Collisions, Casualties, and Costs: Weathering the elements on Canadian Roads

by

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INTRODUCTION

The year 1973 marked a turning point for road safety in Canada. In that year, 6706 people died from road crashes. Since that time, advances in engineering, education, enforcement and medicine have reduced the annual death toll to less than 3000 people per year, despite increases in both population and mobility (Transport Canada 1997; 2003). Nevertheless, road crashes continue to be a serious societal problem—draining over $10 billion from the Canadian health care system each year, according to the Canadian Council of Motor Transport Administrators (2000). Indeed, in the 17-year time period (1984-2000) considered in this study, 2.9 million casualty collisions occurred, resulting in 61,636 fatalities and 4.2 million injured persons (Transport Canada 1997; 2002).

Inclement weather is one of a number of risk factors that affect the frequency and severity of road collisions. Weather reduces road friction, impairs visibility and makes vehicle handling more difficult, all of which translate into elevated risk levels. Using aggregate risk and cost data, a first estimate of weather-related collision costs for Canada was calculated at approximately $1.1 billion per year (Andrey *et al.* 2001). In the current study, we develop a more detailed methodology for estimating costs, using the national accident database (TRAID3) and cost estimates for injuries of different severities from the literature. We then apply this methodology to four Canadian cities—Winnipeg, Regina, Saskatoon, and Edmonton. Further analysis will extend this to urban areas throughout Canada. Finally, as a complementary analysis, we examine the costs of weather-related road collisions in Winnipeg, using claim information obtained from Manitoba Public Insurance.

While aggregate costs are important for establishing the magnitude of the problem, it is also important to understand temporal variations in weather-related crash risk—both in the long term, as a commentary on the adequacy of society's collective response, and within a year or season to identify possible interactions between weather and other risk factors, such as traffic volume. In the current study, we estimate weather-related risk on an annual basis from 1984 to 1993, based on data for the four cities mentioned above. We also conduct an analysis of Ottawa crash data from 1990 to 1998 in order to explore the importance of season, day of week and time of day on weather-related risk.

Driver and institutional response to inclement weather is one area of research that has been given limited attention. With support from the current study, a Master's thesis is being completed on driver responses to inclement weather using traffic loop data on volume, driving speed and vehicle spacing for the Gardiner Expressway in Toronto. In addition, the implications of weather warnings for collision and injury risk in Ottawa, and road-salt usage for collision and injury risk in Hamilton—are considered in two pilot studies on the value of weather information.

In summary, based on Andrey *et al.* (2001) and discussions with ICLR, it was decided to pursue additional research that would improve our understanding of:

- the costs of weather-related casualty collisions in Canada
- temporal variations in weather-related driving risks, and
- the impact of weather information and winter road maintenance on collision risk.

COSTS OF WEATHER-RELATED CASUALTY COLLISIONS

Both the professional safety community and the public at large recognize that weather affects the safety of motorists. Furthermore, a series of empirical studies for Canadian cities (Andrey 1989; Andrey and Olley 1990; Andrey and Yagar 1993; Andrey *et al.* 2003b; Mende 1982; Andreescu and Frost 1998; Suggett 2003) indicate that both property-damage and casualty collisions increase during inclement weather. However, estimates vary from place to place, even within the same climatic region, likely due to differences in study design, weather specifics and a myriad of other factors that affect safety (Andrey *et al.* 2003).

Thus it was decided to conduct new empirical research on weather-related driving risks in Canada. While the long-term goal is to develop a national profile of weather-related risks in a variety of driving contexts, the focus here is on four Prairie cities—Winnipeg, Regina, Saskatoon, and Edmonton—from 1984 to 1995, as available data permit. Ongoing work is extending the analysis to other cities through the year 2000, and there are plans to incorporate a rural component at a later point in time. The revised risk estimates were then combined with collision cost information, derived chiefly from Vodden *et al.* (1994), to develop provisional aggregate weather-related costs. Finally, initial results from a complementary analysis of insured loss data for Winnipeg are described.

Estimation of Weather-related Collision Risk: Prairies Case Study

A matched-pair design was adopted for the current study, similar to several other studies of weather-related risk identified in Andrey *et al.* (2003). More specifically, time periods with inclement weather were paired with control time periods when inclement weather was absent. The advantage of this approach is that many variables that have nothing to do with the weather, but which are time-dependent and do affect risk, are controlled rather effectively. The most important external variable to control is traffic volume, and this is achieved by defining events and controls that occur just one week apart and are matched by time of day and day of week. For example, a rainy Wednesday evening in July would be matched with a Wednesday evening, either one week prior to or one week afterward, when the weather was clear and dry. If such a match does not exist, the precipitation event is not included in the risk estimate. It should be noted that this design cannot account for weather-related changes in traffic volumes, but previous research suggests that these changes—at least for rainfall—are quite modest in Canadian urban areas (Doherty *et al.*1993).

Event-control pairs are used to define the relative risk of an injury, fatality or casualty collision occurring. The calculation involves dividing the number of injuries/fatalities/collisions from the event periods by the number from the control periods. A risk ratio of 1.0 or lower indicates that driving risks are the same or lower during events relative to controls, while a risk ratio greater than 1.0 indicates that inclement weather is associated with higher risk than clear conditions within the same season. Risk ratios can be interpreted as percent increases above baseline, e.g., a risk ratio of 1.35 indicates that there is a 35% increase in casualties during inclement weather.

Because the majority of weather-related crashes are associated with precipitation, and because Canada is a northern country, we focus on both rain events and winter-precipitation events, where the latter includes snowfall, sleet, freezing rain and mixed rain and snow. National casualty-collision statistics indicate that 11.9 and 7.0 percent of casualty collisions occurred in rain and snow/sleet/hail, respectively, from 1988 to 1997 inclusive (Transport Canada 2001). By comparison, Table 1 indicates the relatively lower incidence of inclement weather for traffic casualties at the four study locations, based on police records of the "predominant weather condition" at the accident scene. The lower percentages are most likely a reflection of the drier climate of the prairies relative to other parts of Canada, but may also indicate lower risk rates during inclement weather relative to other places (e.g., Andrey *et al.* 2003).

Table 1 Percentage of Traffic Casualties, 1984-2000, by Weather and Road Condition

	Rain[1]	Snow[1]	Sleet/Hail	Fog/Wind	Wet/Slippery Roads	Clear and Dry	All Known
Winnipeg	3.1	4.7	0.4	1.3	32.7	57.8	100.0
Regina	5.3	4.6	0.5	1.0	28.7	59.8	100.0
Saskatoon	5.5	3.5	0.3	0.7	27.5	62.5	100.0
Edmonton	6.9	5.8	0.3	0.6	20.5	65.8	100.0

[1] More than 99 percent of casualties that occurred during rainfall or snowfall occurred on roads that were wet, snowy, icy or slippery.

As one might expect, different authors define precipitation events and controls in slightly different ways. Some definitions are quite restrictive, including only persistent or intense weather events, whereas other criteria are more inclusive. Since definitions do affect risk estimates (Andrey *et al.* 2003), we use two sets of event criteria—one where both the weather station and police data indicate the presence of precipitation and the other based solely on data from the nearest weather station. In both cases, the temporal unit of analysis is the six-hour period, as defined by meteorological records. The details are explained in Table 2.

