15B.4 ROAD SAFETY IN CANADA: *WEATHER* OR NOT THE ATMOSPHERE MAKES A DIFFERENCE

Brian Mills[1]* and Jean Andrey[2]
[1]Adaptation and Impacts Research Group, Meteorological Service of Canada, Waterloo, Ontario, Canada
[2]Department of Geography, University of Waterloo, Waterloo, Ontario, Canada

1. INTRODUCTION

Motor vehicle collisions exact a significant toll on Canadians each year—2,917 deaths and 227,500 injuries in 2000 alone (Transport Canada 2001). This translates into approximately one injury for every 137 citizens each year. Motor vehicle collisions account for 16 percent of all injury admissions to acute care hospitals in Canada (Health Canada *et al.* 1999), and CCMTA (2000) reports that the cost of casualty collisions to the Canadian health care system exceeds $10 billion per year.

Weather is one of many risk factors that influence collision occurrence and severity. This paper reviews findings from empirical analyses of weather-related collision and injury risk including recent research by the authors for several Canadian cities. Estimated risks are discussed within the context of other atmospheric hazards, including heat stress, air pollution and severe weather events. Research issues and examples of interventions used to reduce risks for each hazard are also noted.

2. COLLISION AND INJURY RISK

Weather influences collision rates primarily by reducing visibility and road surface friction. Andrey *et al.* (2002) assessed the risks of motor vehicle collisions and injuries associated with various types of precipitation relative to normal, dry weather conditions for several Canadian cities. Risk ratios provided in Table 1 were determined by dividing collision (injury) counts for selected precipitation events by collision (injury) counts for corresponding controls. Events were matched with dry weather and road condition controls for the same day of the week and time period either one week before or following a selected event. The matched-pair method enables the researcher to control for time-sensitive factors, such as traffic volume, for which data are unavailable.

Findings from Andrey et al. (2002) and similar investigations support the following observations about weather-related collision risk:

*Corresponding author address: Brian N. Mills, Meteorological Service of Canada, c/o Faculty of Environmental Studies, University of Waterloo, Waterloo, Ontario N2L 3G1; e-mail: Brian.Mills@ec.gc.ca

TABLE 1 Relative Motor Vehicle Collision and Injury Risk for Several Canadian Cities (1995-1998)

	Relative Risk of Collision		**Relative Risk of Injury**	
	Rainfall	Winter Precip.*	Rainfall	Winter Precip.*
Halifax	1.31	1.68	1.16	1.23
Ottawa	1.79	1.83	1.58	1.41
Québec	1.39	1.20	1.19	0.94
Hamilton	1.71	1.86	1.67	1.67
Waterloo	1.89	2.57	1.47	1.96
Regina	1.29	2.56	0.88	2.45
Overall	**1.59**	**1.73**	**1.41**	**1.47**

**snow, freezing rain, ice pellets, and mixed precipitation*
Source: Andrey et al. (2002)

- There is ample evidence to conclude that precipitation is associated with a substantial increase in road collisions and injuries. The situation is less clear for fatalities but it appears that fatality rates are lower during inclement weather—especially for snowfall—probably due to driver adjustments.

- The magnitude of the safety impact varies considerably from one weather event to another, and also in aggregate across both time and space. Some of the variations are due to differences in storm characteristics, but outcomes also appear to be sensitive to research methodology and to situational risk factors, such as roadway geometrics and time of day. Place differences are evident but are not well understood, making it difficult to generalize results.

- Researchers tend to report the influence of weather on safety in one of two ways: either by noting statistical significance in model development, or by reporting relative risk ratios, as shown in Table 1. Translation into absolute incidence rates, morbidity or dollars is seldom done, despite the advantages of these for evaluating and justifying interventions. However, first estimates for Canada indicate that approximately seven percent of traffic injuries and 12 percent of property-damage collisions are directly attributable to inclement weather; this translates into approximately 15,000 injured persons and $1 billion dollars in health and other costs per year (Andrey *et al.* 2001).

