Global Scientific JOURNALS

GSJ: Volume 7, Issue 12, December 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

IMPACTS OF TRAFFIC INTERVENTIONS ON ROAD SAFETY: AN APPLICATION OF CAUSAL MODELS.

Touseef Ahmad, Fazal Haq.

Graduate student, Civil Engineering Department, INU Peshawar, Pakistan, PH: 03154321055. Email:engr.touseef92@gmail.com.

Supervisor, Civil Engineering Department, INU Peshawar, Pakistan, PH: 03479695727. Email:fazalhaq3526@gmail.com.

Keywords

Causal, Traffic Intervention, Road accidents, Road safety.

ABSTRACT

This Paper is concerned with the causal relationship between traffic interventions and road safety. It focuses on two issues that have been overlooked in the existing empirical literature: the establishment of a causal link between traffic interventions and road traffic accidents, and the application and development of formal causal approaches, which have not yet been applied in the field of road safety.

In the past decades substantial studies have been conducted to investigate the risk factors contributing to road accidents. It has been shown that the frequency and severity of road accidents are associated with various factors, including traffic characteristics, road environment and demographic characteristics. However, the existence of a causal link between traffic interventions and road accidents remains unclear due to the complex character of traffic interventions. Meanwhile, the lack of formal causal models makes it difficult fully to address issues such as confounding effects and regression to the mean bias.

This Paper begins by reviewing and discussing different types of traffic interventions in order to demonstrate the chains through which traffic interventions are related to road safety. To address the shortcomings in empirical literature, three models for causal inferences are discussed: the difference-in-difference method, the propensity score matching method and Bayesian methods.

1. INTRODUCTION

1.1. Background

Road accidents place a great burden on individuals, property and society. During the last few decades, considerable research has been conducted to identify important factors related to the occurrence of road accidents, including traffic characteristics, road characteristics, socio-economic and environmental factors

It is worth noting that the road safety measures that have been evaluated in previous studies are different from the traffic interventions in this thesis. “Traffic interventions”, as discussed in this research, are defined as policies, legislation and enforcement, the construction of road networks, and other general-purpose measures which directly or indirectly affect traffic condition, drivers’ behavior and the travel environment. Traffic interventions are different from other road safety measures in that they may influence traffic conditions, the model split of transport, and other aspects. The implementation of traffic interventions, therefore, can have a direct or an indirect impact on road accidents, regardless of whether that impact is expected or unexpected. It is more complicated to estimate the causal effects of traffic interventions than measures designed for road safety. A better understanding of this causal relationship, however, would help policy makers to evaluate the safety outcomes of traffic interventions and hence enhance the prevention of road accidents.

1.2. Motivations and Objectives

1.2.1. Motivation

The first motivation for this thesis regards the causal link between traffic interventions and road safety. A substantial number of studies have been conducted to investigate the risk factors contributing to road casualties. It has been shown that the frequency and severity of casualties are associated with various factors, including traffic characteristics, road environment and demographic characteristics. On the other hand, many studies have focused on the relationship between traffic interventions and traffic flow, travel modes, environment and business matters 19. Despite the fact that several studies have evaluated the effects of traffic interventions on the number of accidents and injuries, the assignment of these interventions are not randomized and the observational inferences are not always of high quality. The nature of the causal link between traffic interventions and road casualties remains unclear, therefore. Although the complex character of traffic interventions makes it difficult to generalize about their effects, a better understanding of the causal relationship would help policy makers to evaluate the safety outcomes of interventions and hence improve the prevention of road accidents. In this thesis, formal causal models are applied to establish a causal link between traffic interventions and road casualties, and to address the shortcomings of previous literature by studying this link.

The second motivation for this thesis regards the dataset used for road safety analysis at the aggregate-level. One issue which is very critical in all road safety analysis is the selection of appropriate traffic exposure variables. Traffic exposure is the most important factor influencing traffic crash counts, however there is not currently an appropriate variable that can be used to control for the traffic exposure in area-level analyses. In analysis at the disaggregate (unit) level, where the study object is usually road sections or intersections, the annual average daily traffic (AADT) or vehicle miles travelled (VMT) is preferred as the traffic exposure variable. At the aggregate (area) level, however, these variables are not always available and, although proxy variables for traffic exposure have been developed, they entail some limitations. A failure properly to control for the traffic exposure could bias the inferences drawn from studies. Another issue concerns the usage of data about road network characteristics. A detailed dataset of the road network, including road class, road length and node information can be obtained from Ordnance Survey (OS) MeridianTM2. The data only covers a single year, which means the variance in the road network over time cannot be accounted for.