Table 2 Criteria Used to Define Precipitation Events and Controls

	SCENARIO 1		SCENARIO 2	
	Event	Control	Event	Control
Amount of Precipitation	≥0.4 mm	<0.2 mm	≥0.4 mm	<0.2 mm
# Hourly Observations Indicating Precipitation	≥ 3	≤1	≥ 3	≤1
# Hourly Observations Indicating Reduced Visibility	n.a.	≤1	n.a.	≤1
% Collision Reports (out of known) indicating Presence of Precipitation	≥50	≤5	n.a.	n.a.
% Collision Reports (out of known) indicating Presence of Icy Pavement	n.a.	None	n.a.	n.a.
Previous Precipitation	n.a.	None for at least 6 hours	n.a.	None for at least 6 hours

The analysis is based on the integration of two federal government databases: hourly and six-hourly weather records from the Meteorological Service of Canada and casualty-collision reports from Transport Canada's national collision database (TRAID3). Weather observations pertain to the airport nearest to the city centre for each of the study locations. Collision data include 32 variables describing the circumstances and severity of all reported traffic casualties (i.e., fatalities and injured persons).

Generally, data availability and coding are not identical from one province or city to another since the collision reports originate with the various police agencies across the country. Four important specific issues concerning the data used in the analysis are noted below:

1. The years included in the analysis vary from city to city primarily due to the limited availability of quality-controlled precipitation accumulation information:
   - Winnipeg and Regina: 1984-1995
   - Saskatoon: 1984-1993
   - Edmonton: 1984-1994
2. The breakout of injuries by severity is not consistent from city to city, as shown in Table 3. This has also been found in U.S. jurisdictions (Blincoe et al. 2002).
3. The weather-road condition is not reported for approximately 8 percent of casualties. Furthermore, this percentage varies by injury severity (Figure 1) and also by city; for example, this information is not provided for Edmonton from 1984 to 1989 inclusive.
4. The accident-location codes used to define the collision set are not necessarily coincident with the city boundaries, depending on the reporting protocols in each city.

These data issues need to be considered when defining events and interpreting results.

Table 3 Percentage of Casualties of Different Severities[1]

	Winnipeg	Regina	Saskatoon	Edmonton
Minimal	56.8	52.9	44.1	n.a.
Minor	31.5	36.0	41.3	95.8
Major	3.0	4.8	7.5	3.9
Fatal	0.3	0.5	0.6	0.4
Unspecified	8.4	5.8	6.4	0.0
TOTAL	100.0	100.0	100.0	100.0

[1] Definitions from TRAID Dictionary

Minimal	No treatment. Minor abrasions and bruises. Complaint of pain, but no medical attention received at time of collision.
Minor	Treated at a medical facility and released. Injuries or complaint of pain that required medical treatment but not admitted to hospital.
Major	Hospitalized. Victim went to the hospital and was admitted for treatment or observation.
Fatal	Death occurred within specified time period [30 days in all jurisdictions except for PEI and the Territories, where the timeframe is 12 months, and Quebec, where it is 8 months] by injuries sustained in the traffic incident.
Unspecified Or Unknown	Injury occurred but extent was not specified or was not known.

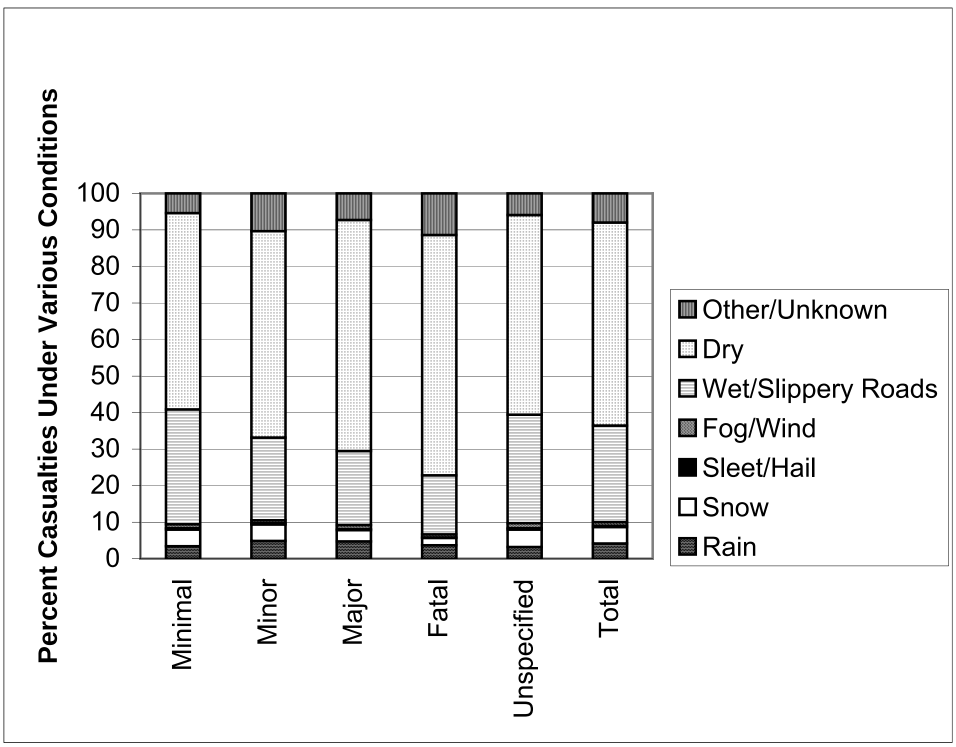

Figure 1 Weather-Road Conditions for Traffic Casualties in Four Prairie Cities

Relative Risk Estimates

Aggregate estimates for each city are based on several hundred event-control pairs, as shown in Tables 4 and 5. For specific levels of injury, relative risk ratios are included whenever both the event and control counts (i.e., number of injuries of specified severity or number of casualty collisions) are greater than or equal to 30. When the counts are less than 30, as in the case of fatalities, risk ratios are not included because of the high degree of uncertainty in these estimates.

Overall, the relative risk of a casualty during rainfall is approximately 1.4—being slightly higher for minimal and minor injuries than for major injuries. These results indicate that casualty rates increase by approximately 40 percent during rainfall relative to dry and clear conditions. The risk ratios are reasonably consistent from city to city. It is also worth noting that the risk estimates are very similar for the two sets of criteria used to define rainfall events and corresponding controls, although the sample size is significantly larger for the second scenario.

For winter precipitation, the risk estimates for minimal and minor injuries are very similar to rainfall but the relative risk of major injury is less than 1.0. These results indicate that casualty rates are elevated for less serious injuries, but not for the more serious injuries. This is consistent with assertions that drivers are more cautious and travel more slowly during snowfall. Also, for winter precipitation, there is more variability in the risk estimates from city to city.

