Safety Impact Analysis of Lane Conversion on Selected Highway Corridor

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doi: https://doi.org/10.21467/proceedings.112.59

ABSTRACT

The safety impact analysis of a widened corridor stretch of NH 66 was carried out in this study. A before and after black spot analysis was conducted using Arc Map 10.6 to identify significant hotspots using spatial joining and Getis Ord analysis. Two Poisson regression models were formulated for the weighted sum of fatal and grievous accidents for both pre lane widening as well as post lane widening conditions. The weighted sum of accidents showed a significant relationship with AADT value and black spot segment length in both models. It was found that 40-50 % reduction of crashes due to the lane conversion was estimated at a selected AADT range.

Keywords: Lane Conversion, Highway Corridor

1 Introduction

The motor vehicle growth and the capacity augmentation mismatch of roads resulted in increased traffic congestion and road accidents throughout Kerala. Most of the State roads do not have adequate width to address the existing traffic level, only one-fourth of the roads have either two lanes or four-lane capacity while most of the roads have a single lane or intermediate lane capacity. In National Highways, about 12 per cent of the roads have four-lane capacities while the remaining roads have only two lanes or intermediate lane capacity. Bulk of the intercity and interstate traffic is carried out by the National and State Highways, which are only 8 per cent of the entire network. Given this demand-supply disparity, the state's new road network is being upgraded to a four-lane carriageway. There is increasing interest in better defining such safety effects on lane conversions. Since there is no systematic way of adopting methods to quantify the safety effectiveness of improvement projects, there is a high need to select and validate proper designs. The best way to analyze these safety effects would be to develop a model that would take a set of preexisting two-lane conditions, and predict the benefit of conversion to a second set of after lane widened conditions.

2 Literature Review

A commonly applied method for evaluating infrastructure safety is before and after study utilizing a comparison group. This approach doesn't fully address the difficulty of regression to the mean it does limit the impact of external factors. The method compares the outcomes at the treatment sites with the results at a group of comparison sites, which have similar characteristics to the treatment sites altogether important aspects, except that the treatment isn't installed. The essential evaluation is to easily compare crashes within the period before an intervention is installed with the crashes after termed an easy or naïve before-and-after study, i.e. without comparing two groups. This approach is not recommended, since it doesn't adequately account for regression to the mean or external variables.

Proceedings DOI: 10.21467/proceedings.112; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-3-3

Cross-sectional studies have also been attempted to spot the results of safety interventions. These studies compare the safety performance of sites with a selected feature with sites that do not have the same feature. There are many issues with using this approach particularly differences between sites aside from the feature of interest; and differential crash rates which will have led to the installation of the feature within the first place, therefore it's be used for this sort of evaluation. F. M. Council and J. Richard Stewart, 1999[1] in a study predictive cross sectional models were developed for different before-and-after conditions for typical sections of two and four-lane roadways in four states, California, Washington, Michigan, and North Carolina. This study aimed to provide at least initial estimates of the safety consequences of converting two-lane rural roads to four-lane divided or undivided configurations. The model predicted reduction of accidents were different for different countries due to differences in other geometric features and traffic volume level. Some of the needed improvements as well as shortcomings in estimates of safety effect were verification of the undivided four-lane results, additional information on the effects of driveways on two and four-lane crash rates, new estimates for higher two-lane ADT levels, expansion of the outcome variable to include crash severity, and verification of all results through before and after studies of actual conversions.

The currently used approach for evaluation of infrastructure development is the Empirical Bayes or EB method, which uses the concept of an expected number of crashes, or the long- term average, calculated over as long a period as is taken into account useful. The reference population acts as a comparison group. In the classical version of EB, the number of crashes which might be expected at a treatment site if no intervention had taken place is estimated and compared with the number of crashes that occurred. Comparing the particular number of crashes with the expected number of crashes indicates the extent of the crash modification factor.

In a study conducted in Ostfold county, by (R. Elvik et al.2017) [2] road safety effects of a new motorway in Norway was evaluated using empirical Bayes before-after studies. The safety estimates were expressed as simple odds (SO), odds ratio (OR), Empirical Bayes (EB) estimators of effect and regression-to-mean modelling for killed, slightly injured, injured crashes. The total length of the project included in the evaluation was 63 km and was segmented to 6 sections. The parameters that were considered killed, seriously injured, injured crashes, section length, year , AADT, the speed limit and road class variables as dummies. Road safety of a new motorway in Norway which upgraded from two lane undivided to four lane divided found that the number of killed or seriously injured road users was reduced by about 75 %. There were only small changes in the number of injury accidents (–3%) and the number of slightly injured road users (+5%).

