Accident Analysis and Prevention 101 (2017) 78–86

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Full length article

Time series trends of the safety effects of pavement resurfacing

Juneyoung Park*, Mohamed Abdel-Aty, Jung-Han Wang

Department of Civil, Environmental and Construction Engineering, University of Central Florida Orlando, FL 32816-2450, United States

ARTICLE INFO

Article history:
Received 6 October 2016
Received in revised form
30 December 2016
Accepted 6 February 2017

Keywords:
Safety effects
Pavement resurfacing
Crash modification factors and functions
Nonlinear models
Time series models

ABSTRACT

This study evaluated the safety performance of pavement resurfacing projects on urban arterials in Florida using the observational before and after approaches. The safety effects of pavement resurfacing were quantified in the crash modification factors (CMFs) and estimated based on different ranges of heavy vehicle traffic volume and time changes for different severity levels. In order to evaluate the variation of CMFs over time, crash modification functions (CMFunctions) were developed using nonlinear regression and time series models. The results showed that pavement resurfacing projects decrease crash frequency and are found to be more safety effective to reduce severe crashes in general. Moreover, the results of the general relationship between the safety effects and time changes indicated that the CMFs increase over time after the resurfacing treatment. It was also found that pavement resurfacing projects for the urban roadways with higher heavy vehicle volume rate are more safety effective than the roadways with lower heavy vehicle volume rate. Based on the exploration and comparison of the developed CMFucntions, the seasonal autoregressive integrated moving average (SARIMA) and exponential functional form of the nonlinear regression models can be utilized to identify the trend of CMFs over time.

1. Introduction

According to the National Highway Traffic Safety Administration (2008), roadway geometric design elements and pavement engineering properties contribute to 16% of traffic crashes and 7% of traffic crashes are due to vehicle related factors. Well-maintained pavement condition is one of the key factors to enhance traffic safety since the pavement condition itself is one of the road environmental factors and it also affects human and vehicle factors simultaneously (Lee et al., 2015). Thus, estimating the safety effects of pavement resurfacing is essential in evaluating traffic safety improvements. Generally, a resurfacing pavement project can be claimed when there are possible safety problems due to the pavement issues such as potholes, shoulder dropoff, and pavement crack. According to the Agent et al. (2004), the improvement of pavement condition can enhance the overall safety of roadway.

Although traffic safety needs to be incorporated into pavement management studies, there are limited number of previous studies that examined traffic safety associated with pavement properties. Previous studies discussed that roadway pavement condition is one of the contributing factors affecting traffic crash rates (Gothie, 1996; Al-Masaeid, 1997; Karlaftis and Golias, 2002; Chan et al., 2010; Labi, 2011; Anastasopoulos et al., 2012; Lee et al., 2015; Abdel-Aty et al., 2016; Park and Abdel-Aty, 2016a, 2016b). Abdel-Aty et al. (2009) examined the safety effects of pavement resurfacing projects on rural multilane roadways using the observational before and after approaches. The study found that pavement resurfacing has safety benefit to reduce the number of total, severe injury, and rear-end crashes. Similarly, Miller and Johnson (1973) showed that the number of crashes was reduced by 45% due to pavement resurfacing. It was also found that pavement resurfacing can reduce the number of crashes in different weather conditions (i.e., dry and wet conditions). It should be noted that pavement resurfacing projects are mostly implemented and combined with re-installation of roadway pavement markings (Abdel-Aty et al., 2016). A number of studies identified that the re-installation of roadway markings can increase the retroreflectivity of roadway pavement markings and has safety benefits (Masliah et al., 2007; Smadi et al., 2008; Donnell et al., 2009; Carlson et al., 2013; Avelar and Carlson, 2014; Bektas et al., 2016).

The safety effects of roadway treatments and geometric changes in planning, design, operation, and maintenance can be quantified through developing crash modification factors (CMFs) (Park and Abdel-Aty, 2015a). The first edition of the Highway Safety Manual (HSM) (AASHTO, 2010) provides a variety of CMFs for safety treatments on roadway segments and at intersections based on different roadway facilities. However, it is worth noting that there is no CMF in the HSM for the pavement resurfacing treatment. The CMFs in

* Corresponding author.
E-mail addresses: juneyoung.park@ucf.edu, jypark@knights.ucf.edu (J. Park).

http://dx.doi.org/10.1016/j.aap.2017.02.006
0001-4575/

the HSM have been developed using high-quality observational before-after studies that can account for the regression-to-the-mean threat. It is known that the observational before and after with empirical Bayes (EB) and comparison group (CG) approaches have been the most common methods to develop CMFs (Gross et al., 2010; Carter et al., 2012; Park et al., 2014; Ahmed et al., 2015). In this paper, two observational before-after studies (i.e., EB and CG methods) have been conducted to evaluate the safety effectiveness of pavement resurfacing projects on urban arterials in Florida.