Table 4 Risk Estimates for Rainfall (Scenario 1 results-unshaded, Scenario 2 results-shaded)

RAINFALL		Winnipeg	Regina	Saskatoon	Edmonton	4 Cities Combined
Event-control pairs		419	444	301	482	1646
		543	567	373	522	2005
Casualty collisions		924	989	535	792	3240
		1349	1419	734	1026	4528
Casualties		1272	1361	763	1130	4526
		1875	1959	1040	1468	6342
Relative Risk Estimates	Minimal Injury	1.39	1.33	1.43	n.a.	1.37
		1.42	1.40	1.31	n.a.	1.40
	Minor Injury	1.34	1.49	1.54	1.46	1.43
		1.46	1.57	1.74	1.45	1.52
	Major Injury	1.18	1.19	*	*	1.35
		1.35	1.36	*	*	1.42
	Fatality	*	*	*	*	*
		*	*	*	*	*
	Casualty (All Severities)	1.36	1.38	1.49	1.46	1.41
		1.44	1.47	1.51	1.45	1.46
	Casualty Collision	1.35	1.39	1.37	1.43	1.38
		1.43	1.45	1.45	1.39	1.43
Event Collisions During Weather (%)		82.9	83.1	85.4	82.1	
		59.9	60.8	64.6	68.1	
Control Collisions During Weather (%)		0.0	0.0	0.0	0.0	
		0.3	0.3	0.7	0.8	
Event Collisions on Wet, Snowy, Icy or Slippery Roads (%)		88.8	89.1	92.8	81.3	
		74.8	75.9	78.4	71.0	
Control Collisions on Wet, Snowy, Icy or Slippery Roads (%)		0.7	0.7	1.3	1.1	
		0.9	0.7	1.9	1.5	

n.a. not applicable
* insufficient number of EC pairs for calculation of relative risk

Table 5 Risk Estimates for Winter Precipitation (Scenario 1 results-unshaded, Scenario 2 results-shaded)

WINTER PRECIPITATION		Winnipeg	Regina	Saskatoon	Edmonton	4 Cities Combined
Event-control pairs		411	467	417	500	1795
		839	915	716	581	3051
Casualty collisions		557	629	352	897	2435
		1982	2107	1033	1511	6633
Casualties		762	868	498	1254	3382
		2640	2821	1459	2109	9029
Relative Risk Estimates	Minimal Injury	1.49	1.50	1.16	n.a.	1.42
		1.28	1.33	1.22	n.a.	1.29
	Minor Injury	1.32	1.55	1.13	1.64	1.52
		1.28	1.37	1.12	1.38	1.31
	Major Injury	*	*	*	*	0.86
		0.87	0.83	0.89	*	0.86
	Fatality	*	*	*	*	*
		*	*	*	*	*
	Casualty (All Severities)	1.39	1.47	1.29	1.61	1.47
		1.28	1.34	1.18	1.36	1.30
	Casualty Collision	1.41	1.50	1.39	1.64	1.51
		1.29	1.37	1.31	1.41	1.35
Event Collisions During Weather (%)		77.2	79.1	89.6	82.4	
		32.3	34.6	38.5	59.5	
Control Collisions During Weather (%)		0.0	0.0	0.0	0.0	
		0.7	0.6	0.7	1.1	
Event Collisions on Wet/Snowy/Icy/Slippery Roads (%)		95.9	95.5	96.4	22.1	
		85.8	86.5	83.8	18.4	
Control Collisions on Wet/Snowy/Icy/Slippery Roads (%)		27.0	25.6	21.2	16.2	
		58.7	57.5	56.0	21.4	

n.a. not applicable
* insufficient number of EC pairs for calculation of relative risk

Estimation of Collision Costs

Crash victims, their families and friends, employers and society-at-large are affected by motor vehicle collisions. Many of the effects are easily accounted for in monetary terms, but there are a number of other negative effects, such as pain and suffering, that are more difficult to quantify. However, a comprehensive assessment of the consequences of crashes in general—and weather-related crashes more specifically—requires that an attempt be made to estimate not only property damage and time and material expended in dealing with crashes, but also the value of human consequences.

Two general approaches have been used for measuring the human consequences of crashes. The first, and most widely accepted today, measures how much society is willing to pay to avoid these consequences.

> *"Individuals continually demonstrate their willingness to accept risks of injury or death through the occupational choices they make, and through other choices they make such as observing speed limits or wearing seat belts"* (Vodden *et al.* 1994, 17).

The second approach, which results in lower cost estimates, is based on the lost earning potential of those affected and thus does not represent social value in the comprehensive sense. For example, it does not value leisure time or pain and suffering. Such estimates are, however, often used in legal proceedings as an indication of the loss to the individual.

A sizable literature exists on the economic costs of traffic accidents. Of particular note is the work of Ted Miller of the Urban Institute in Washington, D.C. (e.g., Miller 1990, 1993 and 2000; Miller and Blincoe 1994; Miller *et al.* 1997, 1998 and 1999) and Rune Elvik of the Institute of Transport Economics in Oslo, Norway (e.g., Elvik 1994, 1995 and 2000). Much of the related discussion in the literature focuses on methodological issues, but considerable effort has also been made to provide provincial, national and international estimates of the economic impacts of motor vehicle crashes (e.g., Elvik 1995 and 2000; Hashem *et al.* 1999; Miller 1993; Blincoe *et al.* 2003; Trawen *et al.* 2002). In the Canadian context, the report by Vodden *et al.* (1994) entitled "The Social Cost of Motor Vehicle Crashes in Ontario" provides one such estimate.

Methods

Because of its use of the willingness-to-pay approach in a Canadian context, comprehensiveness and detailed methodological adjustments and justifications, the Vodden *et al.* (1994) values were used as a basis for estimating the social costs of weather-related casualties in Canada. Values from the report are extracted, re-assembled and then adjusted upward from the base year of the report, 1990, to 2002, using the annual inflation rate (Statistics Canada, Consumer Price Index 2002).

Two steps were taken to arrive at an estimate of costs associated with driving during precipitation. The first step involved estimating the number of major injuries that are attributable to rainfall. As shown in Table 6, the relative risk of a major injury during rainfall is 1.35. Thus 25.9 percent [i.e., (1.35-1.00)/1.35*100] of the major injuries that occurred during rainfall may be attributable to the weather. The remaining 74.1 percent would likely have occurred regardless of weather condition. Altogether, 5.11 percent of all major injuries in the four cities occur during rainfall (Table 7). Therefore 1.32 percent [i.e., 0.259*5.11] of all major injuries may be attributed to rainfall. Based on the past three years of data, an average of 318 major injuries occur per year in the four cities combined (Table 8). Thus 4.19 (i.e., 318*0.0132] major injuries may be attributable to rainfall.

The second step involved determining the social costs of major injuries that are attributable to rainfall. The Vodden *et al.* (1994) report provides estimates of the social costs for Ontario collisions for 1990. The estimates are for collisions of different severities, but details are also provided on the number of injuries by severity class in fatal and injury crashes which facilitated the computation of total costs per injury (including human consequences, health care, property damage, towing, etc.)—broken down by injury severity. These estimates were then multiplied by 1.275 to adjust for inflation to the year 2002, as shown in Table 9. From Table 9, the cost estimate for each person with major injuries is $82,696. Thus the social cost associated with major injuries that are attributable to rainfall is $346,496 [i.e., $82,696 x 4.19].