- Finally, inclement weather is both a high-exposure and high-impact road hazard. Inclement weather in the form of rain, snow, fog or high wind occurs 10 to 20 percent of the time across North America; and casualties are typically 50 percent higher during these episodes than during normal seasonal conditions.

This last observation is useful in comparing road weather hazards with other atmospheric health risks, such as those discussed next.

3. COMPARISONS WITH OTHER HAZARDS

Comparable examples of exposure and risk estimates were sought for other atmospheric hazards including tornadoes and lightning, heat stress, and air pollution (PM_{10} and $PM_{2.5}$). With the exception of air pollution, most of the estimates relate strictly to human mortality; this fact, coupled with methodological differences, preclude direct comparison with weather-related injury collision risk. However, it appears that in most cases the absolute magnitude of other atmospheric hazards is similar or less than for road collisions, either because exposure is low or because the consequences of exposure are less severe.

Tornadoes and lightning might be considered low-exposure but high-impact hazards. Between 1879-1999, tornadoes reportedly killed 231 people in Canada—about 2 people per year (Etkin *et al.* 2001). Lightning on average kills 16 people per year (MSC 2002). The risk of being killed or injured by a tornado or lightning strike is therefore extremely small due largely to low exposure.

Heat stress is another relatively infrequent hazard, at least in Canada, with potentially high magnitude consequences. Statistical studies have demonstrated strong positive relationships between indicators of heat stress and human mortality (e.g., Rainham 2000, Smoyer *et al.* 2000a, 2000b). Mean daily mortality increases during heat stress conditions are variable, with estimates ranging from a few to several hundred percent depending on location and method. Fortunately, in most regions of Canada, heat episodes are infrequent or short-lived.

Particular matter air pollution (PM_{10} and $PM_{2.5}$), on the other hand, is a common hazard with moderate to possibly high magnitude consequences. Results of many epidemiological studies suggest that daily mortality increases by about 0.8 percent for each $10 \mu g/m^3$ increase in mean daily PM_{10} (WGAQOG 1999). This increase in total mortality applies to a very large population that is routinely exposed to PM_{10} and thus could translate into large numbers of deaths (WGAQOG 1999).

4. COMMON ISSUES AND INTERVENTIONS

4.1 Research Issues

Although the frequency and consequences of the hazards discussed previously are somewhat different, a number of similar issues emerge.

The health effects of specific weather or pollution events, whether defined using hourly or daily data, show great variability. Temporal effects show up in results—such as heightened road collision risk during first snowfalls of the season or elevated mortality and morbidity for early season heat waves and air pollution episodes. These observations provide possible evidence of driver adjustment and pre-shifted mortality, respectively.

Studies also provide evidence of spatial and socio-demographic variability in risk. For instance, cities appear to have different heat stress ‘thresholds’ and varying sensitivities to road weather conditions; and dwelling type affects survival rates during tornadoes. As well, different segments of the population (e.g., elderly, infants, children, ill) may be disproportionately at risk during heat waves and air pollution episodes. Similarly, driving experience and age may have effects on collision risk.

Common issues are also apparent in the estimation and evaluation of health risks for each of these hazards with the most significant relating to:

- reliability of health and hazard indicator data;
- confounding or covariation among time- and location-sensitive variables;
- inference of causal relationships from population data to the individual level (ecological fallacy); and
- evaluation of estimated risks (e.g. the appropriateness and comparability of various indicators).

While the latter might be viewed as more of a policy than research issue, it has direct relevance to the selection and treatment of variables in risk analyses and to the evaluation and financing of interventions.

4.2 Interventions

The interaction of technology, human behaviour and weather creates the potential for harm for all of the atmospheric hazards discussed, although non-weather factors are much more important for air pollution and road collision hazards, where humans strongly influence both the physical hazard and exposure. To the extent that temperature is magnified by the urban environment (heat islands) or climatic change, the same might also be said for heat stress hazards.

The ability to influence these hazards has a direct bearing on the range of possible interventions that might be implemented to reduce risk. Most of the resources allocated to deal with atmospheric hazards fall within preparedness, response and recovery functions. Much effort is devoted to predicting the occurrence of hazardous conditions (advisories/warnings for severe weather, heat/humidex, air quality, and travel) or developing information and programs (e.g., hot weather response plans, tornado drills and evacuation planning, young driver training) with the intent of reducing exposure to the hazard.