Mohamed M. Ahmed, Mohamed Abdel-Aty carried out a Bayesian versus empirical bayes evaluation of the safety effectiveness of the conversion of two lane roadways to four lane divided roadways, and Juneyoung Park[3] using various observational before-after analyses to evaluate the safety effectiveness of widening urban and rural roadways. The methods were simple before after, before after with comparison group, empirical Bayes (EB), and Bayesian approach. The proposed method of using the full SPF in the EB method was recommended over the conventional EB observational before-after method. The Bayesian bivariate Poisson lognormal approach provided comparable results showed several advantages over the EB technique. The results indicated that the conversion from two-lane roadways to four-lane divided roadways resulted in a notable reduction in high severity crashes of more than 63% on urban roads and 45% on rural roads. Conversion to a four-lane divided roadway produced a higher reduction in total, and property damage only crashes in urban areas than in rural areas.

Another study[4] assessed the safety effects of changing lane width by applying nonlinear relationships between lane width and crash rate. For that purpose, the study applied the generalized nonlinear models (GNMs) to the estimation of CMFs for changing lane width on all types of roadway segments in Florida. The study also estimated various crash modification factors (CMFs) for different lane width ranges based on the results of the GNMs. The crash rate was highest for 12 ft lanes and lower for the lane width less than or greater than 12 ft. The estimated CMF showed that crashes were comparatively less for lane widths less than 12 ft than the lane widths greater than 12 ft if the speed limit was higher than 40 mph. The study demonstrated that the CMFs estimated using GNMs clearly reflect variations in crashes with lane width, which cannot be captured by the CMFs estimated using GLMs.

3 Scope and Objectives

- To analyze the blackspots before and after the lane conversion on the selected highway corridor
- To identify roadway and traffic parameters affecting the vehicle crash frequencies before and after lane conversion
- To develop suitable safety performance functions based on reference samples
- To analyze the safety effectiveness of lane widening through Empirical Bayes before and after safety design

4 Methodology and Data Collection

The study stretch selected is Karamana to Pravachambalam (case site) of National Highway 66 which was converted from two-lane undivided to four-lane divided roadway. The data collection required the conduction of primary surveys and the secondary data. The proposed methodology was to follow the Empirical Bayes before and after analysis of lane conversion. The control section was taken from Balaramapuram to Neyyattinkara of NH 66. The data collection part includes the inventory data, traffic volume data, crash data, speed data for pre lane widening and post lane widening conditions. The black spot analysis was carried out for before and after lane widening conditions using Arc Map 10.6. The Empirical Bayes (EB) process consists of five steps: determining the safety performance function, SPF, the overdispersion parameter, f, the relative weights, a, the estimated expected crashes, p and the index of effectiveness, q. Empirical Bayes process establishes a specific Safety Performance Function (SPF) equation, that is a negative binomial regression model, that relates the anticipated roadway crash frequency to observable roadway characteristics. The control site was selected from Balaramapuram to Neyyatinkara.

5 Black Spot Analysis

Black spots identification required to determine the highest rate crash locations and that was further used for the accident prediction modeling. The Hot Spot Analysis tool Getis-Ord Gi* statistic was calculated for each feature in a dataset. The accident severity index was used as the input feature class. The Output Feature Class with a z-score, p-value, and confidence level bin (Gi Bin) for each feature in the Input Feature Class was used for identifying statistically significant hotspots. Totally 49 hotspots were obtained based on the pre lane widening condition. However, the Getis Ord analysis showed limitation and difficulties to find the statically significant hotspots since the road was a one-dimensional stretch. Figure 1 shows the hotspot mapping of the widened lane stretch. Simple before and after safety analysis was also carried out. The change in safety was calculated as the difference in the total number of crashes, including fatal, grievous, and minor for the before period from the after period. The effectiveness index was calculated as the ratio of total crashes of before period to the after period. Almost all the crash-prone locations showed an improvement in safety.

Proceedings DOI: 10.21467/proceedings.112 Series: AIJR Proceedings
ISBN: 978-81-947843-3-3 ISSN: 2582-3922