1.2.2. Objectives

a) To explore various factors affecting road traffic accidents and traffic interventions
b) To investigate the causal relationship between traffic interventions and road traffic accidents using empirical studies.
c) To model the assignment mechanism of traffic interventions by applying causal evaluation techniques and identifying confounding factors.
d) To control for traffic exposure and confounding factors, using a time-series database containing information about road casualties, geographic and road characteristics, by collecting and organising data previously unavailable.
e) To provide policy-makers with a better understanding of the causal effects of traffic interventions on road safety, and hence to help policy-makers to evaluate the safety outcomes of traffic interventions and hence improve the prevention of road accidents.

2. LITERATURE REVIEW

Factors affecting road accidents have been the focus of considerable research in transport studies during the past decade. Most studies have shown that a broad range of factors can affect road accidents and many inferences have been drawn based on the exploration of traffic characteristics, primarily, traffic speed, density and flow. Taking each of these characteristics in turn, it can be assumed that increased speed would lead to more severe accidents (Ossiander and Cummings, 2002; Taylor et al., 2002). The relationship between the accident rates and density follows a U-shape relationship (Zhou and Sisiopiku, 1997) and it has been suggested that low traffic flow can induce both a higher accident rate and more severe accidents (Martin, 2002).

2.1. Traffic Characteristics

Speed, flow and density are three main characteristics affecting the occurrence and severity of road accidents. Numerous studies have been conducted to investigate how these factors are associated with road accidents. One common assumption is that high speed, free flow and low density are associated with more severe accidents. Meanwhile other studies have also found that the frequency of road accidents is associated with traffic speed. It seems logical that driving faster is more likely to lead to an accident. Others believe that the crash involvement rate depends on the deviation from the mean speed rather than absolute speed of the traffic. Although there is no conclusive answer to this problem, it is explicit that accident severity increases with pre-crash speed. Baruya (1998) investigated speed-accident relationships on European roads based on accident and speed data collected from four European countries. A Poisson regression model was employed to analyse the discrete data with a negative relationship being found between mean speed and accident frequency. An ecological study designed by Ossiander and Cummings (2002) examined the effect of increased speed limits on freeways in Washington State on the incidence of crashes. (1999) also suggested that reducing the speed limit could result in fewer accidents.

2.2. Road Network and Infrastructure

Abdel-Aty and Radwan (2000) estimated the frequency of accident occurrence on a principal arterial in Central Florida by employing negative binomial models. This paper highlighted the importance of the road infrastructure characteristics, such as the degree of horizontal curvature, the number of lanes, shoulder widths and the road section's length. The results showed that people driving on a road with narrow lane and shoulder width, a larger number of lanes and reduced median width were more likely to be involved in accidents. Noland (2003) investigated the effects of infrastructure changes on road traffic accidents while other factors that may affect the occurrence of such accidents were controlled. The variables on infrastructure characteristics included lane miles, number of lanes for different types of road and the proportion of each type of road. Noland's results suggested that certain changes in highway infrastructure in the US between 1984 and 1997 had the effect of increasing absolute total number of traffic casualties. Another spatially disaggregate analysis of road casualties in England undertaken by Noland and Quddus (2004) examined the effects of road characteristics and land use on road casualties. Their results suggest that an increased length of "B" road 3 can increase serious injuries, although the coefficients for other types of road were not significant. Noland and Oh (2004) examined how changes in road infrastructure can affect the occurrence of road accidents. The authors used fixed effect NB regression to estimate county-level timeseries data in Illinois, USA. The authors found that increased road accidents were associated with increased number of lanes, increased lane widths and decreased outside shoulder width. One suggestion made by them was the need to account for time-variant factors. Amoros et al. (2003) aggregated accident data by road type within a number of counties in France and subsequently analysed this data using the NB regression. One of the findings in this study was that the difference in accident numbers and their severity between the counties depended on the type of road.