The two steps were repeated for the minimal/unspecified and minor injury classes also using information provided in tables 6-9. Table 10 summarizes the estimated annual social costs of precipitation-related driving hazards for the four case study cities. The total annual cost estimate for all casualties, and both forms of precipitation, is $4.8 million for scenario 1 and $4.6 million for scenario 2.

Table 6 Relative Risk of Casualty During Precipitation (four Prairie cities combined)

	RAINFALL		WINTER PRECIPITATION	
	Scenario 1	**Scenario 2**	**Scenario 1**	**Scenario 2**
Minimal Injury	1.37	1.40	1.42	1.29
Minor	1.43	1.52	1.52	1.31
Major	1.35	1.42	0.86	0.86
Fatal	*	*	*	*
Unspecified Injury[1]	Treat as minimal	Treat as minimal	Treat as minimal	Treat as minimal

[1] Treating injuries of unspecified severity as minimal probably understates the true costs of these casualties.
* insufficient data

Table 7 Percentage of Casualties During Precipitation (four Prairie cities combined)

Casualty Level	Rainfall	Winter Precipitation
Minimal or Unspecified Injury	3.59	5.24
Minor Injury	5.41	5.42
Major Injury	5.11	3.64
Fatal	4.17	2.38

Table 8 Average Annual Number of Casualties (four Prairie cities combined)

Casualty Level	Number of Casualties*
Minimal or Unspecified	4,950
Minor Injury	5,090
Major Injury	318
Fatal Injury	31

*based on last 3 years of data

Table 9 Estimates of the Social Costs of Casualty Collisions Broken Out by Casualty Level (based on Vodden *et al.*, 1994)

Casualty Level	YEAR	
	1990	2002
Minimal	7,630	9,729
Minor	15,029	19,163
Major	64,860	82,696
Fatal	5,332,108	6,798,438

Table 10 Estimated Annual Social Costs Associated with Precipitation in Five Prairie Cities

Casualty Level	SCENARIO 1			SCENARIO 2		
	Rainfall	Winter Precipitation	Total	Rainfall	Winter Precipitation	Total
Minimal or Unspecified	466,877	746,309	1,213,186	486,959	567,239	1,054198
Minor	1,586,725	1,808,552	3,395,277	1,805,215	1,251,012	3,056,227
Major	348,393	-155,828	192,565	656,275	-155,828	500,447
TOTAL	2,401,995	2,399,033	**4,801,028**	2,948,449	1,662,423	**4,610,872**

Given that the four cities account for approximately 5 percent of traffic injuries in Canada, one might be tempted to multiply this value by 20 in order to arrive at a first estimate of the national costs associated with precipitation events. This, however, would be imprudent for the following reasons:

1. The estimate does not account for any changes in fatalities. Since the total number of fatalities involved in the risk analysis was relatively small, it was decided that it would be premature to report and use the associated risk ratios to estimate costs. However, it should be noted that these ratios were consistently greater than 1.0 for rainfall, and, given the high social costs associated with fatalities, this is likely to have a major (upward) impact on total cost estimates. When the analysis is extended to more and larger urban areas, a relatively stable estimate of fatality risk should be possible, and fatality costs will be incorporated.
2. The estimate does not account for any changes in property-damage collisions. In the Vodden *et al.* (1994), property-damage collisions accounted for approximately 10 percent of all costs. Furthermore, previous analysis by Andrey *et al.* (2003b) indicates that the relative risk of non-injury collisions during precipitation is typically 1. 5 or higher. Since the current analysis draws only on the casualty-collision database from Transport Canada, it is not possible to define a precise cost value for property-damage collisions. However, an approximation is possible, based on previous analyses reported in the literature, and will be incorporated in future work. Again the expected effect is an increase in the cost estimate for precipitation-related crashes.
3. The Vodden *et al.* (1994) social cost figures used in the analysis are thought to be the most comprehensive and relevant to Canada. However, higher (e.g., Islam *et al.* 2003) and lower (Blincoe *et al.* 2002) estimates for U.S. case studies were also found in the literature. Vodden *et al.* (1994) is also exclusively based on Ontario data and thus may not be representative of all provinces (e.g., higher average incomes in Ontario will lead to greater social costs).
4. The estimate does not incorporate data for collisions on rural highways, which are generally more serious than urban collisions. Furthermore, little is known about how risk ratios during inclement weather compare for urban versus rural roads, but some studies (e.g., Knapp 2001) suggest more sensitivity to weather in rural areas. Thus, again the effect at a national level is expected to be an increase in the costs estimate.
5. Another consideration is the relative frequency with which precipitation occurs. Prairie cities are generally drier, and receive a larger proportion of their precipitation as snowfall. Given these facts and the relative risk ratios in Table 4 versus Table 5, again the effect at a national level should be an increase in the cost estimate.
6. Another source of cost underestimation is due to the fact that we treated the national collision database as both complete and accurate in its reporting of injuries. However, it is well documented that some injuries go unreported, and others are more serious than originallyassessed at the accident scene.
7. Finally, we do not investigate the effects of wet/snowy/icy/slippery roads in the absence of falling precipitation on casualty-collision rates and costs. For the Prairie cities, this results in the exclusion of about 20-30 percent of all casualties. This was also missing from the original estimate of $1.1 billion, but likely adds substantially to the total costs associated with precipitation-related collisions.

Thus, further empirical analysis is needed to arrive at a comprehensive and robust assessment of precipitation-related collision costs in Canada, but the current report outlines a feasible methodology and some preliminary results for four Prairie cities.

Winnipeg case study using Manitoba Public Insurance data

The estimate developed by Andrey *et al.* (2001) was derived from Ontario property damage and national healthcare costs determined by other agencies. The proportion of weather-related injuries or collisions determined by Andrey *et al.* (2003) was used to estimate weather-related costs. Among the many assumptions in this procedure and that used in the Prairie case study is that property damage and healthcare costs associated with weather-related collision costs do not differ from costs for other collisions. This assumption cannot be tested using TRAID3 information since collision-specific cost data are not included in the database. The authors sought a reliable, comprehensive source of insurance claim data that could be incorporated into the methodology used to assess relative collision risk (Andrey 1989, Andrey *et al.* 2003b). Manitoba Public Insurance (MPI) was contacted and agreed to supply claim information for a case study of the City of Winnipeg. This summary provides a review of interim aggregate results.

Data and Methods

Motor vehicle collision insurance claim information was obtained for the City of Winnipeg from MPI. Database variables are listed and defined in Table 11.

