ELSEVIER

Accident Analysis and Prevention 39 (2007) 546–555

ACCIDENT ANALYSIS & PREVENTION

www.elsevier.com/locate/aap

Empirical Bayes before–after safety studies: Lessons learned from two decades of experience and future directions

Bhagwant Persaud *, Craig Lyon

Ryerson University, Department of Civil Engineering, 350 Victoria Street, Toronto, Ontario M5B2K3, Canada

Received 7 May 2006; received in revised form 28 August 2006; accepted 21 September 2006

Abstract

The empirical Bayes (EB) methodology has been applied for over 20 years now in conducting statistically defendable before–after studies of the safety effect of treatments applied to roadway sites. The appeal of the methodology is that it corrects for regression to the mean and traffic volume and other changes not due to the measure. There is, therefore, a natural tendency to put a stamp of approval on any study that uses this methodology, and to assume that the results can then be used in specifying crash modification factors for use in developing treatments for hazardous locations, or in designing new roads using tools such as the interactive highway safety design model (IHSDM). At the other extreme are skeptics who suggest that the increased sophistication and data needs of the EB methodology are not worth the effort since alternative, less complex methods can produce equally valid results. The primary objective of this paper is to capitalize on experience gained from two decades of conducting EB studies around the world to illustrate that the EB methodology, if properly undertaken, produces results that could be substantially different and less biased than those from more conventional types of studies. A secondary objective is to emphasize that caution is needed in assessing the validity of studies undertaken with the EB methodology and in using these results for providing crash modification factors. To this end, a number of issues that are critical to the proper conduct and interpretation of EB evaluations are raised and illustrated based on lessons learned from recent experience with these studies. These include: amalgamating the effects on different crash types; the specification of the reference/comparison groups; and accounting for traffic volume changes. Current and future directions, including the improvements offered by a full Bayes approach, are discussed.
© 2006 Elsevier Ltd. All rights reserved.

Keywords: Safety countermeasures; Road safety; Empirical Bayes; Bayes; Safety evaluation; Before–after studies

1. Introduction

There is an undisputed need to evaluate the safety effect of roadway improvements that may impact accident frequency. What seems to be still in dispute is whether or not it is the worth the effort of using sophisticated methodology such as the empirical Bayes (EB) procedure (Hauer, 1997) for conducting observational before–after studies. This is because (a) the relative complexity of the methodology requires analysts with considerable training and experience, (b) the data needs can be quite extensive, and (c) the result of (a) and (b) is that the personnel and financial resource needs can be prohibitive.

The EB methodology has been developed to account for regression-to-the-mean effects that arise when sites with randomly high short-term accident counts are selected for treatment and experience a reduction in accidents subsequently when these counts regress towards their true long-term mean. While compelling evidence of the existence of the regression-to-the-mean phenomenon has been presented (Hauer, 1997; Hauer and Persaud, 1983) there is a certain amount of skepticism about the need for the EB methodology, doubts that are fuelled by a belief that road safety improvements are implemented for a variety of reasons and that a randomly high accident count is not among the key selection criteria. Numerical data from Norway, presented by Elvik (2004), appears to support this belief in part in that both treated and untreated sites over several years were equally likely to have above or below normal accident rates.

Further skepticism about the need for the EB methodology arises from the belief that when many years of pre-treatment data are used to select entities for treatment or in an evaluation, and these entities have high accident counts, there will be little or no regression-to-the-mean. While there is some validity to this belief, it is difficult to establish how many years of pre-treatment data are required or how high accident counts need to be for regression-to-the-mean to be virtually non-existent. Evidence in Hauer and Persaud (1983) suggests that there is fairly large

* Corresponding author. Tel.: +1 416 979 5345; fax: +1 416 979 5122.
E-mail address: bpersaud@ryerson.ca (B. Persaud).

0001-4575/$ – see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.aap.2006.09.009

regression to the mean for two-lane rural road segments even for a 5-year "before" periods, illustrating that a long before period will not eliminate regression-to-the-mean, especially when the average annual accident count is relatively small. This tends to be the case for many types of treated entities such as short two-lane rural road segments, low volume stop controlled intersections and rail-highway crossings.