2.3. Demographic and Environmental Characteristics

In addition to their impact as vehicle drivers, the populace impacts road traffic accidents in other ways. Factors such as population, employment, age and gender can reflect the social structure and economic activities of an area with an attendant impact on accidents. Furthermore, environmental characteristics, such as land use, are the principal determinant of trips and may also influence accident rates. Previous studies have been published on the relationship between accidents and demographic and environmental characteristics. Zajac and Ivan (2003) evaluated the effect of different types of roadways and area type features, such as the land use type, on the injury severity of pedestrian accidents in rural Connecticut. The authors found that downtown fringe, village and low-density residential areas generally experienced lower injury severity. Graham and Glaister (2003) investigated the impact of land use mix, urban scale and density on pedestrian casualties. Wedagama et al. (2006), primary functional land use, population density and junction density were treated as explanatory variables. Both pedestrian and cyclist casualties during working hours were positively associated with retail land use in the city centre.

Dissanayake et al. (2009) examined the feasibility of using land use factors to analyse child pedestrian casualties on road.

Table2.1 A summary of studies on factors affecting road accidents

Authors	**Modelling Approach**	**Data and Units of Analysis**	**Factors Affecting Road Accidents**	**Main findings**
Baruya (1998)	Poisson Regression	203 links from 4 European Countries for the 1990s	Traffic Speed	A negative relationship was found between mean speed and accident frequency
Aljanahi et al. (1999)	Poisson Regression	1 county of the UK and 1 county in Bahrain, 1987-1990	Traffic Speed	Reducing the speed limit could result in less accidents
Ossiander and Cummings (2002)	Poisson Regression and Negative Binomial Regression	Freeways of Washington State, 1974-1994	Traffic Speed	An increased speed limit was associated with a higher fatal crash rate and more deaths on freeways
Taylor et al. (2002)	Principal components analysis,Generalised Linear Modelling	174 road segments from rural roads in England	Traffic Speed	Accident frequency was positively related with the mean traffic speed
Ivan et al. (2000)	Non-linear Poisson Regression using quasi-likelihood estimation techniques	17 US rural two lane highway segments, 1997-1998	Traffic density and land use	Traffic intensity played an important role in predicting accident rates and interpreting the causes of high accident rates point
Martin (2002)	Poisson Regression and Negative Binomial Regression	2000 km of French interurban motorways	Traffic Flow	Accidents rates were highest in light traffic and accident severity was greater when hourly traffic was light
Golob et al. (2004)	Nonlinear canonical correlation analysis	All police-reported cases on the California State Highway System, 1998	Traffic Flow	There was a relationship between traffic flow and accident rates. Volume had more influence on accident severity than speed
Golob et al. (2003)	Nonlinear canonical correlation analysis	6 major freeway in California, 1998	Traffiflow , weather and lighting condition	
Lord et al. (2005)	Generalized Estimating Equation	A rural section and an urban section in Canada, 1994-1998	Traffic flow, density and V/C ratio	Accident risk and the number of accidents increased as density and V/C ratio increased
Noland and	Negative	15366 spatial units	Traffic	Congestion may affect crash

Quddus (2005)	binomial regression	in the Greater London area, 1999-2001	Congestion	severity on high speed roads rather than in urban conditions
Shefer and Rietveld (1997)	Piece-wise, linear speed density function	Simulated dataset	Traffic Congestion	Congestion led to lower numbers of fatalities
Wang et al. (2009)	Poisson based models using a full Bayesian estimation	M25 motorway in England, 2004-2006	Traffic Congestion	Little or no impact was found due to mixed effects of traffic congestion
Kononov et al. (2008)	Safety performance functions	Multilane freeways in Colorado, California, and Texas	Traffic Congestion	Congestion charging could have the potential for safety improvement as well as mobility benefits

Noland and Quddus (2004)	Negative binomial regression	8414 wards of England, 1999	Road characteristics and land use	Increased length of B roads could increase serious injuries
Amoros et al. (2003)	Negative binomial regression	8 counties in France, 1987-1993	Road types	Difference in accidents and severities between counties depended on the type of road
Noland and Oh (2004)	Fixed effect NB regression	102 counties in Illinois, 1987-1994	Road network infrastructure and geometric design	Increased road accidents were associated with increased number of lanes, increased lane widths, and decreased outside shoulder width
Abdel-Aty and Radwan (2000)	Negative binomial regression	A principal arterial in Central Florida, 1992- 1994	Road infrastructure characteristics	Narrow lane and shoulder width, larger number of lanes and reduced median width were more likely to induce accidents
Noland (2003)	Fixed effect NB regression	50 US states, 1984-1997	Road infrastructure characteristics	Changes in highway infrastructure had the effect of increasing total traffic casualties

3. METHODOLOGY

The following Methodology are use in Road Safety Intervention.

