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Safety effects of low-cost engineering measures. An observational study in a Portuguese multilane road

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ABSTRACT

Single carriageway multilane roads are not, in general, a very safe type of road, mainly because of the high number of seriously injured victims in head-on collisions, when compared with dual carriageway multilane roads, with a median barrier.

In this paper the results of a study on the effect of the application of several low cost engineering measures, aimed at road infrastructure correction and road safety improvement on a multilane road (EN6), are presented. The study was developed by the National Laboratory of Civil Engineering (LNEC) for the Portuguese Road Administration and involved a comparison of selected aspects of motorized traffic behaviour (traffic volumes and speeds) measured in several sections of EN6, as well as monitoring of road safety developments in the same road. The applied low cost engineering measures allowed a reduction of 10% in the expected annual number of personal injury accidents and a 70% decrease in the expected annual number of head-on collisions; the expected annual frequency of accidents involving killed and seriously injured persons was reduced by 26%.

1. Introduction

The case study described in this paper refers to the analysis of the effect of several road safety measures undertaken on a Portuguese single carriageway multilane road (EN 6), following the construction of a new motorway (A5), parallel to the existing road, which links directly Lisboa to Cascais. Several low cost engineering measures were implemented thereafter, on a 3.7 km long stretch of EN6 (between 3.2 km and 6.9 km) to improve its safety record.

The evaluation was carried through a "before–after" study with a control group. A stretch of another single carriageway multilane road (the EN125 in Algarve) was used as control group.

According to the Organization for Economic Co-operation and Development (OECD), integrated programmes on road safety aiming to reduce accident severity should focus on several traffic system elements, namely by adaptation of road environment characteristics to the intended road uses (OECD, 1984).

The application of road safety measures is based on general knowledge on the road safety phenomenon, sometimes complemented by results from the analysis of accident data in the area to be corrected.

Better results may be achieved with road safety interventions if procedures for their implementation include the following steps (Cardoso and Bairrão, 2001):

- Network safety diagnosis to identify locations with high influence of road characteristics on accident occurrence.
- Safety analysis on each selected location for potential interventions, to identify the main road characteristics leading to safety issues.
- Selection and application of appropriate safety measures.
- Safety monitoring of the corrected sites and evaluation of results.

The decision process for selecting corrective measures takes into account the available budget for the programme, the safety issues identified by the diagnosis and the anticipated benefits from the potential suitable measures. Monitoring safety developments following interventions and assessing the results obtained are very important steps for enhancing the efficiency of this type of process, since they allow the improvement of ex-ante benefit estimations, and consequently, better future investment decisions. This is especially relevant when the applied safety measures are transferred from other countries' traffic systems, due to the different response of drivers. This paper allows to increase the knowledge on the effects of safety interventions specifically applied in the Portuguese road environment, which can be different from other European countries due to particular driver behaviour.

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Table 1
Percentage change in the number of accidents expected as a result of several road safety measures.

Accident severity	Percentage change in the number of accidents		
	Types of accident affected	Best estimate	95% confidence interval
Median on multilane roads – rural areas[a]			
Injury accidents	All accidents	−12	(−15;−8)
Property damage only accidents	All accidents	−18	(−21;−14)
Median on multilane roads – urban areas[a]			
Injury accidents	All accidents	−22	(−24;−20)
Property damage only accidents	All accidents	9	(+7;+11)
Small improvements of road alignment[b]			
Unspecified	Unspecified	−20	(−39; −4)
Speed actuated traffic signals – minor intersections in rural areas[c]			
Injury accidents	Unspecified	−11	Unspecified
Speed actuated traffic signals – bends[c]			
Injury accidents	Unspecified	15	Unspecified

[a] Elvik and Vaa (2004).
[b] Gitelman et al. (2001).
[c] Barker and Baguley (2001).