The more conventional alternatives to the EB method, involving a simple before–after comparison of accident counts or rates, with or without a comparison or control group, are appealing in that they are relatively easy to apply. These alternative methods, however, are fraught with difficulties, which are well documented. The "best of the rest" involves a process in which sites are selected for possible treatment on the basis of their safety record and then randomly allocated to either a treatment or a control group—a classical experimental design. This would create similar accident frequency distributions in the two groups, allowing for regression-to-the-mean effects to be controlled for. In practice, this method of project selection is problematic since there may be moral and liability issues if some sites that end up in the control group are more worthy of treatment than some in the treatment group. In addition, this method will not control for changes in safety resulting from changes in traffic volume at the treatment sites that might result from the treatment itself. Measures such as left turn treatments at intersections are known to have such effects.

To avoid these issues in using a control group, a quasi-experimental design is commonly used in which an untreated "comparison" group of sites similar to the treated ones is selected separately from the treatment site selection process. A comparison group can account for unrelated effects such as time and travel trends but will not account for regression-to-the-mean unless sites are precisely matched on the basis of accident occurrence in addition to all the factors that affect accident occurrence. There are immense practical difficulties of achieving this ideal as illustrated in Pendleton (1996). In addition, the necessary assumption that the comparison group is unaffected by the treatment is difficult to test and can be an unreasonable one in some situations. And this method, like the classical experimental design, will not control for changes in safety resulting from changes in traffic volume at the treatment sites that might result from the treatment itself. Most fundamentally, the comparison group needs to be similar to the treatment group in all of the possible factors that could influence safety. A paper by Scopatz (1998) points to the difficulties of fulfilling this need by examining the result from Hingson et al. (1996) that lowering legal BAC limits to 0.08% resulted in a 16% reduction in the probability that a fatally injured driver would have a BAC above that level. The treatment group consisted of States that passed a lower legal BAC law while the comparison states retained a 0.10% BAC legal limit. Scopatz showed that if logically valid but different comparison states are chosen the results change dramatically, and in most cases are in fact consistent with a conclusion of "no effect".

The empirical Bayes (EB) method (Hauer, 1997) can overcome the limitations of conventional methods by accounting not only for regression-to-the-mean effects, but also for traffic volume changes and for time trends in accident occurrence due to changes over time in factors such as weather, accident reporting practices and driving habits. However, there are a number of difficulties which, if not properly resolved, will render this methodology just as invalid as the conventional methods, resulting in a misuse of precious resources and a general lack of faith in the method. It is important to recognize and address these issues since it is natural for those involved in safety management to give a stamp of approval to results from an EB study just because they claim to have been produced by such a statistically sound methodology.

Given the two extremes in beliefs on the EB methodology – blind faith and skepticism – it seems worthwhile and timely to address the concerns in both camps by consolidating the lessons learned in conducting EB evaluations over the past 20 years or so since the first applications of this methodology. This need is the motivation for this paper. First, the basics of EB evaluation are reviewed. This is followed by three substantive sections, one that presents evidence supporting the need for and validity of the EB approach, one that uses the results from several published before–after studies to compare estimates of safety effect obtained by the EB and the naïve methods, and one that addresses issues in EB evaluations that need to be considered in assessing the validity of EB studies.

2. Basics of empirical Bayes evaluation

In the empirical Bayes evaluation of the effect of a treatment, the change in safety for a given crash type at a treated intersection is given by

$$B - A, \tag{1}$$

where B is the expected number of crashes that would have occurred in the "after" period without the treatment and A is the number of reported crashes in the after period. Because of changes in safety that may result from changes in traffic volume, from regression-to-the-mean, and from trends in crash reporting and other factors, the count of crashes before a treatment by itself is not a good estimate of B (Hauer, 1997)—a reality that has now gained common acceptance. Instead, B is estimated from an empirical Bayes (EB) procedure (Hauer, 1997) in which a safety performance function (SPF) is used to first estimate the number of crashes that would be expected in each year of the "before" period at locations with traffic volumes and other characteristics similar to a treatment site being analyzed. The sum of these annual SPF estimates (P) is then combined with the count of crashes (x) in the before period at the treatment site to obtain an estimate of the expected number of crashes (m) before the treatment. This estimate of m is

$$m = w_1(x) + w_2(P). \tag{2}$$

The weights w_1 and w_2 are estimated as

$$w_1 = \frac{P}{P + 1/k}, \tag{3}$$

Download English Version:

https://daneshyari.com/en/article/573829

Download Persian Version:

https://daneshyari.com/article/573829

Daneshyari.com