Climate Change Modeling and the Weather-Related Road Accidents

Md. Shohel Reza Amin[1]; Alireza Zareie[2]; Luis E. Amador-Jiménez[1]
[1]Concordia University, [2] McGill University

ABSTRACT

This presentation projects the climate change and studies the impact of climate change on hazardous weather-related road accidents in New Brunswick province of Canada.

Climate change modeling uses 30-years daily weather records for the seven climate zones of New Brunswick, National Centers for Environmental Prediction (NCEP) re-analysis dataset, large-scale simulation data from the third generation Coupled Global Climate Model (CGCM3) and third version of Hadley Centre Coupled Model (HadCM3). Large-scale simulation data from Canadian GCM under SRES-A2, and SRES-A1B scenarios along with large-scale simulation data from Hadley center CM under SRES-A2, and SRES-B2 during the 21st century are used to model the climate change.

The climate change modeling estimates the increasing rainy days for all climate zones; however, the number of snowy and freezing days may decrease or stay the same for most of the climate zones during three different future periods in 21st century (i.e. 2011-2040, 2041-2070, 2071-2100).

This study also estimates an Exposure to Weather-Accident Severity (EWAS) index using both single and multiple road accident data. The negative binomial regression and Poisson regression models are applied to estimate the relationship between the EWAS index and weather-related explanatory variables of road accidents.

Surface-weather condition, weather-driver's gender, weather-driver's age, weather-driver's experience and weather-vehicle's age have strong positive correlations with EWAS index. Surface-road alignment and surface-road characteristics have negative relationship with EWAS index. These relationships are similar at different census divisions of the New Brunswick.

Increasing number of hazardous weather days estimated by the climate change modeling, and positive relationships among EWAS index and weather-related explanatory variables of road accidents suggest more hazardous weather-related accidents in future.

CONTACT

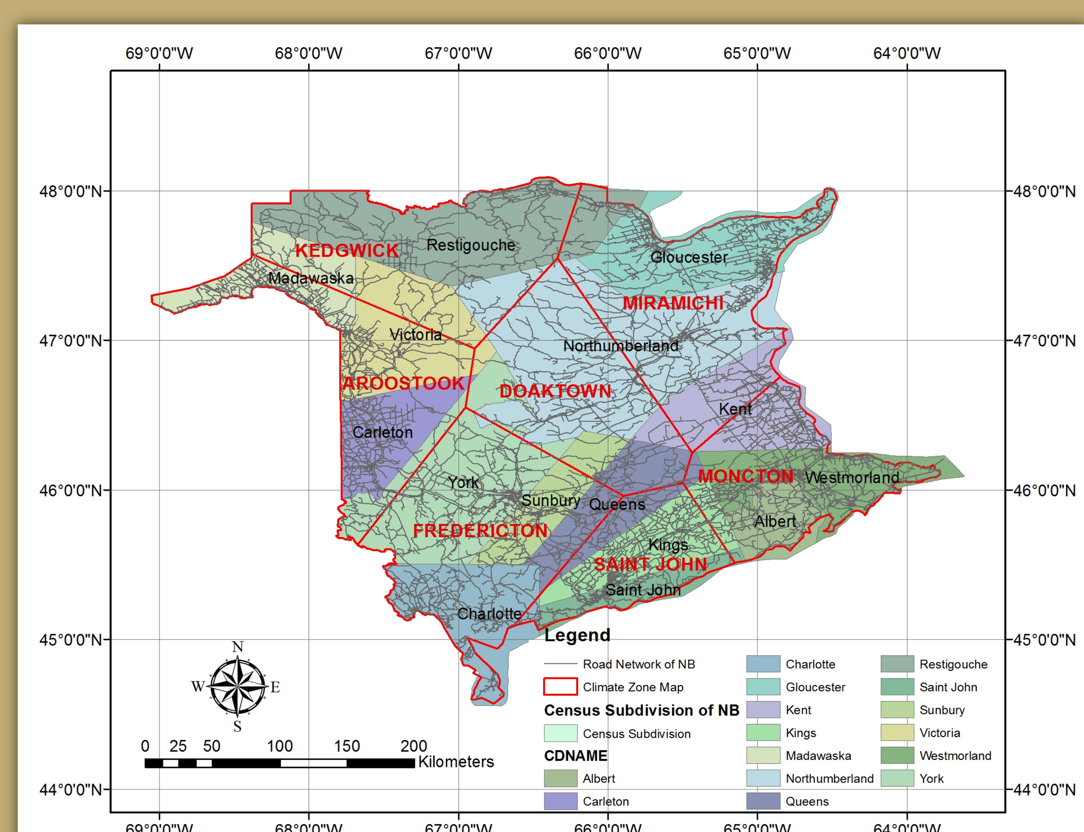
Md. Shohel Reza Amin
Ph.D. Candidate (Civil Engineering)
Concordia University, Montreal, Quebec, Canada
Email: shohelamin@gmail.com
Phone: 438-936-4119