1. Propensity Score Matching
2. Implementing PSM
3. Estimating the propensity score
4. Matching Algorithm
5. Estimating treatment effects

4. RESULT AND CONCLUSION

4.1. The estimation of propensity scores

The first step in the propensity score matching method is to estimate the probability of being selected in the treatment group. The log model is regressed on the covariates and the covariates that influence the participation and the outcome should be included in the model. This shows us covariates except minor roads are significant in the estimation of the propensity score. This is probably because there are very few speed cameras installed on minor roads in the study sample. The result confirms that the covariates included in the propensity score model are important in predicting the possibility of being selected as camera sites.

4.2. Tests of matching quality

Before estimating the effects of speed cameras, the validity of the PSM method must be checked. One approach is through a visual inspection of the propensity score distribution for both the treatment and comparison groups. From the histograms of propensity scores for both groups, the extent to which there is overlap in the scores between the treatment and comparison groups is apparent. Observations that fall outside the region of common support must be discarded and cannot be estimated. The estimation will be unaffected if the proportion of discarded observations is small (Bryson et al., 2002). If the proportion is too large, however, the estimated treatment effect could be inaccurate.

4.3. Effects of speed cameras on road accidents

The effects of speed cameras on road accidents were estimated using three different methods: a naïve before-after approach, the PSM method and the EB method. Since different algorithms can be chosen when employing the PSM method, the robustness of the results must be checked to ensure that the estimation does not depend upon the chosen algorithm. In this study, results from five algorithms, two of which were of one type (K-nearest neighbours), were compared to increase confidence in the PSM method.

5. RECOMMENDATION

A large number of the recent studies on safety evaluations have focused only on estimation of the average treatment effects on treated individuals. Although researchers have typically allowed for general treatment effect heterogeneity, there has been little formal investigation of the presence of such heterogeneity. In treatment evaluation studies, it is sometimes interesting to learn about distributional effects besides the average effects of the treatment, and to examine whether there is any subpopulation for which a programme or treatment has a non-zero average effect, or whether there is treatment effect heterogeneity. For example, a policy maker might be interested in the effect of a treatment on the lower or higher tail of the outcome distribution. In recent years, there have been some studies on this issue. Crump et al. (2006) developed two nonparametric tests for the presence of treatment effect heterogeneity. Later, Firpo (2007) proposed approaches for estimating quintile treatment effects with the restriction that the treatment assignment is based on observable characteristics. This has not been studied in the field of road safety, however. A study on treatment effect heterogeneity would make an interesting question.

Most of the recent studies have mainly focused on a binary treatment. Little attention is devoted to investigating settings with multi-valued, discrete or continuous treatments, which are common in practice. Hirano and Imbeds (2004) proposed a generalization of the binary treatment propensity score, known as the generalized propensity score (GPS). They demonstrate that the GPS has many of the attractive properties of the binary treatment propensity score. The GPS has been applied by several studies in the context of evaluating active labor market policy (Flores et al., 2007; Kluve, 2009). These studies also provide scope for future research.

In this Paper the causal approaches applied are univariate rather than multivariate. Multivariate techniques allow researchers to look at relationships between variables and quantify the relationship between variables. This gives a much richer and realistic picture and provides a powerful test of significance compared to univariate models. To the best of the author's knowledge, the multivariate techniques have not been applied in causal analysis. This would be an interesting topic for the future research.

6. ACKNOWLEDGEMENT

All praise due to ALLAH alone and most merciful and the most compassionate, who created men and women and taught, them manners. He best owned us Holy Quran, which is guidance for their believers, and Peace be upon him Holy Prophet "Mohammad" most perfect and the best among us and of even born on the surface of earth, who lightness the hearts of believers in their lives.
I would like to acknowledge the assistance of the following people: -

- Engr Abdul Farhan INU University, for guidance, encouragement, understanding and supervision of the research without him none of the finding would have been possible.

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