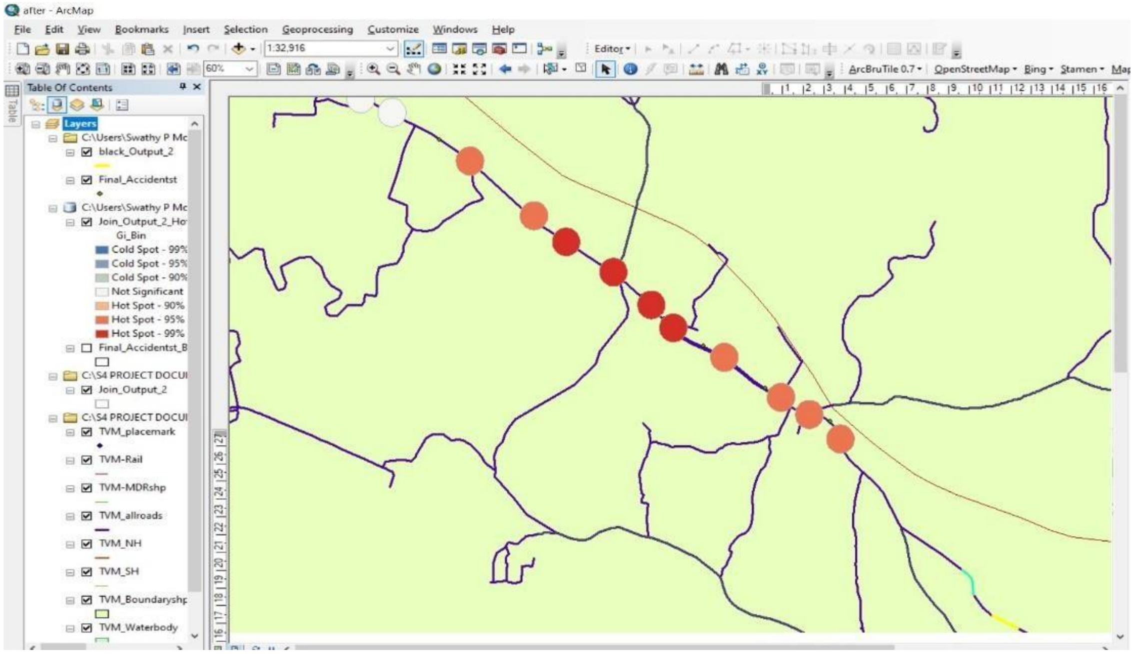

Figure 1. Hotspot mapping after lane widening 6 Development of Accident Prediction Models

5.1 Pre Lane Widening Model

In the EB procedure, the safety performance function is used first to 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 the one being analyzed. Different generalized linear models were developed in SPSS 25 software to identify the best relationship among variables. The dependent variable was the weighted sum of grievous and fatal injuries. Pearson correlation analysis for the aggregate data was processed. Significant Variables were identified as AADT(Veh/h),black spot segment Length(m), and carriageway (m). In order to identify the factors influencing the severity of accidents, models were developed for weighted sum of 4 grievous and fatal injuries. From the total 49 sections identified as the study area, randomly selected 38 sections were kept for modelling, whereas the remaining sections were reserved for validation. After validation and selection of the best fit model, final models were developed using all the sections. Among the generalized linear models developed using SPSS software, Poisson regression model provided a better fit. The best model was preferred as the one having the least Akaike Information Criterion (AIC) value. The parameter estimates are shown in Table 1 .

The obtained model was of the form:

$SUMFG = e\ (18.049 + 1.410 \ln AADT + 1.287 \ln L - 0.009CW)$

The R square value was obtained as 0.992, which indicate better robustness of the model and Root Mean Square Error value obtained as 2.0933. Due to lack of overdispersed data and since a statically significant overdispersion parameter was not obtained and negative binomial regression modeling was not able to do due to which the exact Empirical Bayes before and after the analysis was not able to follow. In that context, a separate accident model was made for post lane widening condition.

5.2 Post Lane Widening Model

The accident prediction models were developed using the weighted sum of accidents at each blackspot sections as the dependent variable. The weightage given to the fatal and grievous accidents were 7 and 3 respectively. The weightage was selected based NHAI. After the Pearson correlation analysis AADT (Veh/day), segment

length L (m), and spot speed S (Km/h) were found to be significant variables for post lane widening condition. From thetotal
22 sections identified as the study area, randomly selected 15 sections were kept for modelling, whereas the remaining sections were reserved for validation. Among the generalized linear models developed using SPSS software, poison regression model provided a better fit. The best model was preferred as the one having the least Akaike Information Criterion (AIC) value. The models were said to be valid only if all the parameters used in the model were significant at 5 percentage level ofsignificance.

