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HIGHWAY SAFETY INFORMATION SYSTEM

An Analysis Tool for Making Informed Safety Decisions

Safety Evaluation Of Discontinuing Late-Night Flash Operations at Signalized Intersections

Background

During late-night flash (LNF) mode (from late night to early morning hours), traffic signals flash yellow for one road (typically, the major road), requiring caution but no stopping, and flash red for the other road (typically, the minor road), requiring drivers to stop and then proceed through the intersection after yielding to the traffic on the major road. The intent of LNF is to reduce energy consumption and delay during periods of low traffic demand. However, in recent years, many agencies have begun replacing LNF with normal phasing operation because of safety concerns.

The safety impacts of replacing LNF with normal phasing operation have been studied since the 1980s. Gaberty and Barbaresso analyzed crash data at 59 four-leg intersections in Oakland County, MI, where the nighttime flash mode was replaced with normal phasing operation.(1) Results indicated a 91-percent reduction in angle crashes and a 95-percent reduction in injury right-angle crashes. However, it was not clear whether high-crash locations were selected for the change and whether the results may have been biased due to regression to the mean (RTM). Similarly, Polanis evaluated the safety of removing LNF from 19 sites in Winston-Salem, NC, using a naïve before–after method and concluded that nighttime right-angle crashes decreased by 78 percent.(2) Srinivasan et al. conducted a before–after evaluation of LNF conversion using the empirical Bayes (EB) method based on a small sample of 12 intersections in Winston-Salem, NC.(3) The EB method was used to specifically address the possible bias due to RTM. The authors concluded that nighttime crashes decreased by 35 percent, and nighttime angle crashes decreased by 34 percent. More recently, Murphy conducted an evaluation of 67 intersections in North Carolina using a before–after EB method but without using data on traffic volumes.(4) Murphy found that for sites where LNF was discontinued, there was a 27-percent reduction in nighttime crashes, a 23-percent reduction in injury and fatal crashes, and a 48-percent reduction in frontal-impact crashes.(4)

It is clear that while all the previous studies seem to indicate that removing LNF (and replacing it with normal phasing operation) will reduce crashes at night, each study had at least one limitation—possible bias due to RTM was not explicitly addressed, the sample was small, or traffic volumes were not considered. The objective of this effort was to evaluate the effect of eliminating LNF operations at signalized intersections using state-of-the-art methods and to address the noted limitations. The goal was to include an adequate sample of locations for which traffic volume data were available.

Overview of Analysis Methods

For the past two decades, the EB method has been used successfully to conduct before–after evaluations.(5) To evaluate safety treatments with the EB approach, the before period crash experience at treated sites is used in conjunction with a negative binomial crash prediction model for untreated reference sites to estimate the expected number of crashes that would have occurred without treatment. This estimate is compared with the crashes observed after treatment to evaluate the effect of the treatment. This approach accounts for possible bias due to RTM that can result from the natural tendency to select high-crash locations for treatment.

With the availability of the software package WinBUGS, the Bayesian method, also called the fully Bayesian (FB) approach, has been suggested by a few recent studies as a useful alternative to the EB approach for the following reasons (see references 6, 7, 8, 9, and 10). The FB approach can be applied even if the reference group is limited. The FB approach is also better in accounting for uncertainty in the data used and provides more detailed causal inferences and more flexibility in selecting crash count distributions. In addition, it can more explicitly account for spatial correlation and correlation

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between crash types. FB methods can be implemented in a univariate or multivariate form. The multivariate FB method can account for correlation between the crash types that are evaluated in a study. This study used both the EB and FB before–after evaluation methods to examine the safety effect of eliminating LNF operations. Further details about the two methods are provided in Lan and Srinivasan.[11]

Data

The North Carolina Department of Transportation (NCDOT) provided data for 67 signalized intersections where LNF had been removed between 2001 and 2006. (These are the same sites that Murphy used in an earlier evaluation.[4]) In addition, NCDOT identified 395 intersections that remained on LNF operation from 2000 to 2007—this group served as reference sites for the evaluation. NCDOT staff extracted crash data by crash type and severity for years 2000 to 2007 for treatment and reference groups from the Traffic Engineering Accident Analysis System (TEAAS). Each crash that occurred at the treatment sites was examined closely by NCDOT staff to ensure that it was accurately coded. Annual average daily traffic (AADT) data were extracted from AADT maps by NCDOT staff. NCDOT also provided information on the number of legs and area type (rural or urban). In addition, Highway Safety Research Center staff used Google Maps™ to verify the number of legs for all the treatment and reference sites.