Table 11 Variables included in the Manitoba Public Insurance data set

VARIABLE	DESCRIPTION
Reference Key	This is a unique identifier used to reference the incident being reported on.
Loss Date	The reported date the damage occurred.
Loss Time	The hour in which the damage occurred.
Claim Peril Code	This is the type of claim being filed COLLI = Collision, COALO = Comprehensive All Other, COLWI = Collision Wild Life, HAIL = Hail Damage, LIGHT = Lightning
Claim Class Code	There are two classes of claims; P – Physical Damage and I - Injury
Vehicle Type Code	This is the abbreviation we use to define vehicle types. They are; PASVE = Passenger Vehicle, TRUCK = Truck, MCYCL = Motorcycle
Single Vehicle Accident Indicator	This is a flag use to identify accidents involving only one vehicle. The flag is either N for no, it is not a single vehicle accident or Y, yes it is a single vehicle accident.
Collision Bucket	Costs incurred for first party collision damage.
Property Damage	Costs incurred for property damage covers. Includes Third Party Deductible payments
Accident Benefit	Costs incurred for accident benefit covers.
Comprehensive	Costs incurred for comprehensive covers

Several steps were taken to prepare the original July 1999-July 2002 hourly data for analysis including:

- hail and lightning claims were removed from the data set as the primary interest was motor vehicle collisions;
- time codes were adjusted to Central Standard Time;

- individual claim level data were aggregated by hour; and
- fields representing incident, injury incidents and injury claim counts were derived.

Characteristics of the final data set of approximately 27,000 hourly entries are noted in Table 12.

Table 12 Summary of processed hourly MPI claim data for Winipeg, MB (July 1999-July 2002)

Indicator/Field	Total	Hourly Mean	Hourly Standard Deviation
Incidents	147,437	5.45	5.62
Injury incidents	19,510	0.72	1.22
Injury claims	26,665	0.99	1.77
Total claim costs*	$493,185,528	$18,234	$61,304
First party damage*	$310,527,783	$11,481	$13,948
Accident benefits*	$140,073,855	$5,178	$57,852

*real dollars (uninflated)

Climate information from the Meteorological Service of Canada Winnipeg International Airport observing station was used to characterize the weather throughout the three-year study period. Variables included hourly observed weather (e.g., rain, snow, freezing rain, fog, etc.), temperature and visibility; and daily and six-hourly precipitation accumulation. Based on past research (Andrey *et al.* 2003b) it was decided to focus on the role of precipitation in the initial analysis.

Matched-pair approach

The matched-pair approach involved identifying a number of variable-length weather events and corresponding control periods. As noted in the Prairies case study, this technique compensates for the lack of information on traffic volume and other time-sensitive factors that might influence exposure, with the assumption that travel patterns are similar by day-of-the-week and time-of-day for a suitably large data set. The relative risk or relative cost is determined by summing incident counts or claim costs for all of the events and dividing by the sum for all controls. Four types of weather events were selected for examination in the initial analysis: rain, snow, rain plus snow, freezing rain/drizzle, and freezing rain/drizzle plus rain or snow. The criteria used to select the events and controls are defined in Table 13.

Table 13 Criteria used to define events and controls

Event Criteria	- daily and 6-hourly precipitation accumulation > 0.2mm for each respective hour in event - at least 2 consecutive hourly observations of precipitation in each event - event can include one-hour breaks in hourly precipitation observations - hourly observations used to define event type - statutory holidays and associated weekends removed from analysis
Control Criteria	- all corresponding hours either one week before or one week following event have no observations of precipitation - no hourly observations of precipitation during 6 hours previous to control start - zero daily and 6-hourly precipitation accumulation for respective control hours

Initial Results

Using the criteria described in Table 13, 172 event-control pairs were identified. As inferred from Table 14, the pairs represent about 15 percent of the total number of incidents and costs in the entire database. The events include 1438 hours of precipitation observations—roughly 44 percent of all precipitation observations from July 1999-July 2002.

Summary statistics pertaining to the relative incident risk and relative costs are provided in Table 15.

Table 14 Summary statistics for events and controls

Indicator	**Events**		**Controls**	
	sum	**% total**	**sum**	**% total**
Incidents	13,420	9.1	7,774	5.3
Injury incidents	2,288	11.7	1,155	5.9
Injury claims	3,054	11.5	1,589	6.0
Total claim costs*	$47,822,339	9.7	$28,025,545	5.7
First party collision damage*	$29,722,737	9.6	$16,144,897	5.2
Accident benefits*	$13,786,680	9.8	$9,660,189	6.9

*real dollars (uninflated)

Table 15 Relative risk of incident and relative cost for Winnipeg, MB matched pair analysis

Indicator	All event-control pairs	Rainfall	Snowfall	Mixed Rain and Snow	Freezing rain	Freezing Rain Mixed with Rain or Snow
n (event-control pairs)	226	132	69	14	2	9
Event hours	1451	763	446	136	6	100
Relative risk of incidents	1.73	1.67	1.78	1.66	1.76	1.91
Relative risk of injury incidents	1.98	1.93	2.10	1.95	1.33	1.81
Relative risk of injury claim	1.92	1.84	2.09	2.00	1.33	1.64
Relative costs of all claims	1.71	1.63	2.60	0.58	1.16	2.25
Relative first party collision damage	1.84	1.72	1.94	2.08	1.23	1.90
Relative accident benefits	1.43	1.27	5.97	0.12	0.54	5.32

Several observations are summarized below. Note that incidents and costs refer only to those for which claims were made to Manitoba Public Insurance—many minor collisions are likely missing from the database and thus our analysis. As well, it is not possible to make confident statements for those precipitation types that have fewer than 30 event-control pairs (i.e., freezing rain and mixed precipitation).

Incidents

Precipitation events increase the relative risk of incidents, injury incidents and injury claims by about 75, 100 and 95 percent, respectively. The chance of being in an injury incident increases by about 95 percent during rainfall and by almost 125 percent during snowfall. Empirical studies using police collision records generally confirm that snowfall has a greater effect than rainfall.

The greater relative risks observed for all incidents compared to injury incidents is, however, counter to that concluded in many previous studies. Previous studies indicate however that weather generally increases the risk of less-severe collisions (i.e., property damage only) more than for injury collisions (Andrey *et al.* 2003b). A possible explanation for the conflicting observation in this analysis is that insurance claims cover a much broader definition of injury than police records where the extent of an injury is assessed at the scene or if the vehicle occupant is hospitalized.

Costs

The cost of collisions increases by approximately 70 percent during precipitation. The increase in relative cost is much greater for snowfall (160 percent) than for rainfall (60 percent) consistent with the observations for incidents.

A greater relative increase in costs was observed during precipitation events for first-party collision (i.e., vehicle property) damage (85 percent) than for accident benefits (45 percent). This is consistent with the literature but opposite to that observed for incidents.

Snowfall events are associated with an almost 500 percent increase in accident benefits compared to just 20 percent for rainfall. This implies that snowfall-related collisions are more severe than those during rainfall or dry weather. After removing two event outliers, the relative accident benefit cost was 3.8—approximately a 280 percent increase in costs—and the respective relative total cost ratio was 2.2.

Assuming that the relative risk calculations are fairly robust, it is possible to estimate the impact of weather on incidents and costs in Winnipeg over the 3-year period. It was already noted that the events capture about 44 percent of all hours with observed precipitation. Table 16 presents a simple extrapolation, using this factor and the absolute differences between weather events and controls for incident and cost indicators. Absolute values are then expressed as a percentage of the total incident counts and collision costs that were shown in Table 12. Over the three-year period, it is estimated that precipitation contributed to about $45 million worth of insured losses for collisions in the City of Winnipeg.