INTRODUCTION

- Canada is one of the highest ranked countries in terms of road accident fatalities among countries of OECD (Transport Canada, 2011).
- During 1999-2008, 30% of registered road accidents in Canada were occurred at hazardous weather conditions (Transport Canada, 2012).
- Proportion of vehicle damages, human injuries and fatalities in road accidents at hazardous weather conditions is similar to that of total accidents (Transport Canada, 2012).
- Hazardous weather reduces visibility and causes loss of vehicle control.
- Objectives of this study are to simulate the climate change scenarios during 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.
- Trend of temperature changes and 15% - 25% 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 future.

Study Area & Data Collection

- Road accidents data, traffic flow, environmental conditions, and road geometry were collected for the road network of New Brunswick province.
- Accident data, both single and multiple accidents, were based on police accident reports for the period of 1997-2007.
- 30-year (1961-1990) continuous record of daily rainfall, snowfall and mean temperature for seven climate zones in New Brunswick province.
- Reanalysis data (National Centers for Environmental Prediction) during calibration period (1961-1975) were used to estimate a relationship between selected predictors and predictands.
- Robustness of estimated relations was validated using the reanalysis data of the validation period (1976-1990).



Methodology

Step 1: Accident Severity Index (ASI) (Afghari, 2012)

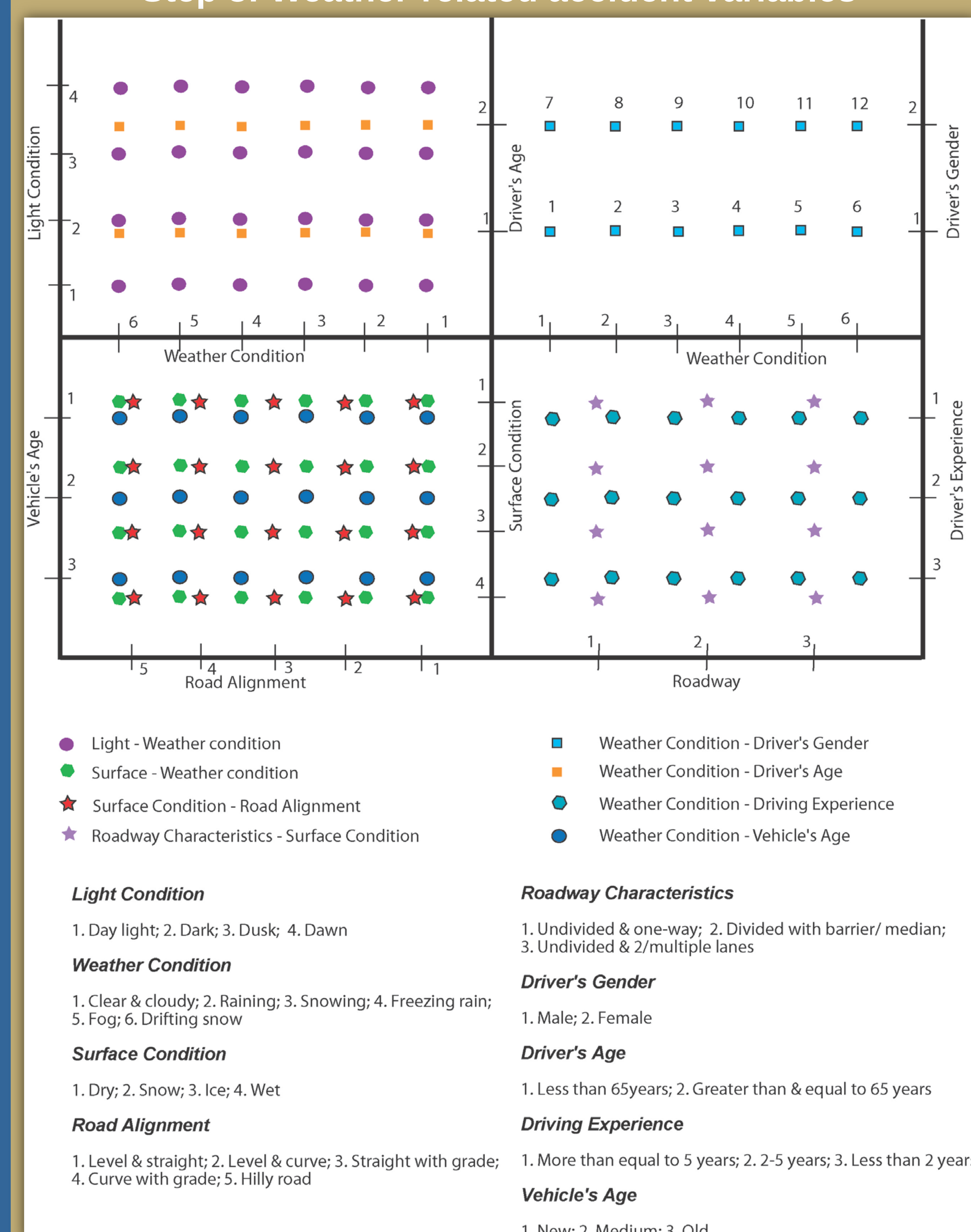
$$ASI = PDO + 5I + 15F$$

PDO = property damage only; *I* = injuries; *F* = fatalities

Step 2: Exposure to Weather-Accident Severity (EWAS) Index

EWAS index = *ASI* × severity of hazardous weather conditions

Step 3: Weather-related accident variables



Step 4: Methods for accident analyses

Negative Binomial Regression (NBR) model

$$Function\ (EWAS_{it}) = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_8 X_{8it}$$

$$\Pr(Y_{it} = EWAS_{it};\ \alpha, \gamma) = \frac{(EWAS_{it} + \gamma - 1)!}{(EWAS_{it})!\,(\gamma - 1)!}\ \frac{\alpha^{EWAS_{it}}}{(1+\alpha)^{(EWAS_{it}+\gamma)}}$$

Poisson regression (PR) model

$$\log(EWAS_{it}) = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_8 X_{8it}$$

Step 5: Method for climate change modeling

- Third generation Coupled Global Climate Model (CGCM3) for A2 and A1B emission scenarios (SRES).
- Third version of Hadley Centre Coupled Model (HadCM3) for A2 and B2 emission scenarios (SRES).
- GCMs are often characterized by coarse resolutions that limit their direct application for many impact studies.
- Statistical DownScaling method (SDSM) → links between large-scale climate variables and observed local predictands.
- Perfect Prognosis (PP) of SDSM estimates possible future changes in number of rainy, snowy, and freezing days in New Brunswick during reference and future time periods (2011-2040, 2041-2070, and 2071-2100).

