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Reducing posted speed and perceptual countermeasures to improve safety in road stretches with a high concentration of accidents

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ABSTRACT

Traffic accidents are one of the leading causes of life loss in Europe. Inappropriate or excessive speed is one of the largest contributors to traffic accidents and has a stronger effect on injury severity than almost any other known risk factor. This paper evaluates the possibility of inducing a substantial speed reduction in a hazardous section using perceptual countermeasures to improve safety via a low-cost solution. To validate the solution, the proposed methodology was applied to a road in northern Spain with a significant number of accidents per km including traffic volume effects (a black spot). This paper describes the proposed solution and presents the results, which show that a low-cost solution can reduce traffic speed and accidents.

1. Introduction

In Europe, road accidents are a leading cause of life loss, especially among young people. In 2011, more than 30,000 people died on the roads of the European Union, the equivalent of the population of a medium-sized town. For every death on Europe's roads, there are an estimated 4 permanently disabling injuries, such as damage to the brain or spinal cord; 8 serious injuries; and 50 minor injuries (European Commission, 2012).

In 2011, 1603 people died on state roads outside urban areas in Spain, and the total number of deaths on non-motorway roads (country/rural roads) was 1267 (Dirección General de Tráfico, 2012).

The first step in reducing road deaths is to identify the causes of traffic accidents. Currently, an increasing number of indicators are used to determine the factors contributing to accidents, identify conditions associated with increased accident/injury risk, and describe the structure of traffic injury patterns (Elvik et al., 2009; Gitelman et al., 2010). The SafetyNet project (Hakkert et al., 2007) identifies seven descriptors for a safety performance indicator approach: alcohol and drugs, speeds, protective systems, daytime running lights, passive vehicle safety, roads and trauma management.

Inappropriate or excessive speed is a leading risk factor on the road (Aljanahi, 1995; Aljanahi et al., 1999; Allpress and Leland, 2010; Aarts and Van Schagen, 2006; Fildes and Lee, 1993; Hakkert et al., 2007; Hirst et al., 2005). Speed has a greater effect on the number of accidents and injury severity than almost any other known risk factor (Elvik, 2009).

Considering that speeding is very common (European Transport Safety Council, 2010), a substantial reduction of the number of accidents, especially fatal accidents, can be attained if speeding is eliminated or reduced (Elvik, 2011). Speed limits were first introduced to improve safety on roads by restricting excessive vehicle speed (Harkey et al., 1990).

Nilsson (1981, 2004) demonstrated the effects of speed on safety and proposed the Power Model to predict the effects of average speed on safety. Elvik (2011) concluded that the effects of speed enforcement on accidents exhibit a dose–response pattern that is theoretically plausible. As Hirst et al. (2005) summarise, a progressive relationship may exist between accident reductions and reductions in mean speed (Finch et al., 1994; Taylor et al., 2000; Webster and Mackie, 1996), and the changes in speed vary among speed management measures.

Nonetheless, a significant reduction in traffic accidents cannot be achieved by changing the posted speed limit alone. A change in the speed limit induces a change in the average speed by one-quarter of the change in the limit (Finch et al., 1994). In addition, by analysing all previously published data, Taylor et al. (2000) concluded that small changes in speed limits are proportionately more effective at changing average traffic speeds than are

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substantial changes. A significant change in the posted speed limit is not automatically noticed or effective in slowing traffic because most drivers determine their speed by observing visual cues from their surroundings (WSDOT, 2011). Therefore, in addition to changing the posted speed limit, visual cues could assist in reducing average traffic speed.

Furthermore, adequate perception of the road is obviously crucial to keeping a vehicle on the road (Kallberg, 1993; Roseya and Auberletb, 2012; Tenkink, 1988; Steyvers and de Waard, 2000). Different studies have revealed that the use of fluorescent traffic signs improves safety by reducing speed and centre line crossings and increasing attention to the danger presented by curves (Jenssen et al., 1998; Land and Horwood, 1996). Fluorescent lighting increases the visibility of the signs under all conditions, creating a stronger cognitive impression (de Vos et al., 1998; de Waard et al., 2004; Jenssen et al., 1998; Schnell et al., 2001a,b).

Based on the relationship between speed, visibility, and accidents, this paper presents a way to improve safety in road stretches with a concentration of accidents by reducing the speed and providing appropriate visual cues about what a reasonable speed is. Due to the current economic situation, a low-cost solution was developed based on the use of perceptual countermeasures. This project was the winner of the 2010–2011 STARS competition organised by the European Transport Safety Council (ETSC).