Three intersections that were on freeway ramps were excluded because AADT data were not available for at least one of the legs. In addition, three other treatment sites were excluded because the treatment was implemented in 2007, and NCDOT did not provide crash data for subsequent years. Finally, 61 treatment sites were used for further study. With respect to signal operations at the treatment sites in the before period, 32 of them had LNF from 11 p.m. to 6 a.m., 20 of them had LNF from midnight to 6 a.m., and the other 9 sites had LNF periods sometime between 9:10 p.m. and 6:20 a.m. Among the 395 reference sites that remained on LNF operation from 2000 to 2007, one group (Group 1) had LNF from 11 p.m. to 6 a.m., while the other group (Group 2) had LNF from midnight to 6 a.m.

Total crashes, injury and fatal crashes, and frontal-impact crashes in LNF periods were investigated as part of the evaluation. Summary statistics for the treatment sites are shown in table 1. NCDOT indicated that there were at least two possible reasons for removing LNF: (1) policy decision—a jurisdiction decides to remove LNF as a policy, or (2) crash history during the LNF operation.

Table 1. Summary statistics for treated intersections.

VARIABLE	MEAN	MINIMUM	MAXIMUM
Years before	4.46	2	6
Years after	2.13	0.58	4.58
Total crashes/site-year before	1.77	0.00	6.75
Total crashes/site-year after	0.66	0.00	3.75
Injury and fatal crashes/ site-year before	1.05	0.00	4.75
Injury and fatal crashes/ site-year after	0.30	0.00	2.25
Frontal impact crashes/ site-year before	1.40	0.00	6.50
Frontal Impact crashes/ site-year after	0.35	0.00	3.00
Major road AADT before	22,103	2,550	59,000
Major road AADT after	21,281	3,000	48,500
Minor road AADT before	7,941	1,000	22,375
Minor road AADT before	7,983	1,000	23,333

Note: The crash statistics refer to crashes that occurred during late night. Nighttime traffic volumes were not available for this evaluation.

Implementation of the EB Method

To estimate the crash modification factor (CMF) associated with a treatment using the EB method, the following steps are required:

- Develop reliable safety performance functions (SPF) using data from the reference group. Negative binomial (NB) regression is the most common method for developing SPFs. The SPF estimating process also develops annual calibration factors that are used to account for trends such as changes in crash reporting, weather, demographics, and vehicle population.
- Obtain the EB estimate of the crashes in the before period of the treatment (after correcting for possible bias due to RTM) by combining the estimates from the SPF with the observed crashes.
- Estimate the EB expected value of the crashes that would have occurred in the after period if the treatment had not been implemented.
- Estimate the CMF based on the observed crashes in the after period, the estimate of the EB expected value of the crashes, and the variance of the EB estimate.

Because the focus is to estimate the safety effects of the conversion at night, it is necessary to reliably estimate the predicted number of crashes at night. However, the number of crashes at night in the reference groups was not sufficient to develop reliable SPFs. In addition, as mentioned in the previous section, there was not always a one-to-one correspondence between the LNF time period in the treatment sites (before LNF removal) and the LNF period in the reference groups. SPFs were first estimated using 24-h data from the reference groups and then adjusted to predict the number of crashes during the before period (i.e., LNF period) in the treatment sites. Adjustment factors were estimated based on the percentage of crashes at night in the reference and treatment groups, and the time period of the LNF in the before period of the treatment groups and the reference groups. Further details about the adjustment factors are available from Lan and Srinivasan.[11]