Results

Summary of NBR and PR models for the New Brunswick province

Variables	Coefficient		Std. error		Z-value		P>|Z|		95% confidence internal			
	NBR	PR	NBR	PR	NBR	PR	NBR	PR	NBR		PR	
Light-weather condition	.006	.024	.001	.0003	9.80	81.34	0.00	0.00	.006	.008	.006	.008
Surface-weather condition	.071	.076	.003	.001	29.47	73.86	0.00	0.00	.066	.075	.066	.075
Surface-road alignment	-.011	.004	.002	.001	-5.40	4.67	0.00	0.00	-.014	-.007	-.014	-.007
Surface-road character	-.048	-.065	.004	.002	-12.3	-37.9	0.00	0.00	-.055	-.040	-.055	-.040
Weather-driver's gender	.024	.037	.002	.001	27.63	97.06	0.00	0.00	.022	.025	.022	.025
Weather-driver's age	.031	.056	.001	.001	27.07	113.0	0.00	0.00	.029	.034	.029	.034
Weather-driver's experience	.013	.023	.001	.001	21.10	84.39	0.00	0.00	.012	.015	.012	.015
Weather-vehicle's age	.014	.019	.001	.001	25.47	80.25	0.00	0.00	.013	.015	.013	.015

Regression coefficients of explanatory variables

Census Subdivisions of New Brunswick	Light-weather condition		Surface-weather condition		Surface-road alignment		Surface-road character		Weather-driver's gender		Weather-driver's age		Weather-driver's experience		Weather-vehicle's age	
	NBR	PR	NBR	PR	NBR	PR	NBR	PR	NBR	PR	NBR	PR	NBR	PR	NBR	PR
Saint John	.017	.033	.05	.052	-.009	-.009	-.023	-.011	.023	.035	.033	.057	.01	.017	.014	.021
Charlotte	.002	.016	.078	.056	.006	.013	-.089	-.048	.024	.032	.051	.091	.017	.029	.019	.038
Sunbury	-.003	.005	.055	.045	-.027	-.018	.008	.053	.029	.045	.041	.056	.013	.018	.017	.016
Queens	-.01	.019	.041	.051	.045	.096	-.094	-.174	.022	.042	.042	.069	.0176	.025	.013	.013
Kings	-.002	.01	.071	.11	.007	.039	-.073	-.164	.023	.024	.029	.053	.0121	.02	.014	.017
Albert	.010	.023	.097	.14	.013	.052	-.121	-.237	.022	.034	.026	.051	.01	.02	.014	.026
Westmorland	.012	.026	.08	.095	-.015	.01	-.054	-.105	.02	.033	.028	.048	.015	.025	.01	.013
Kent	.003	.02	.093	.129	-.001	.005	-.094	-.135	.02	.024	.018	.02	.02	.03	.017	.02
Northumberland	.001	.016	.059	.051	.001	.004	-.052	-.033	.026	.042	.027	.048	.016	.026	.016	.021
York	.008	.029	.052	.042	-.006	-.007	-.027	.001	.024	.034	.032	.055	.01	.018	.01	.012
Carleton	.007	.016	.093	.168	-.002	.049	-.102	-.27	.033	.058	.044	.068	.012	.019	.02	.032
Victoria	-.002	.006	.04	.049	-.001	-.008	-.015	.009	.016	.024	.048	.085	.018	.024	.014	.013
Madawaska	.015	.04	.078	.109	-.041	-.049	-.017	-.037	.03	.045	.035	.055	.012	.017	.018	.027
Restigouche	.024	.05	.065	.06	.015	.038	-.093	-.099	.032	.051	.038	.075	.023	.04	.013	.013
Gloucester	.006	.024	.09	.08	-.003	.02	-.09	-.096	.027	.042	.024	.05	.014	.023	.015	.02

Annual average changes in the number of rainy days

	CGCM						HadCM					
	A2			A1B			A2			B2		
Zone	2011	2041	2071	2011	2041	2071	2011	2041	2071	2011	2041	2071
Aroostook	0.01	0.04	0.07	0.01	0.03	0.05	0.00	0.01	0.02	0.01	0.01	0.02
Miramichi	0.02	0.04	0.06	0.02	0.03	0.04	0.02	0.04	0.09	0.02	0.04	0.06
Doaktown	0.03	0.06	0.09	0.03	0.05	0.07	0.01	0.02	0.03	0.01	0.01	0.02
Fredericton	0.03	0.06	0.09	0.02	0.04	0.06	0.01	0.02	0.04	0.01	0.02	0.03
Kedgwick	0.00	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Moncton	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.02	0.03	0.01	0.00	0.02
Saint John	0.02	0.03	0.03	0.02	0.02	0.02	0.00	0.01	0.02	0.01	0.01	0.01

