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Traffic calming along rural highways crossing small urban communities: Driving simulator experiment

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ABSTRACT

The paper investigated drivers' speed behaviour in a section of a rural highway crossing a small urban community in the existing scenario without any traffic calming device and in two different design scenarios with traffic calming in the urban community. Two gateways and four integrative traffic calming devices along the route within the urban area were tested. The gateways were aimed at slowing down the vehicles entering in the built-up area, while the traffic calming devices were aimed at complementing the gateway effect inside the built-up area. Two design options were tested: first option (alt1) is a combination of low cost measures, whereas the second option (alt2) is more expensive as includes a chicane and requires land acquisition.

Drivers' behaviour was investigated by means of a driving simulator experiment. The VERA dynamic-driving simulator operating at the TEST Road Safety Laboratory located in Naples (Italy) was used. Simulation results were validated by the comparison of speed behaviour in the real world and in the driving simulator, in the scenario without traffic calming.

Analysis of the driving simulator experiment results was performed using two different approaches: (a) explorative description of data by cluster analysis; (b) inferential procedures about population using statistical tests. Cluster analysis was carried out in order to test if the drivers' speed behaviour in the different design alternatives was substantially different. Statistical tests were performed in order to verify if speeds in specific sections were significantly different. Cluster analysis looked at speed profiles, whereas statistical tests looked at speed data in specific points.

The obtained results showed a different behaviour of drivers approaching the urban community in the existing scenario and in the design scenarios. In the south direction, mean speed reduction ranging between 16 and 17 km/h, with 5% level of significance, was observed. In the north direction, mean speed reduction equal to 11 km/h, with 10% level of significance, was observed. Differences between the two design alternatives were not statistically significant. Along the urban community, a statistically significant mean speed reduction ranging between 9 and 15 km/h was observed in the south direction. In the north direction, speed reduction was not statistically significant.

Overall, combined results of cluster analysis and statistical tests showed that the treatments were more effective in the direction with higher speeds in the base scenario.

1. Introduction

Rural highways crossing small urban communities are used by pedestrians, cycles, powered two wheelers, and different types of vehicle users with substantial differences in speed, mass, and degree of protection. This produces inconsistency between the mobility of motor vehicle users and the safety of pedestrians and cyclists. In rural highway sections, the drivers maintain high operating speeds and generally they do not adequately reduce speeds crossing the small urban areas (DfT, 2000, 2005; Hallmark et al., 2007; NRA, 2005). Frequently, the transition from the rural environment to the urban one consists only on the posted speed limit (Van Schagen, 2003), and this condition is totally inadequate to induce appropriate behaviours.

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The aim of the paper was to investigate drivers' speed behaviour in a section of a rural highway crossing a small urban community in the existing scenario without any traffic calming device and in two different scenarios with traffic calming in the urban community. Drivers' behaviour was investigated by means of driving simulator experiments. Simulation results were validated by the comparison of speed behaviour in the real world and in the driving simulator, in the scenario without traffic calming.

The remainder of the paper summarizes the state-of-the-art, the main features of the design site, the two alternative designs of perceptual measures and physical devices for traffic calming, and the results of the driving simulator experiments.

2. Previous studies

In Italy, crashes in rural highways crossing small urban centres account for 14.5% of the total urban crashes, causing 33.2% of the total fatalities in urban area (Lamberti et al., 2009). In these highway sections, main crash risk factors (high severity of pedestrian crashes, over-representation of wet-road crashes, run-off-road crashes, and crashes at curves) are strictly related to operating speeds inconsistent with the urban environment. Thus, measures aimed at speed reduction might give rise to substantial safety improvement.

The European Transport Safety Council (1995) defined design principles for the transition zones located on the approaches to towns and villages on major routes. One principle is that measures in such transition zones must be complemented by measures along the urban area. A second principle is that these measures should be such that they achieve a cumulative effect culminating at the gateway. Gateways are the combination of traffic calming devices, such as traffic islands, road narrowing, coloured surfaces, change in pavement material, horizontal deflections, trees and shrubs, lighting, etc. (CROW, 1998; Highways Agency, 2004; NRA, 2005; Road Directorate, 1999). The UK Department for Transport (2005) suggests two conditions in which gateways can result particularly effective: (a) high operating speeds approaching small villages; (b) city centres where the beginning point of the built-up area is not clearly recognizable.

