the beginning of the narrowing. The distance described from the sequence of sections N, O and P is uphill, with longitudinal slope of 1.5%.

The experimental survey has been carried out for a period of one week. In order to estimate the real effect of the road narrowing like a traffic calming measure, they have been selected three hour bands representative of three hours ’of soft’, that is temporal periods in which the conditionings for the road users derive mostly from the traffic calming measures presence than from the interactions with the other vehicles. The hour intervals for experimental survey, therefore, they have been: 10.00-11.00, 15.00-16.00, 16.00-17.00. After the experimental survey, finally, has been obtained the speed values of 462 vehicles (148 for the “N” section, 152 for the “O” section and 162 for the “P” section). Subsequently the following assessments have been executed: A) the calculation of average speed ($S_a$) on all the speed measurement sections; B) the calculation, for the same sections, of the 85th percentile speed ($S_{85}$).

3. RESULTS

In figure 4 there are the speed profiles (for average speed and for 85th percentile speed) relative to speed tables.

![Speed profiles relative to speed tables](image)

From the analysis of such diagrams, it is possible to make the following considerations:

- the speed profiles for $S_a$ and for $S_{85}$ show an attended result: both for the uphill road and for downhill road, has lowest speed in correspondence of road portion comprised between the speed tables;
- from the comparison between the $S_{85}$ values associates to the measurement sections farther from the speed tables sequence and those relative to the intermediate sections between the two traffic calming measures, it has deduced an average reduction of 25 km/h approximately (variation percentage of 40%) in the case of downhill road, and an average reduction of 30 km/h approximately (equal to 48%) in the case of uphill road;
- from the comparison between the $S_a$ values associates to the measurement sections farther from the speed tables sequence and those relative to the intermediate sections between the two traffic calming measures, it has deduced an average
reduction of 19 km/h approximately (variation percentage of 42%) in the case of downhill road, and an average reduction of 23 km/h approximately (equal to 50%) in the case of uphill road.

In figure 5 there are the speed profiles (for average speed and for 85th percentile speed) relative to chicane. From the analysis of such diagrams, it is possible to make the following considerations:

• the speed profiles for $S_a$ and for $S_{85}$ evidence remarkable speed reductions during the run on the chicane;

• from the comparison between the $S_{85}$ values associates to the measurement sections farther from the chicane and those relative to the intermediate sections between the two vehicle parking lines (“H” and “I” sections), it has deduced an average reduction of 22 km/h approximately (variation percentage of 50%);

• from the comparison between the average speed values ($S_a$) associates to the measurement sections farther from the chicane and those relative to the intermediate sections between the two vehicle parking lines (“H” and “I” sections), it has deduced an average reduction of 20 km/h approximately (variation percentage of 42%).

![Figure 5. Speed profiles relative to chicane](image)

In figure 6 there are the speed profiles (for average speed and for 85th percentile speed) relative to road narrowing. From the analysis of such diagrams, it is possible to make the following considerations:

• the speed profiles for $S_a$ and for $S_{85}$ evidence remarkable speed reductions during the run on the road narrowing;

• from the comparison between the $S_{85}$ values associates to the measurement section farther from the narrowing and those relative to the two sections nearer the road narrowing, it has deduced an average reduction of 17 km/h approximately (variation percentage of 35%);

• from the comparison between the $S_a$ values associates to the measurement section farther from the narrowing and those relative to the two sections nearer the road narrowing, it has deduced an average reduction of 16 km/h approximately (variation percentage of 38%).
4. DISCUSSION

The speed reductions caused by the traffic calming measures analyzed in this study cannot be generalized. This follows from the fact that the three interventions considered have specific characteristics that strongly affect their effectiveness in terms of speed reduction. In particular: 1) the speed tables are located at a distance of 40 m from each other and on a road section with a gradient of 2%; 2) the chicane is placed on a one-way street and has a fairly short "characteristic length" (about 11 m); 3) the road narrowing is very conditioning as it involves reducing the lanes from two to one.

However, it is important to highlight how the results of this research are consistent with those found in literature, with reference to traffic calming devices having characteristics similar to those studied.

In particular, based on American and Canadian experiences, the results of which are contained in the Canadian guide to neighbourhood traffic calming, the presence of speed tables results in reduced operating speeds of up to about 75-80% of the initial value. In any case, on roads characterized by operating speeds between 50 km/h and 60 km/h, there was no decrease in speed below 42 km/h. Test experiences of Department for Transport (United Kingdom) has characterized some correlations between the lane width, the axis deviation, the chicane length and the consequent speed (Tab. 1). These are correlations compatible with the results of our research.

<table>
<thead>
<tr>
<th>Lane width</th>
<th>Axis deviation</th>
<th>Chicane length and consequent speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>24 km/h</td>
</tr>
<tr>
<td>3,00 m</td>
<td>2,00 m</td>
<td>6,00 m</td>
</tr>
<tr>
<td>3,00 m</td>
<td>3,00 m</td>
<td>9,00 m</td>
</tr>
<tr>
<td>4,00 m</td>
<td>4,00 m</td>
<td>12,00 m</td>
</tr>
<tr>
<td>3,50 m</td>
<td>2,50 m</td>
<td>-</td>
</tr>
<tr>
<td>3,50 m</td>
<td>3,50 m</td>
<td>9,00 m</td>
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<tr>
<td>4,50 m</td>
<td>4,50 m</td>
<td>11,00 m</td>
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<tr>
<td>4,00 m</td>
<td>3,00 m</td>
<td>-</td>
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<tr>
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<td>4,00 m</td>
<td>-</td>
</tr>
<tr>
<td>5,00 m</td>
<td>5,00 m</td>
<td>-</td>
</tr>
</tbody>
</table>
Finally, Table 2 shows, consistent with the results of our study, that road narrowing results in a strong reduction in speed, in the case of configurations that cause the road to be reduced to a single lane. (Harvey, 1992).

Table 2. Expected speed reduction effect of road narrowing

<table>
<thead>
<tr>
<th>Road narrowing</th>
<th>Upper limit of maximum speed (km/h)</th>
<th>Upper limit of 85 percentile speed (km/h)</th>
<th>Range of average speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Road narrowing to a single lane</td>
<td>100</td>
<td>65</td>
<td>75</td>
</tr>
<tr>
<td>Road narrowing to a reduced width</td>
<td>100</td>
<td>95</td>
<td>75</td>
</tr>
</tbody>
</table>

5. CONCLUSION

The urban accidents represent approximately 70% of those altogether relative to the Italian road net.

In this paper, the authors have been able to demonstrate the concrete possibility “to force” the road users to reduce the speed.

If the traffic calming measures were distributed warily and systematically on all the urban road net, it could be obtained, with a little investment, a result of great importance both in terms of safety and, more in general terms, in terms of ethicality.

6. REFERENCES

Daham, B., Andrews, G.E., Li, H., Partridge, M., Bell, M.C., Tate, J. (2005). Quantifying the effects of traffic calming on emissions using on-road measurements. 2005 SAE World Congress, Detroit, MI, United States.