Table 16 A rough estimate of precipitation-related incidents and costs

Indicator	Added Risk Associated with Weather (Event subtract Control)	Absolute precipitation-related impact (divide by 0.44)	Percent of total incidents and costs
Incidents	5,646	12,929	8.8
Injury incidents	1,133	2,594	13.3
Injury claims	1,465	3,355	12.6
Total claim costs*	$19,796,794	$45,332,709	9.2
First party damage*	$13,577,840	$31,091,917	10.0
Accident benefits*	$4,126,491	$9,449,258	6.7

*real dollars (uninflated)

Extrapolating the annual insured costs for Winnipeg ($15 million) to all of Canada using a population factor (of about 50) yields a national estimate of weather-related collision costs of approximately $750 million. This assumes that exposure and weather conditions are similar throughout Canada and that driver response to weather is uniform.

TEMPORAL VARIABILITY IN COLLISION RISK: OTTAWA AND PRAIRIE CASE STUDIES

Several authors have documented long-term trends in travel and road safety (e.g., Page 2001). In Canada and in most developed countries, fatality and injury rates per unit of travel and per registered vehicle have declined significantly over the past two decades (Andrey 2000). Improved health care and emergency response, coupled with advanced vehicle and highway engineering and changes in driving norms are the main factors responsible for this improvement. However, this raises the question as to whether all driver and vehicle groups, and all driving situations, have benefited equally from the various safety interventions. With respect to weather hazards, it raises the question as to whether society is becoming more or less vulnerable to weather-related driving hazards. To the best of the authors' knowledge, this issue has not been addressed. This section of the report examines temporal trends analyzed for the Prairie cities discussed previously and those obtained from a more detailed analysis of collision data for Ottawa.

Prairies Case Study Results

Using output from the analysis discussed in the costs section of this report, the relative risk of casualty during precipitation was calculated for each year from 1984 to 1993 inclusive. The results represent the aggregate or combined risk for four Canadian prairie cities—Winnipeg, Regina, Saskatoon, and Edmonton.

As shown in Figure 2, there is no clear temporal trend in precipitation-related risk. Rather, year-to-year variations probably reflect, in part, the specific mix of storm types that occurred in particular years. The absence of a clear trend suggests that the safety gains that have been observed in the aggregate do extend to periods of inclement weather, but that the benefits are not disproportionately high or low. In other words, as driving has become safer per unit travel, this protection has been realized in both good and bad weather. Despite this positive interpretation, it is important to note that casualty rates remain elevated (i.e., greater than 1.0) during both rain and winter precipitation, and thus the need for further improvement in this area.

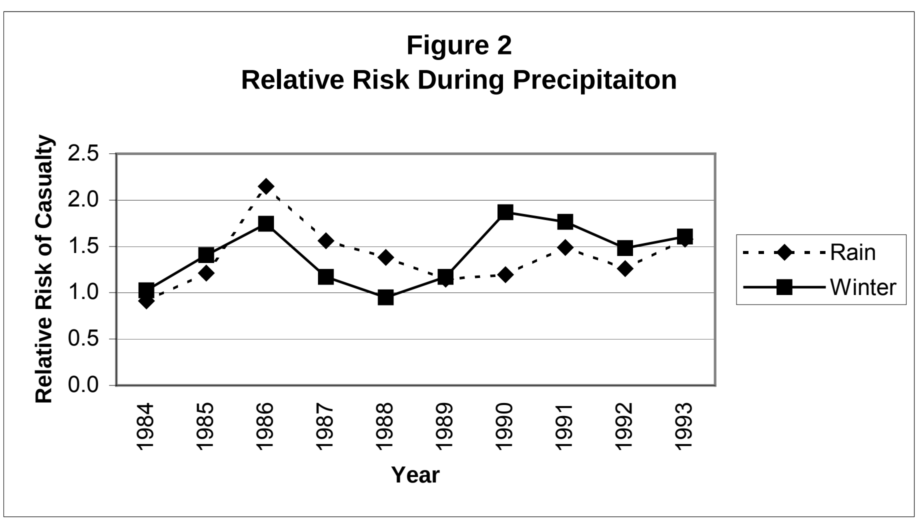

Figure 2 Annual relative risk of casualty during precipitation (4 Prairie cities combined)

A Temporal Analysis of Weather-Related Collision Risk for Ottawa, Canada: 1990-1998

A detailed analysis of collision risk was completed for Ottawa using data from 1990-1998 (Andrey *et al.* 2003b). Relevant points from this paper are extracted into the following section.

Research indicates that travel risks increase during precipitation relative to normal driving conditions. Less effort has been devoted to studying how weather-related risks vary over time, and what these variations suggest about interactions between weather and other risk factors. This study examines temporal variations in precipitation-related collision and injury risk using collision and weather data for Ottawa, Canada over the period 1990-1998.

<u>Research Context</u>

Although there are a few exceptions (e.g., Shankar *et al.*'s 1995 paper on weather and roadway geometrics), most studies of weather-related driving risks examine atmospheric variables in isolation from other risk factors. It is likely, however, that weather-related risks are exacerbated in some situations and ameliorated in others. Since some risk factors vary temporally (e.g., traffic volume and mix, light condition), time provides a useful starting point for exploring the combined effect of weather and other risk factors.

A few authors have examined how weather risks vary by time of day and day of the week. In terms of time of day, Haghighi-Talab (1973), Satterthwaite (1976) and Brodsky and Hakkert (1988) all provide evidence that increases in collision rates due to rainfall are greater at night than during the daytime, suggesting an interaction between weather and natural lighting. Also looking within the day, Levine *et al.* (1995) observed that rainfall-related effects were greatest during the afternoon peak period, from 4 to 7 p.m. With respect to day of the week, Satterthwaite (1976) and Smith (1982) both found that weather-related increases in collisions were generally greatest on the weekend. Results from the only similar Canadian study are less conclusive (Suggett 2003).

On a longer timescale, seasonal variations in collision frequency and severity are well documented. With few exceptions, studies in North America and Europe show that the absolute number of fatalities peaks during summer (Evans 1991; Brown and Baass 1997); but in more northern climates, property-damage collision rates usually peak in winter, and are especially elevated at the onset of the snow season (Fridstrom and Ingebridsten 1991; Andrey *et al.* 2003b).

<u>Methods</u>

Matched-pair analysis was used in the current study to examine the relationship between collision statistics and weather, based on the integration of weather data from the Meteorological Service of Canada for MacDonald-Cartier International Airport with collision data from Transport Canada's national collision database (TRAID3). The approach is similar to that explained in Part 1 of this report, except that events are of variable length and the criteria used to define precipitation events and controls are slightly different than the earlier application. Details of the latter are summarized in Table 17. When applied to the 1990-1998 weather data, the event-control criteria produced a final set of 771 matched pairs.

Table 17 Criteria used to define variable-length events and controls for the Ottawa case study

	Events	Controls
Precipitation Amount	≥ 0.2 mm	Zero both during control and six hours prior to control
Persistence of Precipitation	Must begin and end with observed precipitation and include at least 2 consecutive hours of precipitation. May include one-hour breaks.	n.a.
Other Weather	n.a.	No hourly observations of fog or visibility < 0.5 km

Relative risk was modeled using the logit function in GLIM (Generalized Linear Interactive Models) software. Four different models were developed: the relative risk of injury during rainfall, the relative risk of injury during winter precipitation, the relative risk of collision during rainfall and the relative risk of collision during winter precipitation.

