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Original Research Paper

Evaluating the safety benefit of retrofitting motorways section with barriers meeting a new EU standard: Comparison of observational before–after methodologies

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HIGHLIGHTS

- The paper investigates how the wrong methodology can negatively influence the decision making process.
- The implementation on motorways of a new class of EU safety barrier was tested from a safety point of view.
- Three different approaches were used, such as the empirical Bayes before–after, the before–after with comparison group and the naive before–after.
- The reliability of the two "simple" approaches was compared with the empirical Bayes before–after analysis.
- A benefit-cost analysis was performed considering the three approaches.

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ABSTRACT

The road safety barriers are today designed and installed in compliance with the European standards for Road Restraint Systems (EN 1317), which lays down common requirements for the testing and certification in all EU countries. The introduction of the European Union (EU) regulation for safety barriers, which is based on performance, has encouraged European road agencies to perform an upgrade of the old barriers installed before 2000, with the expectation that there will be safety benefits at the retrofitted sites. Due to the high cost of such treatments, a benefit-cost analysis (BCA) is often used for site selection and ranking and to justify the investment. To this aim a crash modification factor (CMF) has to be applied and errors in the estimation of benefits are directly reflected in the reliability of BCA. Despite the benefits of empirical Bayes before–after (EB–BA) analysis or similar rigorous methods are well-known in the scientific world, these approaches are not always the standard for estimating the effectiveness of safety treatments. To this aim, the differences between the EB–BA and a naive comparison of observed crashes before and after the treatment are presented in the paper. Crash modification factors for total and target crashes are estimated by performing an EB–BA based on data from a motorway in Italy. As expected the results suggest a strong safety benefit for the ran-off-road crashes by reducing the number of severe crashes (fatal and injury). The statistical significance of results obtained by the EB–BA approach show that the retrofits are still cost-effective. The

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comparison pointed out as selection bias effects can overestimate the safety benefit of the retrofits when a naive approach is used to estimate the CMF and how those can significantly affect a benefit-cost analysis.

1. Introduction

Agencies are required to evaluate the safety effects of a specific improvement to compare its net benefit to other improvement options as well as to justify its implementation at subsequent locations. The typical method of evaluating the safety improvements of a treatment is comparing the crash prevalence associated with the transportation facility before and after the treatment implementation (a before–after study). A challenge inherent in these studies is that crashes change from year to year with a random variation known as regression to the mean, unlike laboratory experiments in which the analyst can control many extraneous conditions. Other parameters that affect the safety of a facility, such as traffic volume and weather conditions, change over time. Consequently, specific evaluation techniques are required to account for changes in order to estimate the true effects of safety improvements (ITE, 2009) avoiding naive methodologies which are not able to take into account possible bias due to the random nature of crashes and the other confounding factors described earlier. Because of that, since Hauer (1997) formalized the use of empirical Bayes before–after analysis as one of the way to account for regression to the mean effects.

This paper, particularly focuses on the safety improvements that can be achieved by replacing old guardrails with new ones to improve protection against roadside hazards on motorways. Retrofitting old guardrails with new ones complying with modern EU standards is one of the main retrofitting policies for infrastructure safety adopted by Italian motorway agencies, with the expectation that there will be a reduction in serious and fatal crashes. The high construction costs for updating the barriers are estimated to be about €300,000/km and €200,000/km for bridges and embankments respectively, so it is important to assess whether the safety benefits would offset these costs. The present study aims to assist in this assessment by estimating the change in the frequency of crashes following barrier retrofits by using an empirical Bayes before–after methodology (Hauer, 1997; Persaud and Lyon, 2007). The comparison with the naive approach is useful to assess how an agency can make mistake in the evaluation of the safety benefit of a treatment when methodologies not able to account for regression to the mean effects are applied. Crashes are random effects and crash frequency in a "short" period of time is not always able to estimate the long term mean of the expected number of crashes in a site with that characteristics and in that context. The phenomena for which a different number of crashes are registered in a site year by year, and the probability to have few (or zero) crashes the year following one that registered a high number of crashes is very high and due the regression to the mean (RTM) effect. In this context, and using just crash frequency which is not able to account for RTM bias, the chance of making mistake, evaluating the effects of a treatment is very high. The new class of EU barriers are designed and installed in compliance with the European Norm (EN) 1317 standards. The EN 1317 for Road Restraint Systems was created in 1998 and lays down common requirements for the testing and certification of road restraint systems in all countries of the European Committee for Standardization (CEN), i.e., the 27 member states of the European Union as well as Croatia, Iceland, Norway, Switzerland and Turkey.

Since 1998, EN 1317 standards have been continuously reviewed and subjected to change. This study pertains to road safety barriers placed in 2005 complying with the EN 1317-2 in force from 2004, which is not substantially different from the present 2010 version. Old barriers that were replaced in 2005 were not classified by any standard because they were placed during the A18 motorway construction in the years 1965–1971. Fig. 1 provides examples of old and new barriers on embankments (Fig. 1(a) and (c)) and on bridges (Fig. 1(b) and (d)).

The two barrier types can be compared only basing on the maximum containment level (CL_{max}) because there are not other common indices in the two standards related to the old and to the new one.

$$CL = \frac{1}{2}M[V\sin(\Theta)]^2 \quad (1)$$

where M is vehicle weight (kg), Θ is impact angle (rad), V is impact speed (m/s).

The containment level establishes the strength of the system, essentially specifying the maximum capacity for redirecting a vehicle. Higher containment levels produce stronger restraint systems. In Table 1 CL_{max} for old (before) and new (after) barriers are reported highlighting the notable increase in the containment capacity of the new barriers placed in 2005.

2. Literature review

An investigation of the relationship between crash and median barrier was carried out by Fitzpatrick et al. (2008) who developed a CMF from the coefficient of a regression model for Texas freeways that related crashes to the presence of a barrier and its offset from the edge of the carriageway. The results suggested a safety benefit for ran-off-road crashes, while, for the total number of crashes the impact on safety was negligible; for small offsets, the results actually suggested an increase in the total number of crashes.