Table 1. Parameter Estimates

Pre Lane Widening Model				Post Lane Widening Model			
Parameter	**Estimates**	**s.e**	**p Value**	**Parameter**	**Estimates**	**s.e**	**p Value**
Intercept	-18.049	0.5281	0	Intercept	-14.834	3.6001	0
ln AADT	1.41	0.4536	0	ln AADT	2.231	0.3658	0
ln L	1.287	0.2954	0	ln L	1.809	0.6409	0.005
CW	-0.009	0.0115	0.002	S	0.05	0.0123	0
RMSE	2.0933			RMSE	4.7213		
R^2	0.992			R^2	0.852		

The obtained model was of the form:

SUMFG =e (14.834 + 2.231ln AADT + 1.809ln L + 0.05S)

The model for predicting the weighted sum of accidents was validated using R2 values were also obtained in order to verify the robustness of the model. The R square value was obtained as 0.852, which indicate better robustness of the model and Root Mean Square Error value obtained as 4.7213. Before the Lane widening, the carriage width showed a significant effect on the 5 weighted sum of the fatal and grievous crashes. For the model after lane conversion, the carriageway width did not show that much significance instead, the spot speed was showing a better significance. This means that after the lane conversion, the speed of vehicles contributed to the increased accident cause. The final step in the analysis was to estimate the safety effects of two lane undivided to four lane divided conversion. Although prediction equations were developed for essentially the full range of AADTs, the percentage difference between the two and four-lane estimates (i.e., the safety effect) was developed only for common AADT ranges where data existed for both two and four-lane roadways The safety effects were expressed as the percentage reduction of predicted crash totals which can be expressed as:

$$R(a)= \frac{P2(a) - P1(a)}{P2(a)} * 100$$

The percentage reductions for a selected AADT range for sections represented in Figure 1. From the visual examination of graph, it shows that conversion from a two lane to a four lane divided road resulted in a crash reduction of between 40 and 50 percent. Also, the reduction of crashes was slightly decreasing with increasing

Proceedings DOI: 10.21467/proceedings.112
ISBN: 978-81-947843-3-3

Series: AIJR Proceedings
ISSN: 2582-3922

AADT values.

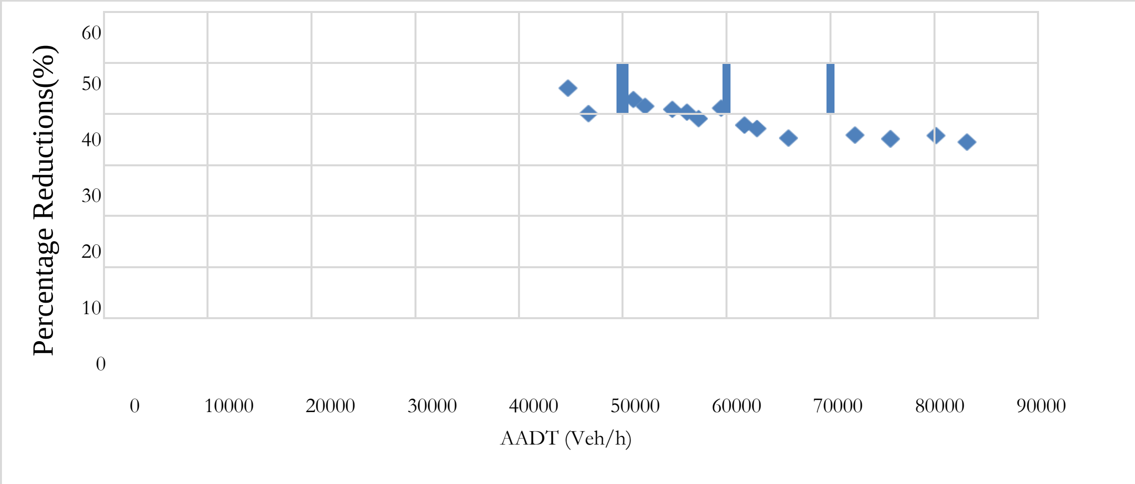

Figure 2. Percentage reduction in estimated crashes

6 Conclusions

The study aimed to carry out the impact analysis of lane widening on the national high- way corridor stretch from the Karamana to Pravachambalam. The stretch had undergone widening due to increased congestion and accidents at frequent locations. Before and after black spot analysis were carried out using ARC MAP 10.6 to identify significant hotspots. Two models were formulated for the weighted sum of fatal and grievous accidents for both pre-lane widening and post lane widening conditions. In both models, the total number of accidents showed a significant relationship with AADT value and segment length. The carriageway width showed significance in pre widening model. Spot Speed showed significance in post widening model. Safety effect of lane conversion was expressed as the percentage reduction in the predicted crashes over a 3-year period as functions of AADT in the most typical sections. Conversion from a two-lane to a four-lane divided road resulted in a crash reduction of between 40 and 50 percent, and the percentage reduction showed a slight decrease with increase in AADT values.

How to Cite this Article:

Mohan, S. P., & Archana, S., Ebin, S S., (2021). Safety Impact Analysis of Lane Conversion on Selected Highway Corridor. *AIJR Proceedings*, 488-493.

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