Results

Risk Levels

Overall, collision risks more than doubled during rainfall events and increased by approximately 50 percent during snow events relative to normal seasonal conditions. The corresponding increases for injury risks were approximately 70 percent and 20 percent. The greater increases for rainfall relative to snowfall may be explained by the fact that snowfall accumulations were available for six-hour periods only (rather than hourly). Thus snowfall events may include periods of time when precipitation was absent. In contrast, defining rainfall events on a variable hourly basis seems to isolate and concentrate the effects of weather.

Temporal Patterns

Risk estimates were broken down by time of day, traffic condition, day of the week and time of year. In most cases, differences were not statistically significant. There are two exceptions. First, winter-precipitation collision rates were found to be significantly higher on weekends (Friday to Sunday) than on weekdays (Monday to Thursday). Second, winter-precipitation risk ratios for collisions were higher in November-December (early winter) than in January-April. Although not statistically significant, weekend rates were also higher for rainfall collision rates, rainfall injury rates and winter-precipitation injury rates. The results by time of day were variable.

In summary, weather does appear to interact with some situational factors, resulting in especially high risk levels during precipitation that occurs on weekends and at the beginning of the snow season.

ADJUSTMENTS TO WEATHER-RELATED DRIVING HAZARDS

A range of adjustments in response to weather hazards are made by drivers and agencies responsible for designing, constructing and maintaining roads. For instance, a considerable amount of time and effort is spent informing the driving public about potentially hazardous weather and to clear snow and ice from the road network. Canadian municipal and provincial transportation agencies spent approximately $1.3 billion on winter maintenance activities in 1998 alone (Jones 2003). The Meteorological Service of Canada issues over 14,000 severe weather warnings each year (MSC 2002). Unfortunately, little analysis has been completed to assess the effectiveness of these and other interventions whether measured in terms of safety or using economic indicators (Andrey *et al.* 2001). The intent of this section is to discuss preliminary results from applications to evaluate the impact of weather on driver adjustments (through indicators such as traffic volume) and the effectiveness of weather information and aspects of winter road maintenance.

Driver Adjustments to Inclement Weather: Synopsis of Thesis by Dan Unrau

As reviewed in Andrey *et al.* (2001), some of the possible driver adjustments to inclement weather involve advanced planning (e.g., installing snow tires), whereas others are reactive in nature (e.g., trip reduced travel speed). Trip cancellation is the most-studied pre-trip response, and is usually inferred from traffic volumes. However, results are variable, with some studies suggesting only minimal reductions in traffic volumes during rainfall (Doherty *et al.* 1993; Andrey and Knapper 2003), whereas others report substantial reductions, especially during winter storms (OECD 1976; Hanbali and Kuemmel 1993; Ibrahim and Hall 1994; Hassan and Barker 1999; Knapp 2001; Perrin *et al.* 2001). Lower traffic volumes indicate that there are either fewer travelers or slower speeds translating into lower exposure. In either case, the net effect should be improved safety, although it should be noted that the relationship between volume and collisions varies by accident type and severity (Ceder and Livneh 1978, 1982; Brodsky and Hakkert 1983).

In terms of in-car adjustments, the dominant response is reduced travel speed. Again estimates of adjustments vary from one study to another. For wet roads and light rain or snow, adjustments are usually minimal and travel speeds often exceed the posted speed limit (Doherty *et al.* 1993). For heavier precipitation, especially snowfall, and for situations where compound hazards exist (e.g., slippery roads and reduced visibility), speed reductions of 15 to 50 percent have been reported (Ibrahim and Hall 1994; Shepard 1996; Knapp *et al.* 2000; Kyte *et al.* 2001). Again, speed reductions should result in lower collision severity and, to a lesser extent, lower collision rates. However, there is the possibility of perverse effects since possible changes in speed variability would affect the opportunity for traffic conflicts.

Self-reported adjustments of increased caution have also been noted (e.g., Andrey and Knapper 2003). One concrete indicator of caution is the time gap between vehicles. To the best of the authors' knowledge, the effects of weather on this variable have not been explored. However, one would expect that vehicle gaps would increase as friction or visibility decrease, due to risk compensation.

The thesis by Dan Unrau (Department of Geography, University of Waterloo) focuses on the effects of precipitation on traffic volume, driving speed and vehicle gaps with a view to understanding the nature and adequacy of driver responses to rain and snow.

Methods

This study draws on data from the Gardiner Expressway in Toronto. This highway links several major highways to downtown Toronto, and serves as a major commuter route. In order to monitor traffic conditions on the highway, the City of Toronto installed both video surveillance equipment and in-road sensors. The in-road double-loop inductors provide the traffic volume, average speed, occupancy (defined as the time that the sensor detects a vehicle's presence), and average vehicle length data for this study. The latter two variables are used to calculate time gap between vehicles. All variables are available at 20-second intervals for each lane of traffic, on a continuous basis.

One of 21 available matched loop stations for the Gardiner Expressway was chosen for the study. This station is at a sufficient distance (>450 metres) from ramps to avoid the influence of merging and exiting traffic, and is located on a straight section of roadway with little gradient. Also, the data for this station are relatively complete and appear to be free of instrument malfunction.

Using a matched-pair design, as discussed previously, times of precipitation and corresponding controls were defined. Events and controls were defined using data are from the Toronto Pearson International Airport and the Toronto Island Airport weather stations. In total, 29 event-control pairs of variable length were defined. Analysis is now underway and will focus on the direction and magnitude of the differences between events and controls.

Weather Warning Information: Ottawa Case Study

Another type of adjustment involves the provision of weather information to the driving public. The following section reviews a pilot case study to assess the possible influence of weather warning, watch and advisory information issued to the public by the Meteorological Service of Canada on collision and injury risk.

Collision data were obtained from Transport Canada and processed according to the methods described in previous sections. Climate information from the Meteorological Service of Canada Ottawa MacDonald-Cartier International Airport observing station was used to characterize the weather throughout the 1996-1998 study period. Variables included hourly observed weather (e.g., rain, snow, freezing rain, fog, etc.), temperature and visibility; and daily and six-hourly precipitation accumulation. Based on past research (Andrey *et al.* 2003a, 2003b) it was decided to focus on the role of precipitation in the initial analysis. Weather warning, watch and advisory (WAW) bulletins were obtained from the MSC for the City of Ottawa (formerly Ottawa-Carleton) forecast region.

The matched-pair approach was again used to determine relative risk. Four types of weather events were selected for examination in the analysis: rain, snow, rain plus snow, freezing rain/drizzle, and freezing rain/drizzle plus rain or snow. The criteria used to select the events and controls are defined in Table 18.