Other interventions aim to reduce the magnitude of the hazard or the severity of impacts—examples include winter road maintenance, vehicle design (safety and emission standards), and building standards.

Occasionally such interventions have unintended and undesirable consequences (e.g., road salt effects on the environment and infrastructure, exacerbation of air pollution in meeting electricity demands for air conditioning during heat waves).

When these adjustments or responses fail, insurance and government assistance programs are available to facilitate recovery—a modest consolation for lost lives however.

These interventions have been relatively effective at reducing casualty risk for many forms of severe weather hazards (tornadoes and hurricanes). However, the risks associated with atmospheric hazards dominated by human influences, like air pollution and road collisions, remain high despite these programs. Substantive risk reduction in these areas demands more than the simple treatment of symptoms—greater attention must be given to the design of urban environments, and land use and transportation planning.

5. CONCLUSION

Weather-related injury collision risk is a serious health issue—and likely more important than 'higher profile' atmospheric hazards such as tornadoes, lightning, and hurricanes. Many of the research issues and challenges to reduce road collision and injury risk are similar to those affecting other atmospheric hazards, especially heat stress and air pollution. This initial insight suggests that more thorough comparisons among these hazards and more cooperation across the disparate research communities would be beneficial—both for research and in guiding policy.

REFERENCES

Andrey, J., B. Mills, M. Leahy and J. Suggett 2002: Weather as a chronic hazard for road transportation in Canadian cities. *Natural Hazards*, in press.

Andrey, J., Mills, B. and Vandermolen, J. 2001. Weather Information an Road Safety. Institute for Catastrophic Loss Reduction Paper Series 15, University of Western Ontario, London, ON.

CCMTA 2000: *Road Safety Vision 2001 – 2000 update*, Transport Canada, Ottawa, http://www.tc.gc.ca/roadsafety/vision/2000/pdf/RSV.pdf, Accessed June 2001.

Etkin, D., S.E. Brun, A. Shabbar, and P. Joe 2001: Tornado climatology of Canada revisited: tornado activity during different phases of ENSO. *International Journal of Climatology*, **21**, 915-938.

Health Canada, Statistics Canada, and the Canadian Institute for Health Information 1999: *Statistical Report on the Health of Canadians.* Report commissioned by the Federal, Provincial and Territorial Advisory Committee on Population Health for the Meeting of Ministers of Health, Charlottetown, P.E.I., September 16–17, 1999, Health Canada, Ottawa.

MSC 2002: Thunder, lightning and hail stomrs. Fact sheet. Meteorological Service of Canada. http://www.smc.ec.gc.ca/cd/thunder_e.cfm. Accessed July 2002.

Rainham, D.G.C. 2000: *Atmospheric Risk Factors of Human Mortality.* MSc. Thesis. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton. 135 pp.

Smoyer, K., L. Kalkstein, J. Scott Greene, and Y. Hengchun 2000a: The impacts of weather and pollution on human mortality in Birmingham, Alabama and Philadelphia, Pennsylvania. *International Journal of Climatology*, **20**, 881-897.

Smoyer, K., D. Rainham and J. Hewko 2000b: Heat stress mortality in five cities in southern Ontario: 1980-1996. *International Journal of Biometeorology,* **44**, 190-197.

Transport Canada 2001: *Transportation in Canada 2001 Annual Report*. TP1319E. Transport Canada, Ottawa.

Transport Canada: 1998, *Canadian Motor Vehicle Traffic Collision Statistics,* TP 3322, http://www.tc.gc.ca/roadsafety/STATS/stats98/RK_98E.pdf. Accessed June 2001.

WGAQOG 1999: *National Ambient Air Quality Objectives For Particulate Matter – Part 1: Science Assessment Document*. CEPA/FPAC Working Group on Air Quality Objectives and Guidelines. Health Canada and Environment Canada, Ottawa. http://www.hc-sc.gc.ca/bch.