The gateway treatment effect depends on the context and on the type of the implemented measures. In the UK, speed reduction equal to 10 km/h was found if the gateway was not followed by further devices in the urban centre and equal to 15 km/h if there were other devices (VISP, 1994). Still in the UK, the Department of the Environment, Transport and the Regions (2005) found operating speed reductions equal to 25 km/h at gateways with other traffic calming devices in the urban area. Taylor and Wheeler (1998) evaluated the effectiveness of nine projects. They found a speed reduction between 5 and 24 km/h at gateways and between 5 and 22 km/h in the city centre. In a following study extended to 56 cases, in the projects with only gateways (2000), crash reduction equal to 10% for slight injury crashes and equal to 43% for fatal and serious injury crashes were found. In the cases in which the gateways were integrated with additional provisions inside the city centres, greater crash reductions were achieved: 37% for the slight injury crashes and 70% for fatal and serious injury crashes.

In the US, a recent evaluation of two gateways and five isolated traffic calming devices was carried out (Hallmark et al., 2007). The results showed up to 10 km/h reduction in the operating speed.

The effectiveness of traffic calming treatments has been assessed also by means of driving simulator experiments. Indeed, driving simulators have the potential to explain interaction between drivers and roadway surroundings, and more important, to explore effective countermeasures (Godley et al., 2002; Yan et al., 2008). In support of this concept, many validation studies related to driving speed behaviours have shown that drivers have similar speed performances in driving simulators as those measured in the real world or in real instrumented cars.

Yan et al. (2008) replicated a signalized intersection with as many important features into a high-fidelity driving simulator. A driving simulator experiment with eight scenarios at the intersection was conducted to determine if the subjects' speed behaviour in the driving simulator was similar to what was found at the real intersection. The experiment results showed that speed data observed from the field and in the simulator experiment have equal means for each intersection approach.

In the Netherlands, a project to simulate the impact of a series of measures (coloured asphalt, gateway, and median strip, either separately and in combination) aimed at reducing the speed of traffic approaching the village of Weiteveen was performed (Riemersma et al., 1990). Real world and driving simulation experiments were compared. The comparison showed the feasibility of using a driving simulator to analyse the effectiveness of speed-reducing measures as a suitable alternative to full-scale field-trials.

Traffic calming road treatments were also investigated in the TRL driving-simulator (Lockwood, 1997). The entrance of three villages was simulated. All the villages presented different infrastructural measures. Sixteen subjects participated to the study, driving on the simulated village with and without treatments. The resulting speeds were compared with data collected before and after the measures implementation in the real village. The simulated and real speed data were extensively comparable.

Various traffic calming treatments were simulated in the Leeds Driving Simulator (Jamson et al., 1999). Traffic calming measures were simulated in entrance to sharp bends and rural villages. Significant reductions in speed and in speed variance were observed in both situations.

Godley et al. (2002) used an advanced driving simulator for the evaluation of speeding countermeasures. Using drivers with a minimum of 3 years driving experience, 24 participants drove an instrumented car and 20 participants drove the simulator in two separate experiments. Participants drove on roads which contained transverse rumble strips at three sites (approaches to stop sign intersection, right curve, and left curve), as well as three equivalent control sites. At the treatment sites, speeds were slower than at the control sites in both experiments. The authors found a close correlation between the speeds in the simulator and in the real driving situations.

Katz et al. (2008) investigated several alternative peripheral transverse bars designs in the Highway Driving Simulator (HDS) at Turner-Fairbank Highway Research Center (TFHRC). Four curves and two tangent sections were treated with peripheral transverse bars including four different design patterns. First, the participants drove the roadway under baseline conditions. Second, the participants drove the roadway with one set of experimental treatments. The results showed that treatments were effective in reducing speeds but there were no overall significant differences between the different treatments.

Still using the HDS at TFHRC, Molino et al. (2010) investigated five low cost traffic calming treatments directed at slowing traffic on rural roads in small towns. Thirty-six participants completed three drives. In each drive participants crossed six towns, each with one treatment (plus the base scenario) in a quasi-random order. The town consisted of a main two-lane roadway with marked parking spaces on each side. Each town segment was 137 m long, and was preceded and followed by a long rural tangent. There was no traffic on the roadway in either direction. There were no pedestrians in the town. Curb and gutter chicanes offered the most potential safety benefit, with a mean speed reduction equal to 14 km/h in the beginning of town and 8 km/h in the middle of town.