Spatial analysis of road weather safety data using a Bayesian hierarchical modeling approach

X. Qin [1] J. Han [2] J. Zhu [3]

[1] *Traffic Operations and Safety (TOPS) Laboratory, University of Wisconsin-Madison, 1415 Engineering Drive, Madison, WI 53706, email: xqin@engr.wisc.edu*
[2] *Department of Mathematical Science, 315, SCEN Building, University of Arkansas, Fayetteville, AR 72701 email: jhhan@uark.edu*
[3] *Department of Statistics, University of Wisconsin-Madison, 1300 University Avenue, Madison, WI 53706 email: jzhu@stat.wisc.edu*

subm. 31st March 2008 *approv. after rev. 4th December 2008*

Abstract

Adverse weather has a major safety impact on travelers on highways. Weather events and their impact on highways can be viewed as predictable, non-recurring incidents that display strong geographic patterns. This study attempts to address the Wisconsin counties with high crash relative risk (RR) under various inclement weather conditions such as snow, rain and fog. Within a Bayesian hierarchical modeling framework, a Poisson model with a log link function including a spatial random effect is proposed. In particular, two types of spatial models are considered. One is a conditional autoregressive (CAR) model that specifies spatial dependence via autoregression among neighboring counties. The other is an exponential model that assumes an exponential decline of spatial dependence as the distance between two counties increases. A spatially independent model is also considered as a baseline model.
Bayesian statistical inference results show fairly consistent crash patterns with weather impact. Higher-than-expected snow-related crashes occurred in the northern Wisconsin counties where more snowfall was experienced throughout the long winter. Rain-related crashes clustered in the areas close to Lake Michigan with more rainfall than other parts of the state**.** The counties in the southwestern region have overrepresented fog-related crashes partially because of more foggy days in the mountainous valley terrain. Our modeling approach can be recommended to rank the counties for road weather safety planning and programming.

Keywords – Bayesian hierarchical model, conditional autoregressive (CAR) model, crash prediction, Poisson distribution, Relative Risk (RR), road weather safety, spatial autocorrelation

1. Introduction

The lives and affairs of human being constantly interacting with the natural world brings us both useful assets and harmful impacts. Without even mentioning extreme natural disasters such as earthquakes, hurricanes, tsunamis and so on, adverse weather events such as snow, rain, fog, ice, sleet and wind affect road safety in terms of reduced pavement friction, reduced driver visibility and deteriorated traffic control device functions. To cope with the harmful effects of nature, improvements have been developed for transportation systems to mitigate serious and detrimental road weather safety hazards for decades.