From a safety point of view, road infrastructure and environment interventions are especially important because they have frequently allowed casualty reductions of about 30% at interventioned places. Speed reduction is a major concern of all network managers. Whether in urban or rural areas, broadly, several specific measures may be applied. Table 1 presents the percentage change in the number of accidents as a result of some road safety measures aiming at reducing speed and the severity of speed related crashes, as reported internationally (Elvik and Vaa, 2004; Gitelman et al., 2001; Barker and Baguley, 2001).

Low cost engineering measures (LCEM) are corrective measures applied to the road environment or to traffic management, characterized by small investments and short implementation periods, when compared with the ones for other types of road works. Furthermore, LCEM can be applied within existing road limits, in both the construction and the operation phases.

LCEM are selected taking into account the main types of accidents in the site where they are applied, whose frequency or severity they are intended to decrease; LCEM selection criteria also warrant that their application will not have undesirable effects on other accident types, on traffic operation efficiency nor will they raise serious negative environmental issues. These facts, combined with the low cost and quick results, justify the favourable cost/benefit relations, even for those road sites where major interventions are planned for in the short term (3–5 years). Indeed, according to international experience, very good cost/benefit relations may be obtained with LCEM (Gorell and Tootill, 2001).

2. Safety analysis of corrective measures

The safety assessment of a road infrastructure corrective measure deals with the estimation of the effect of the intervention on the number of accidents or victims. This may be made through a “before–after” study, that includes the following steps: estimation of the safety level of a road section in a period of time previous to the application of the corrective measure; estimation of the actual safety level in a period of time subsequent to the application of the corrective measure, and also the expected safety level that would occur if the measure had not been applied; the application of an algorithm for comparing the actual development with the one that would have occurred without intervention (Hauer, 1997).

Usually, developments in the safety level of a road section following the application of a set of corrective measures do not reflect solely their effect. Other factors may influence the way safety changes over time, namely the regression-to-the-mean (RTM), long term trends in the number of accidents and victims, changes in the percentage of registered accidents by the responsible authorities and traffic volume developments (Hauer, 1997).

The RTM effect consists of a statistical trend: after a period with frequencies very far from the average value, it is normal to observe frequencies closer to this value. Thus, after a period with very high accident frequencies, the normal trend is that in subsequent periods, lower accident frequencies will be observed. In most road safety interventions this is basically due to the way road authorities select sites for improvement: interventions are implemented where higher accident occurrence has been observed. One way to mitigate RTM would be to randomly select the intervention sites, as described in Hutchinson (2007). This not being possible in all cases, one may use estimators developed through Bayesian inference methods, where the expected number of accidents for one specific time period and section under study is calculated multiplying the observed number of accidents by a factor that takes into account the average and the variance of the number of accidents observed in previous time periods (Abbess et al., 1981).

Ideally the effect due to the remaining disturbing factors could be estimated in two ways: using statistically derived models of their influence on accident frequency, assuming all the disturbing variables and their effects are known, which is seldom the case; or using control groups, assuming that the effect of the disturbing variables will be identical in both the treated sites and the control group sites. In practice, usually control groups are used.

To control for the RTM effect the Empirical Bayes Method (EBM) was used in this study. The EBM was originally developed for the purpose of controlling for regression-to-the-mean in before-and-after studies evaluating the effects of road safety measures (Hauer et al., 2002). It states that $E(m|x)$ – the expected number of accidents at a site where x accidents were observed – can be estimated by:

$$E(m|x) = \hat{m} = \alpha \cdot E(m) + (1 - \alpha) \times x \quad (1)$$

where x – observed number of accidents; $E(m)$ – expected number of accidents in a similar site, calculated using a safety performance function; and

$$\alpha = \frac{E(m)}{E(m) + Var(m)}; \quad \mathrm{Var}(m) \approx \frac{(E(m))^2}{k};$$

VAR(m) – variance of the calculated expected number of accidents in a similar site; k – dispersion parameter of the safety performance function.

In this study, possible migratory effects in accident occurrence were not considered, since the road used for comparison is not linked to the road where the engineering measures were applied, and road sections adjacent to the study site were also subject to intervention. According to available evidence there were no major