Although a CMF represents overall safety effectiveness of specific treatment for all treated sites in a fixed single value, the variation of CMFs with different roadway characteristics and time changes among treated sites is mostly ignored. In order to consider the changes of CMFs with different roadway information, previous studies have suggested to develop crash modification functions (CMFunctions) (Elvik, 2005; Elvik, 2009; Elvik, 2011; Elvik, 2013; Park et al., 2015a; Park and Abdel-Aty, 2015b; Park and Abdel-Aty, 2016a, 2016b). Moreover, there are very few studies that assessed the changes of safety effects over time. Sacchi et al. (2014) developed the CMFunctions to incorporate the effectiveness of a safety treatment (signal head upgrade program) with changes over time using Poisson-lognormal linear intervention and non-linear intervention models. Sacchi and Sayed (2014) found that the variation in safety effects of the treatment over time cannot be represented by using a single CMF, and thus estimated the CMFunctions that accounted for Annual Average Daily Traffic (AADT) changes among treated sites and time trends. Similarly, Wang et al. (2015) investigated the trends of CMFs for signalization and adding red-light running cameras (RLCs) treatments over time. The study estimated the CMFunctions for the two treatments for each month and 90-day moving windows. Park et al. (2015b) introduced an approach to utilize the Bayesian regression models with nonlinearizing link functions to develop the CMFunctions for adding a through lane treatment with consideration of the variation of CMFs over time.

While several previous studies tried to investigate the effects of pavement resurfacing, there are no studies that have addressed the changes of safety effects of pavement resurfacing projects on urban arterials with different traffic information and time trends. Therefore, the objective of this paper is to evaluate the safety effects of pavement resurfacing projects on urban arterials in Florida and investigate the variation of safety effects over time. The safety effectiveness of pavement resurfacing was evaluated using the observational before-after with EB and CG methods. To perform the EB method, the full safety performance functions (SPFs) were developed for different severity levels. The CMFs with different ranges of heavy vehicle traffic volume rate were also estimated to check the variation of the effects among treated sites. In order to explore the changes of CMFs over time, the CMFs were also estimated for different time periods. Lastly, the nonlinear regression and time series modeling approaches were utilized to develop the CMFunctions at different time periods. In this study, crash severities were categorized according to the KABCO scale as follows: fatal (K), incapacitating injury (A), non-incapacitating injury (B), possible injury (C) and property damage only (O).

2. Data description and preparation

In this study, three data sources maintained by the Florida Department of Transportation (FDOT) were used for the analysis: roadway characteristic inventory (RCI) data, financial project information from the financial management (FM) system, and crash data from the crash analysis reporting system (CARS). The RCI database provides current and historical roadway characteristics data and reflects the features of specific segments for selected dates. The FM system offers a searching system named financial project search.

The road geometry data for urban arterials were collected from the RCI for 4 years (March 2004- February 2008) before and 4 years (March 2009–February 2013) after periods. Also, crash records were collected for the same 4 years before and 4 years after periods from the CARS database. Based on the information from the FM system, a total of 195 and 205 urban segments with 115.443 and 122.515 miles in length were identified for the analysis as the treated and reference sites, respectively. Roadway characteristics data from the RCI for the target segments were matched with crash data by roadway ID and segment mile point for each segment. Moreover, any missing values or errors of data were verified Transtat-Iview (a GIS searching system offered by FDOT) and Google Earth. The descriptive statistics for the parameters of treated and reference sites are presented in Table 1.

3. Methodology

3.1. Safety performance function

It is known that a SPF generally relates the crash frequency to traffic and geometric parameters and the negative binomial (NB) model (known as Poisson-Gamma) is most commonly used to develop a SPF to account for the over-dispersion issue (AASHTO, 2010; Gross et al., 2010). In order to estimate SPFs, the data from untreated reference sites need to be obtained. According to the Abdel-Aty et al. (2016), there are two types of SPFs: the full SPF and the simple SPF. Generally, the simple SPF uses a traffic parameter (e.g., AADT) as an explanatory variable whereas the full SPF relates the frequency of crashes to both traffic and roadway characteristics. Although the HSM provides the CMFs calculated based on the simple SPF only, the full SPFs were developed and used in this study since the simple SPF is an over-simplified function. The functional form of SPF for fitting the NB regression models is shown in Eq. (1) as follows:

$$N_{predicted,i} = \exp\left(\beta_0 + \beta_1 ln(AADT_i) + +\beta_k (X_{ki})\right) \quad (1)$$

where,

$N_{predicted,i}$ = Predicted crash frequency on segment i,
β_k = coefficients for the variable k,
$AADT_i$ = Annual Average Daily Traffic of segment i (veh/day),
X_{ki} = Roadway characteristic k of segment i ($k > 2$).

3.2. Observational before and after with CG and EB methods

The observational before-after approaches are based on the research by Hauer (1997). The before-after with CG method uses a comparison group of untreated sites to compensate for the external causal factors that could affect the change in the number of crashes. A comparison group is a group of control sites that remained untreated, and that are similar to the treated sites in trend of crash history, traffic, geometric and geographic characteristics. The CG method can be adopted to account for the influence of a variety of external causal factors that change with time, The method is based on two main assumptions: 1) the factors that affect safety have changed in the same manner from the 'before' period to 'after' period in both treatment and comparison groups, and 2) these changes in the various factors affect the safety of treatment and comparison groups in the same way.

The observational before-after with EB method is a well-accepted approach to evaluate safety effects of treatments due to its statistical strength. The safety effectiveness of a treatment is calculated by comparing the observed number of crashes to the expected number of crashes in the after period. The main advantage of the EB method is that it can account for the observed changes in crash frequencies in the before and after periods, regression-to-the-mean