Table 18 Criteria used to define events and controls

Event Criteria	- daily and 6-hourly precipitation accumulation > 0.2mm for each respective hour in event - at least 2 consecutive hourly observations of precipitation in each event - event can include one-hour breaks in hourly precipitation observations - hourly observations used to define event type - statutory holidays and associated weekends removed from analysis
Control Criteria	- all corresponding hours either one week before or one week following event have no observations of precipitation - no hourly observations of precipitation during 6 hours previous to control start - zero daily and 6-hourly precipitation accumulation for respective control hours

Initial Results

Using the criteria described in Table 19, 249 event-control pairs were identified representing about 23 percent of all collisions reported during the 1996-1998 study period. Table 2 described the relative risk profile for collisions and injuries. Overall, collision risk increased by 75 percent during precipitation while injury risk was elevated by about 60 percent over normal, dry conditions.

Table 19 Relative collision and injury risk ratios for Ottawa (1996-1998)

		RELATIVE RISK		Number of	Percent
	n (e-c pairs)	Collision	Injury	Collisions	Total
All Events	249	1.75	1.59	4820	23.1
Rain	175	1.87	1.61	2270	10.9
Snow	58	1.60	1.86	1057	5.1
Mixed 1: Rain and Snow	25	1.31	1.90	821	3.9
Freezing Rain/Drizzle	2	0.82	1.00	31	0.0
Mixed 2: Freezing Rain/Drizzle and Rain and/or Snow	22	1.64	1.41	641	3.1
All Winter	107	1.65	1.57	2550	12.2

Meteorological Service of Canada weather watch, advisory, and warning (WAW) bulletins covering the 1996-1998 period were obtained for the Ottawa forecast region. Hourly fields indicating the occurrence of the following WAW types were added to the database:

- winter storm
- heavy snowfall/snowfall
- blowing snow
- flash freeze
- heavy rainfall/rainfall
- freezing rain/drizzle
- severe thunderstorm
- fog
- wind

Fields noting the number of hours since a bulletin was first issued and the last hour it was in effect were also calculated.

The first evaluation involved comparing the relative risks for events that included one or more hours during which a WAW was in effect against events during which no WAW products were issued. If it is assumed that drivers and road transport authorities will take action to reduce risks if WAWs are issued, then relative risks should be higher for the latter group. Results, as provided in Table 20, suggest minimal difference between the two groups for either collision or injury risk, although the direction is consistent with the assumed relationship. The differences for injury risk are smaller for winter-type events when compared to rain events. Also of note is the observation that WAWs were only in effect during 12 percent of the events.

Table 20 Relative collision and injury risk ratios for Ottawa (1996-1998): Presence or absence of watches, advisories and warnings

		RELATIVE RISK	
	n*	**Collision**	**Injury**
All Events	249	1.75	1.59
No watch, advisory or warning in effect during event	219	1.77	1.61
Watch, advisory or warning in effect during event	30	1.66	1.47

*event-control pairs

The second evaluation was constructed around the concept that any relationship between risk and weather information might be dependent on the timing of the WAW. A somewhat arbitrary decision was made to compare events for which a WAW had been in effect within the past 24 hours with all other events (i.e., >24 hours since last bulletin—whether related to the specific event or not—had expired). Similar differences were observed for both rain and winter-event types (Table 21).

Table 21 Relative collision and injury risk ratios for Ottawa (1996-1998): Timing of watches, advisories and warnings

		RELATIVE RISK	
	n*	**Collision**	**Injury**
All Events	249	1.75	1.59
No watch, advisory or warning in effect within past 24 hours	216	1.82	1.66
Watch, advisory or warning in effect within past 24 hours	33	1.39	1.20

*event-control pairs

These initial results simply suggest that reductions in relative risk are coincident with the timely issuance of weather watches, advisories and warnings. Although from a risk management perspective this observation is positive, it is not clear if the changes in relative risk can be attributed to weather information.

Relative Risk and Salt Use: Hamilton-Wentworth Winter Road Maintenance Case Study

The objective of the final case study was to incorporate winter road maintenance into the analysis of weather-related collision and injury risk in Canadian cities.

Data and Methods

Collision data were obtained from Transport Canada and processed according to the methods described previously but at a daily timestep. Daily climate information from the Meteorological Service of Canada Hamilton International Airport observing station was used to characterize the weather throughout the 1995-1998 study period. Variables included maximum and minimum temperature and precipitation accumulation.

Understandably, very few municipalities have the resources (or need) to maintain detailed, long-term, records of winter maintenance that could be matched with the hourly or even daily collision and weather data referred to in previous case studies. However, daily levels of road salt use were available for the City of Hamilton (formerly Regional Municipality of Hamilton-Wentworth) from a previous study (Mills *et al.*, 2003). It should be noted that these data serve only as an indicator or winter maintenance for the region and do not represent the activities of all agencies responsible for roads for which collision records were obtained.

The matched-pair technique as described previously was also adopted in this case study, However, events and controls were defined for days rather than hours. Rainfall, snowfall and mixed (any combination of snow, rain or freezing rain) events were matched with corresponding days, one week following or prior to the event, during which no trace or measurable precipitation was recorded.

Initial Results

As expected the impact of weather on collision and injury risk is diluted as the temporal resolution of the analysis becomes coarser. Hours lacking precipitation or other hazardous weather are stripped from the hourly assessment but included in the daily analysis. Nevertheless, as shown in Table 22, collision and injury risks are still elevated during days with measurable rainfall, snowfall or mixed precipitation.

Table 22. Relative daily collision and injury risk ratios for Hamilton (1995-1998)

		RELATIVE RISK		Number of	Percent
	n (e-c pairs)	**Collision**	**Injury**	**Collisions**	**Total**
All Events	340	1.32	1.31	9671	47.7
Rain	240	1.29	1.33	6959	34.3
Snow	60	1.39	1.12	1687	8.3
Mixed	40	1.46	1.50	1025	5.1

The next step in the study involved examining relative risks and levels of road salt use. Mixed and snow events, plus rain events during which salt was applied, were grouped into four categories of road salt use and analyzed. Results are presented in Table 23.

Table 23. Relative daily collision and injury risk ratios by level of salt use for Hamilton (1995-1998)

		RELATIVE RISK	
Daily Salt Use (kg/km)	**n**	**Collision**	**Injury**
0	26	1.38	1.44
1-25	21	1.11	1.02
25.01-75	32	1.35	1.11
>75	32	1.70	1.35
Any Salt	85	1.40	1.18

It appears that salt use is coincident with lower injury risk suggesting a positive influence on collision severity. Injury risk for days when salt is applied is on average well below the baseline risk for all events (1.31) and rainfall (1.33). Conversely, when measurable snowfall or mixed precipitation occurs and salt is not applied, injury risks are much greater.

FURTHER RESEARCH

Based on data that have already been acquired for the project, the initial next steps are to extend the cost analysis, presented in the first part of this report, to other urban areas in Canada and to more recent years; and to incorporate both other cost estimates from the literature and other criteria for defining inclement weather in order to conduct a sensitivity analysis of weather-related casualty-collision costs.

Beyond this, we plan to look more carefully at the results for Winnipeg in order to understand differences in results obtained from police reports of collisions versus insurance data.

Future work should focus more on rural collisions and on the interaction between weather and a range of situational risk factors.

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