Implementation of the FB Method

The FB method could not be applied to four of the sites because of missing data in certain years for these sites. Hence, the FB method was applied to 57 sites. Unlike the EB method, the FB method does not need to use 24-h crash data for the evaluation and was applied using only the crash data from the nighttime period. The FB method was implemented in both univariate and multivariate forms using Poisson-gamma and Poisson lognormal models with two time effects functions (time trend and time multiplier models) to account for trends. In the implementation of the FB method, the best model was selected based on the deviance information criterion (DIC), which is discussed in Spiegelhalter et al.[6,12] In general, the model with a lower DIC value is considered better.

Results and Discussion

Table 2 shows the results of the before–after evaluations. It is important to note that the CMFs are for crashes that are expected to occur during late night conditions when the signal is operating in late night flash mode. Results include those from (1) the before–after EB evaluation, (2) the best models from the univariate FB evaluation, and (3) the best models from the multivariate FB evaluation. To directly compare the results from the EB and FB methods, the results shown are based on the information from the 57 sites for which the FB method could be applied.

The table shows that the results from the EB method are almost identical to the univariate FB method. The EB method, however, required data from both day and night to estimate the SPFs and adjustment factors to account for the differences between the reference and treatment groups. The FB method (univariate FB or multivariate FB), on the other hand, did not need such information and was more straightforward to formulate and implement. Moreover, the FB method offers more flexibility in selecting the functional form of the relationship between crash frequency and site characteristics, and the ability to address uncertainty in the data. Compared with the univariate FB method, the multivariate Poisson-log normal (MVPLN) model provided better results based on much lower DIC values. Furthermore, the MVPLN model is able to account for the correlation between the crash types.

For this particular data set, the MVPLN model was favored, and the recommended CMFs are 0.52, 0.47, and 0.43 for nighttime total, injury and fatal, and frontal-impact crashes, respectively. Discontinuing LNF operations results in substantial reductions in crashes during late night periods. Future research should investigate the conditions under which removing LNF may be more or less beneficial, and possibly develop crash modification functions. Data on nighttime traffic volumes are needed to develop more precise results.

Table 2. Crash modification factors from the before–after evaluations.

CRASH TYPE	EVALUATION METHOD					
	EB—Univariate Negative Binomial		FB—Univariate Poisson-Gamma (DIC=6,773†)		FB—Multivariate Poisson-Log Normal (DIC=6,392)	
Total LNF crashes/ site-year before	CMF	S.E. of CMF	CMF	S.E. of CMF	CMF	S.E. of CMF
Total	0.60	0.07	0.60	0.07	0.52	0.06
Injury & Fatal	0.59	0.10	0.61	0.11	0.47	0.08
Frontal Impact	0.52	0.08	0.52	0.08	0.43	0.07

†DIC for the univariate case was the sum of the DIC values from the models estimated for the three crash types.
CMF: crash modification factor
S.E.: standard error

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For More Information

The research was conducted by Bo Lan and Raghavan Srinivasan, of the University of North Carolina Highway Safety Research Center. Further details about the evaluation can be found in "Safety Evaluation of Discontinuing Late Night Flash Operations at Signalized Intersections," which was presented at the 2013 Annual Meeting of the Transportation Research Board.[11] For more information about HSIS, please contact HSIS program managers Carol Tan, (202) 493-3315, carol.tan@dot.gov, or Ana Maria Eigen, (202) 493-3168, ana.eigen@dot.gov, at the FHWA.

The Highway Safety Information System (HSIS) is a safety database that contains crash, roadway inventory, and traffic volume data for a select group of States and cities. The participating States of California, Illinois, Maine, Minnesota, North Carolina, Ohio, and Washington and the city of Charlotte were selected based on the quality of their data, the range of data available, and their ability to merge the data from various files. The HSIS database also contains historic data from Michigan and Utah. The HSIS is issued by FHWA staff, contractors, university researchers, and others to study current highway safety issues, direct research efforts, and evaluate the effectiveness of crash countermeasures.

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