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Gateway design assessment in the transition from high to low speed areas

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ABSTRACT

Transition zones from high-speed areas to low-speed areas are particularly critical. In this study the effectiveness of 12 gateways located at the entrance and exit of 6 towns aligned along 15 km of a same route was assessed. Gateways varied according to chicane deflection (0°, 3°, 4°), and central island (raised versus ghost). All gateways had dragon's teeth and a extended town sign.

The effectiveness of gateway design has been assessed by before–after analysis of speed parameters and crash statistics, and also by driver's eye movement analysis. The aims were to assess which components of the gateway were most looked at, how the gateway design could reduce distraction behaviour (gaze directed to non-relevant driving targets) and how gaze behaviour was related to speed reductions.

The comparison of before–after crash data demonstrated the efficiency of the adopted solutions, having obtained a substantial reduction in the number of accidents, injuries and deaths of respectively 50.4%, 61.1% and 100%. The raised island was the most effective element for speed reduction (−7.24 km/h), being also the most seen. The raised island significantly lowered distractions in gaze behaviour. The amount of gaze to the gateway components was significantly correlated to speed reduction entering the gateway.

1. Introduction

A transition zone is a section of road that is continuous with and connects a road section with a high posted speed limit to a road section with a lower posted speed limit (Forbes, 2011).

The transition from high-speed to low-speed zones, typically the entrance to an urban area, is particularly critical. Drivers tend to extend the driving style of a high-speed section to a section in which traffic density, pedestrians, cyclists and visual complexity increase (DfT, 2000, 2005; Hallmark et al., 2007). There is a tendency for motorists to underestimate their travel speed after having driven at a higher speed for a longer period; a phenomenon that is known as speed adaptation (Denton, 1976; Matthews, 1978; Schmidt & Tiffin, 1969).

The design of high- to low-speed transition zones is closely related to the traffic calming methodologies. Although different treatments were proposed and validated in the past by researchers and road agencies, the efficiency depends upon a

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system composed by infrastructure–environment–vehicle in which the user represents a key variable (Bucchi, Sangiorgi, & Vignali, 2012; Dondi, Simone, Lantieri, & Vignali, 2011). In fact the transition zone has not to be intended as the specific point in which the lower speed limit is enforced, but as the whole section in which the perceptual change from rural to urban takes place (Torbic et al., 2012).

In this regard the present paper investigates the effectiveness of gateways which are a combination of traffic calming designs, aiming to alert the driver about the transition from high-speed to low-speed areas.

In particular we tested the effectiveness of 12 gateways along a same route, that matched to 12 high to low speed (rural to urban) transitions. All the gateways had a high extended town sign (showing town name and speed limit) and dragon's teeth in common. Two components varied systematically between the gateways: the presence and radius of a chicane and the central island, which in some gateways was raised with solid curbs and in others was only marked on the road (ghost island).

The design consistency was assessed by measuring the lateral acceleration acting on the vehicles and a before–after speed analysis. An eye-tracking in-situ campaign allowed the study of the driving visual behaviour, in order to understand which elements of the gateway were more salient and how visual behaviour was related to speed.

The chicanes tested in this study had a low radius deflection (3° and 4°) in order to keep to a minimum the lateral acceleration. These radius are much lower than the conventional chicanes used as traffic calming devices in residential areas (Sayer, Parry, & Barker, 1998). It would be interesting therefore to test if these low radii are wide enough to record a significant reduction in speed.

1.1. Transition zones and driving behaviour

Research studies indicate that, in terms of traffic safety, the transition between rural and urban areas is a serious problem (Ariën et al., 2013). Crossing small urban centres, these roads are used by pedestrians, cyclists, powered two wheelers and various types of vehicles with substantial differences in speed, mass and level of protection. This results in inconsistency between the mobility of motor vehicle users and the safety of pedestrians and cyclists (Galante et al., 2010).

In rural roads sections, drivers maintain high speeds and generally do not slow down sufficiently when crossing through small urban zones. Speed adaptation may cause motorists to travel faster than they should upon entering the urban area (Matthews, 1978). As drivers are able to process less of what is in their field of view, they have less time to react and avoid collisions, so the impact in an accident is more severe. Frequently, the transition from a rural to an urban environment is marked only by a speed limit indication, which is totally inadequate to induce an appropriate driving behaviour.

Tziotis (1992) found that transition zones experience crash rates that are markedly higher than those recorded on rural roads. He collected five years of crash data on road sketches being on average 2.2 km length and defined by a speed limit of 75–90 km/h in the transition and 100–110 km/h in the rural zone. The former had an annual crashes rate of 45 casualties per 100 million vehicle-kilometre, while the latter 27 crashes per 100 million vehicle-kilometre. The researchers concluded that the increased crash rate in the transition zones was related to inadequate road design and an increase in roadside development that occurs in the transition zone.

Road users make errors of judgement concerning, for example, appropriate speeds to approach intersections, curves and developed areas. It is often the road environment that gives wrong cues to the drivers, suggesting operating speeds which are incorrect in relation to the objective crash risk (Montella et al., 2011). Estimates are that in about one third of fatal crashes excessive speeds are involved (FHWA, 2000). In many situations, drivers experience a sustained period of driving at higher speed before accessing an urban area. This might have detrimental effects leading to reduced cognitive arousal and workload (i.e., mental underload), and the risk of underestimating the actual travel speed. Mental underload and speed adaptation can cause unsafe situations, mainly because of the inadequate way in which speed reduction is performed (Ariën et al., 2013). Several studies have shown the relationship between speed and the risk of a crash, underlying that at a particular road the crash rate increases when speed increases (Aarts & Van Schagen, 2006).

Most road agencies attempt to achieve the right operating speed among drivers by imposing speed limits. Unfortunately several studies have shown that the speed limit is often violated and at best serves only as a guide to drivers. The major reason for not obeying speed limits could be that the limits are not reflective of the roadway conditions and most drivers feel that they are lower than what the roadway can accommodate (Montella et al., 2011).

Costa et al. (2014), furthermore, have showed that in mean only 25.06% of vertical traffic signs are looked by drivers. Speed limits, specifically, were looked with a mean frequency of 32.06%.

Perceptual cues to traffic hazards may induce drivers to detect them earlier and to naturally select appropriate speeds as a result of their perception of the roadway environment as a whole (Montella et al., 2011). A two phase study by Rowan and Keese (1962) investigated possible factors that influence operating speeds along rural-to-urban transition areas, in order to develop new criteria for the establishment of speed zones. More than 150 sites were studied, which included several combinations of roadway functional classification, traffic volumes and land use development. The results indicated that posted speed limits have little effect on operating speeds. The second phase of the study aimed to identify geometric features that influence drivers' choice of speed in rural-to-urban transition areas by use of two study methods: individual vehicle speed and the test car methods. The individual vehicle speed method concluded that horizontal and vertical curves are the two most common elements that influence operating speeds, mainly due to sight distance restrictions. It was also concluded that changes in the cross section resulted in traffic speed variations, but these factors could not be isolated in order to quantify