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Climate change modeling and the weather-related road accidents in Canada

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A B S T R A C T

The objective of this research is to study the impact of climate change on the hazardous weather-related road accidents in the New Brunswick, Canada. We develop an Exposure to Weather-Accident Severity (EWAS) index multiplying accident and weather severity. The Negative Binomial Regression and Poisson regression models are applied to estimate the spatial–temporal relationship between the EWAS index and weather-related explanatory variables of road accidents. The regression results show that the surface-weather condition, weather, driver's gender, weather-driver's age, weather-driver's experience, and weather-vehicle's age have strong positive correlation with the EWAS index, while the surface-road alignment and surface-road characteristics have negative relationship with the EWAS index. The climate change model also indicates that the number of accidents declines during snowy and freezing days—most people stay at home and those who travel extra cautious—accidents do occur. The study suggests that the Road Safety Strategy 2015 of the Transport Canada should take a holistic approach to help minimize the incidences of severe road accident during the normal as well as hazardous weather conditions.

Introduction

Transport Canada (2011) has prepared a Road Safety Strategy (RSS) 2015, the third in a series of national road safety programs, to reduce the number of fatalities and serious injuries from the road accidents. The RSS 2015 proposes a Safer System approach for each jurisdiction based on the primary risk groups and key contributing factors. The RSS 2015 identifies the young drivers, medically-at-risk drivers, vulnerable road users, motor carriers and high-risk drivers as the target groups of the safety plans (Transport Canada, 2011). Meteorological conditions such as temperature, precipitation, and wind speed are also the important contributing factors to road accidents as they reduce visibility and cause the loss of vehicle control. During the period of 1999–2008, thirty percent of the registered road accidents in Canada occurred during hazardous weather conditions (Transport Canada, 2012). The proportion of vehicle damages, human injuries and fatalities in road accidents during hazardous weather conditions is similar to that of total. The change in meteorological conditions may have significant impact on the road accidents. Different studies (Vincent and Mekis, 2006; Zhang et al., 2000) evaluate the changes

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in precipitation and temperature indices in Canada. Vincent and Mekis (2006) found out that the mean temperature and the frequency of precipitation and rainfall have increased in New Brunswick province during the 20th century. Zhang et al. (2000) also discovered that the maximum and minimum daily temperatures were increased by 0.5–1 °C and 1–1.5 °C in the same province during the 20th century. The trend of temperature changes and the 15–25 percent increases in total precipitation along with changes in the form of precipitation and the snow to precipitation ratio in New Brunswick province support the possible climate change scenarios in the future.

The objectives of this research are to simulate the climate change scenarios during the 21st century and to study the impact of climate change on the hazardous weather-related road accidents. This study considers the New Brunswick province of Canada as a case study.

Literature review

Several studies (Cromley, 2007; Palutikof, 1991; Edwards, 1996) have examined the impact of hazardous weather on the road accidents. Edwards (1996) examined the spatial dimension of weather-related road accidents in the United Kingdom and found a positive relationship between the incidences of weather hazards and road accidents. The pattern of relationship between the weather and accidents changes over seasons and locations. Edwards (1999) carried out another study on the panel longitudinal data of road accidents in England and Wales during the hazardous weather. This study also found out a relationship between accident occurrence in adverse weather and actual weather patterns. Andrey et al. (2003) executed a study on the mid-sized Canadian cities with different climates using a standardized method. The study revealed that the sensitivity to hazardous weather varied from city to city and the probability of risk of injury was lower than that of risk of accidents. Andrey et al. (2003) estimated that the number of road accidents and related injuries were increased by 75 percent and 45 percent because of the precipitation. The snowfall effects were more pronounced than rainfall effects for accidents as a whole (Andrey et al., 2003). Eisenberg and Warner (2005) also identified snowfall as a hazardous weather condition. Fridstrøm (1999) estimated a similar relationship for Norway. Fridström et al. (1995) applied the generalized Poisson regression to estimate the contributions of various factors to monthly crash rates in the provinces of Denmark, Finland, Norway and Sweden during the period of 1973–1987.

The study indicated that rainfall increased the accidents while snowfall decreased accidents in the study areas. Rainfall increased the fatal accidents in Denmark but had no significance in Norway and Sweden. Keay and Simmonds (2006) examined the impact of rainfall on daily road accidents in the metropolitan area of Melbourne (Australia) over the period of 1987–2002. The analysis of accident data, standardized for variation of traffic volume, indicated a complex effect of rainfall on road accidents. Andreescu and Frost (1998) identified a significant positive correlation between daily precipitation and daily number of accidents in Montreal (Canada) for the period of 1990–1992. Eisenberg (2004) supported the hypothesis that rainfall caused a stronger increase in the number of fatal accidents after a dry spell since precipitation makes the roads slippery by clearing the oil accumulated on roads during dry periods. Eisenberg (2004) concluded that some states in the United States experienced very high rates of fatal accidents in wet conditions(e.g. Arizona and Maryland) and some others States were hardly affected at all (e.g. Connecticut and Indiana). Musk (1991) showed that accident rates and multiple accidents were increased during thick-fog occurrences. The tendency to maintain the speed and unable to reduce the speed and inability to reduce speed in poor visibility conditions cause the accidents during fog (White and Jeffrey, 1980; Musk, 1982). Drivers become isolated from the road environment while driving in fog and cannot perceive speed and actual distance from the preceding vehicle (Miller, 1967). Moore and Cooper (1972) estimated that the number of accident injuries increased in fog although the traffic volume decreased by 20 percent. Rosenfeld (1996) estimated that the number of people died in fog-related road accidents was more than twice comparing to total deaths in hurricanes, lightning and tornadoes in US during the period of 1982–1991.

Very few studies (Andersson and Chapman, 2011) investigated the relationship between climate change and road accidents. Andersson and Chapman (2011) studied road accidents across the West Midlands (United Kingdom) during the winter months applying UK Climate Impacts Programme (UKCIP) climate change scenarios. The study found that road accidents would be reduced because the low freezing temperatures would not be frequent and the winter season would be shorter. Andersson and Chapman (2011) did not include other seasons in their study. This paper simulates climate change scenarios and studies the impact of climate change on the hazardous weather-related road accidents.

Methodology

Data

Road accidents data, traffic flow, environmental conditions, and road geometry were collected for the road network of New Brunswick. Data on Property Damage Only (PDO), injuries, and fatalities from both single and multiple accidents were collected from police accident reports during the period of 1997–2007. This study also used a 30-year (1961–1990) continuous record of daily rainfall, snowfall and mean temperature for climate change modeling. The selected data for the 1961–1990 study period include: (1) observed daily data for seven different zones in New Brunswick province (Fig. 1); (2) National Centers for Environmental Prediction (NCEP) re-analysis dataset and large-scale simulation data from the third generation