Annual average changes in the number of snowy days

	CGCM						HadCM					
	A2			A1B			A2			B2		
Zone	2011	2041	2071	2011	2041	2071	2011	2041	2071	2011	2041	2071
Aroostook	0.01	0.01	0.02	0.01	0.02	0.02	0.00	0.00	0.00	0.00	-0.01	-0.02
Miramichi	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01
Doaktown	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	-0.01	0.00	0.00	0.00
Fredericton	-0.02	-0.02	-0.02	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01
Kedgwick	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Moncton	0.02	0.03	0.04	0.03	0.04	0.04	0.00	0.00	-0.01	0.00	0.00	0.00
Saint John	0.00	-0.01	-0.02	0.00	-0.01	-0.02	0.00	-0.01	-0.01	0.00	0.00	-0.01

Annual average changes in the number of freezing days

	CGCM						HadCM					
	A2			A1B			A2			B2		
Zone	2011	2041	2071	2011	2041	2071	2011	2041	2071	2011	2041	2071
Aroostook	0.00	-0.01	-0.02	0.00	-0.01	-0.02	-0.01	-0.02	-0.03	-0.01	-0.01	-0.02
Miramichi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Doaktown	0.00	0.01	0.01	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00	0.00	-0.01
Fredericton	0.00	-0.01	-0.02	0.00	-0.01	-0.02	0.00	0.00	-0.01	0.01	0.00	0.00
Kedgwick	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	0.00	0.00	0.00	0.00	0.00	0.00
Moncton	-0.02	-0.03	-0.03	-0.01	-0.02	-0.03	0.01	0.00	-0.01	0.00	0.01	0.00
Saint John	-0.01	-0.02	-0.03	-0.01	-0.02	-0.03	0.00	-0.01	-0.02	0.00	0.00	-0.01

DISCUSSION

- One degree increase of poor light-weather condition increases EWAS index by 0.6% to 2.4%
- One degree increase of poor surface-weather condition can contribute 7.1% to 7.6%.
- Female drivers are more vulnerable to weather-accident severity comparing to male drivers. EWAS index is increased by 2.4% to 3.7% for female drivers.
- EWAS index can be increased by 3.1% to 5.6% for aged drivers.
- Inexperienced drivers increase the probability of weather-accident severity by 1.3% to 2.3% because of less driving experience and lack of what-to-do knowledge in adverse weather conditions.
- Older vehicles increase the probability of weather accident severity by 1.4% to 1.9%.
- Poor surface-road character can decrease weather accident severity by 4.8% to 6.5%.
- Poor surface-road alignment condition can decrease accident severity during adverse weather conditions.
- Regression models for each census division of New Brunswick estimate the outcomes almost similar to that of regression models for whole New Brunswick province.
- CGCM3 simulations predict higher increase in number of rainy days for selected periods comparing to HadCM3 simulations.
- Annual number of rainy days may increase up to 10% per year for A2 emission scenario during 2071-2100.
- Number of snowy days may decrease for almost all simulations in all climate zones except in Moncton and Aroostook zones.
- Number of freezing days may decrease or stay the same for most of the climate zones in the province

CONCLUSIONS

- Combined effects of hazardous weather conditions and factors of road accidents are significant.
- Climate change models estimate that the ratio of hazardous weather days will be increased in most of the climate zones of New Brunswick during 21st Century.
- More hazardous weather will result in increased accident severity.
- Road Safety Strategy 2015 of Transport Canada should adopt the holistic approaches containing hazardous weather conditions along with other factors of road accidents.

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