Allpress and Leland (2010) proposed that research investigating perceptual countermeasures to speeding may prove particularly useful in roadwork contexts. Perceptual countermeasures are manipulations of the roadway or roadside environment designed to increase drivers' estimation or perception of speed (Fildes and Lee, 1993; Yagar and Van Aerde, 1983). The most common perceptual countermeasures are lane-width reduction and transverse lines (Fildes and Lee, 1993; Rutley, 1975). Numerous studies have revealed that speed reduction measures, e.g., transverse bars, are effective in reducing vehicles' speeds on curves (Agent, 1980; Comte and Jamson, 2000; Helliar-Symons, 1981; Hungerford and Rockwell, 1979).

2. Material and methods

2.1. Description of the selected stretch

The proposed approach was applied in Asturias, a small region in northern Spain. To choose a suitable site to carry out the experimental procedures, the ten-year accident data (2000–2010) for 6 of the most important roads in central Asturias (total of 215 km) were analysed.

An extensive recompilation of different procedures for the identification of hazardous sections can be found in (Sørensen and Elvik, 2008). In this case, the methodology was the same as that used by the Spanish Traffic Administration (Diez et al., 2010).

A sliding window with a length of 1 km was used to identify the hazardous sections. The longitudinal coordinate of the starting point of the window was increased in 100-m increments in every analysis step. For every sliding window, the total number of injury accidents (U) and the risk index (R) over a five-year period (2006–2010) were calculated. The risk index was calculated as follows:

$$R = \frac{10^8 \cdot U}{AADT \cdot 365 \cdot \text{section length}}$$

AADT: annual average daily traffic.

In a first step, the road sections that met the two following conditions were selected:

$$U \geqslant N$$

$$R \geqslant P$$

N = Integer ($\mu + 2\sigma$) where μ is the mean and σ the standard deviation of the maximum number of accidents for all sections with similar characteristics.

P = Integer ($\mu' + 2\sigma'$) where μ' is the mean and σ' the standard deviation of the risk index of all sections with similar characteristics.

The constants N and P depend on the type of road, the area, and the traffic intensity. Because the selected roads are of the same type and located in a small area, the constants only vary according by the *AADT*.

In a second step, the road sections that fulfilled the two conditions above were ranked according the percentage of fatal accidents and the percentage of speed-related accidents.

The data analysis was complemented by field investigations to determine 'in situ' the particular characteristics of each stretch.

The selected site for the experiment is located at km point (KP) 6.0 of the AS-19 main road. The AS-19 Main Road connects the cities of Gijón and Avilés. This main road features the most accidents per km of the 6 roads studied (16 accidents per km). This section includes more than 44% of the fatal accidents on the AS-19, over 21% of which are speed-related. Furthermore, due to its proximity to an industrial area, this road has a high traffic flow during rush hours and a high ratio of heavy vehicles. In 2010, the annual average daily traffic (AADT) was 20801 vehicles in some stretches, and the percentage of heavy vehicles exceeded 14%.

The selected site consists of a crossing located at KP 6.0 of the AS-19 main road, in the locality of Prendes. The experiment was performed in a stretch of approximately 300 m around the crossing (150 m before and 150 m after). This stretch had some characteristics that make this crossing especially hazardous. First, this crossing provides entrance to an industrial park. Many vehicles enter and exit the industrial park, including a high percentage of heavy vehicles. Second, the visibility of the crossing heading from Avilés to Gijón is very limited because there is a curve with limited visibility. Third, there are two bus stops (one for each direction) at the crossing. One of the bus stops is especially hazardous because it is located after a curve. Finally, the maximum speed in the crossing is the general speed limit of the road: 90 km/h.

A five-year period was chosen to investigate the main causes of accidents at this location before the intervention proposed herein. This assessment revealed that in 5 out of every 6 serious accidents in this stretch, the cause was "inadequate driving speed". According to Spanish regulations, every driver is required to respect the speed limits and take into account his or her own physical and mental conditions; the characteristics and conditions of the road; the vehicle and its load; the weather conditions, environment and traffic; and the general circumstances present in each moment to determine the appropriate vehicle speed. The Road Administration introduces the concept of "inadequate driving speed" when these conditions are not reflected in the driver's chosen speed. Half of the serious accidents occurred during at night or under poor visibility conditions.

Under a scientist point of view, the concept of inadequate driving speed does not represent a numerical vale of speed that a normal driver can guess directly from objective data. Any case, this concept has been traditionally used in traffic accident investigation in Spain, in order to identify the accident causes. The authors suggest the revision of this concept and its use. The only objective available information to the driver is the posted speed limit. Therefore, the posted speed limit should not be greater than the adequate driving speed.

Given the causes of the most serious accidents, this site is suitable for this study.

The better solution to improve safety in this hazardous section is a complete redesign of the intersection. This redesign should imply: