INVESTIGATION OF COLLISIONS AT URBAN INTERSECTIONS USING INSURANCE CLAIMS DATA

BY

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Investigation of Collisions at Urban Intersections Using Insurance Claims Data

BY

Mitchell Jacobson, B.Sc., EIT

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

Of

Master of Science

Mitchell Jacobson, B.Sc., EIT © 2005

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ABSTRACT

The research is an investigative analysis of the characteristics of motor vehicle collisions at urban intersections using insurance claims data.

Previous investigations between injury type and the roadway characteristics of intersections, the use of insurance claims in road safety research, and the use of insurance claims in the development of relationships with the roadway engineering characteristics of intersections are summarized.

The comparison of collisions based on insurance claims data and police-reported collision data revealed that insurance claims provide a robust dataset with the potential for urban intersection collision investigation.

The temporal and geographic characteristics of intersection collisions based on insurance claims are investigated in terms of collision frequency, collision rate, incurred cost, and injury type. Intersections of greatest safety concern based on these characteristics are identified, as are injury types of greatest safety concern at intersections.

Intersections between four-leg two-way arterial roadways are selected as candidates for the investigation of relationships between injury type and incurred cost as a function of the roadway engineering features of intersections. Geometric and operational

characteristics of these intersections are summarized, from which specific characteristics are identified as being suitable candidates as variables in relationship investigation.

The investigation examines relationship forms where one roadway engineering feature is considered. Whiplash injury collisions and the total incurred cost are each related in three ways: (1) as a function of the total number of collisions by approach roadway median presence; (2) as a function of the entering vehicular traffic by approach roadway median presence; and (3) as a function of the average approach roadway entry speed for intersections with divided roadways for all approaches. The relationships which are a function of the total number of collisions perform best at predicting actual conditions of individual intersections, while the relationships which are a function of entering vehicle traffic and average approach roadway entry speed reflect the general trend amongst all of the investigated intersections.

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CHAPTER 1

INTRODUCTION

1.1 THE RESEARCH

The research is an investigative analysis of the characteristics of motor vehicle collisions at urban intersections using insurance claims data. The characteristics of these collisions are investigated in terms of temporal and geographic attributes, incurred cost, and injury type. As possible, relationships between incurred collision cost and injury type as a function of the roadway engineering features of intersections are also investigated.

1.2 BACKGROUND AND RESEARCH NEED

Motor vehicle collisions are the ninth leading cause of death worldwide, with 1.2 million people killed annually and many more million injured (WHO, 2004). In Canada, about 3,000 people die annually and in the United States this figure exceeded 44,000 fatalities in 2003 (NTSB, 2004). These collisions have a significant economic cost to society. In the United States, motor vehicle collisions are estimated to cost US$ 234 billion annually. In Canada, the economic cost of motor vehicle collisions is estimated to be between CAD$ 10 billion and CAD$ 25 billion annually (Transport Canada, 2004).

In Manitoba, based on public insurance information, there were 139 fatal and 15,554 injury claims as a result of motor vehicle collisions in 2003, which resulted in $234 million in incurred injury and fatality insurance claims costs. There was also $326 million in property damage claims costs in 2003, resulting in total incurred claims costs of \$560 million (Manitoba Public Insurance, 2004). These costs exceed by three times the combined annual infrastructure budgets of Manitoba Transportation and Government Services (\$128.9 million in 2003/2004 (Province of Manitoba, 2003)) and the City of Winnipeg Public Works Department (\$60.7 million in 2003 (City of Winnipeg, 2003)). These incurred costs do not include additional costs such as lost productivity, lost wages, and decreased quality of life.

Intersections in urban areas have been identified as particularly dangerous by Transport Canada. For intersection collisions, urban intersections account for 47 percent of fatalities and 57 percent of persons seriously injured. Overall, 25 percent of road collision fatalities occurred at intersections (Transport Canada, 2004). Intersections account for over 50 percent of collisions in urban areas and 30 percent in rural areas in the United States (NCHRP, 2004). Approximately 8,500 fatalities and almost 1 million injury collisions occur at or within an intersection environment in the United States every year, where the cost of intersection-related collisions is estimated at US\$ 40 billion/year (FHWA, 2003). In Manitoba (urban and rural), right-angle intersection and rear-end collisions accounted for 37 percent of all fatal collisions, 46 percent of all injury collisions, and 27 percent of all property damage collisions in 2001 (MTGS, 2003).

Collision data is used to facilitate the identification of collision-prone locations as well as to identify other collision characteristics which may be mitigated through improved engineering. The most commonly used and available form of collision data is police-reported data, which provides many useful attributes in engineering applications. There are, however, some shortcomings from police reported collision data. Not all reportable collisions are necessarily reported, as the onus is on collision victims to report the collision when police do not attend the incident scene. There is also a minimum reporting threshold of combined damage exceeding $1,000 or incidence of bodily injury in Manitoba. When considering injuries from police-reported collision data, Persaud notes that "Injury data based on police reports have known limitations, especially in regard to injury severity." (Persaud et at, 2001: pg 3)

Insurance claims data includes unique attributes which provide opportunities for roadway safety analysis. There is information about any collision for which there is a claim, which therefore includes collisions which have not met police-reporting minimum thresholds. Also, a claim must be reported for any person involved who wishes coverage, while no similar essentiality exists for reporting a collision to the police. Claims data provides the incurred costs for each claim, which in turn provides the incurred cost per collision. Insurance claims data provides specific injury information for every injury claim. With this data, it is possible to investigate the characteristics of where and when specific injuries are occurring and the associated incurred costs of these injuries. By examining specific intersections, it may be possible to relate this information to specific roadway engineering characteristics of intersections.

1.3 OBJECTIVES AND SCOPE

Specific objectives of the research are:

1) To understand current and previous research relating engineering characteristics of intersections with injury type and costs.

2) To compare and contrast insurance claims data and police-reported collision data in order to establish the nature of, and differences in, the datasets as they can be used in intersection collision analysis.

3) To obtain comprehensive knowledge of the nature of collisions at intersections in Winnipeg through the investigation of temporal characteristics, geographic characteristics, collision frequencies, collision rates, collision severity, and incurred collision cost.

4) To identify intersections with high collision frequencies, collision rates, and/or incurred collision costs

5) To investigate the possible relationships between injury type and incurred collision costs as a function of intersection characteristics from the civil engineering perspective for the intersections identified in objective 4.

The scope of this research is constrained as follows:

- It relies on Manitoba Public Insurance claims data, City of Winnipeg collision and traffic volume data, and DDVL collision information from the period between 2000 and 2003.

- It does not consider the following issues which may impact the safety of intersections: roadway operating policies, enforcement levels, engineering characteristics of vehicles, and explicit environmental considerations.

1.4 RESEARCH APPROACH

The following research approach is undertaken in order to accomplish the objectives:

- A literature review investigating the methods used in relating injury type and incurred collision cost to the engineering characteristics of intersections and results obtained from the application of these methods.

- Gaining an understanding of the databases involved. To do this, discussions with Manitoba Public Insurance officials on the nature and characteristics of the insurance claims database, as well as discussions with traffic engineers at the City of Winnipeg Public Works Department are conducted.

- The analysis of collision characteristics at intersections in Winnipeg using Manitoba Public Insurance claims records for 2003.

- The use of a geographic platform with Winnipeg's streets and intersections spatial databases to show the geographical characteristics of intersection collisions. This also facilitates the geographic manipulation of data, which is done using several geographic and database software programs (Maptitude, Paradox). This involves the examination of collision frequencies, collision rates, incurred collision costs, and injury types at intersections.

- The identification of intersections of high safety concern as identified from a combination of high collision frequencies, collision rates, incurred collision costs, and injury type.

- The following is done for the identified intersections:

    - intersection roadway engineering features are identified from intersection site visits, orthophotos of the intersections and approach roadways, the City of Winnipeg spatial footprint, and discussions with traffic engineers at the City of Winnipeg.

- A comparison of injury type and incurred collision cost to the roadway engineering features for the identified intersections to establish any apparent relationships.

1.5 THESIS ORGANIZATION

The thesis is organized as follows:

Chapter 2 comprises the results of a literature review investigating efforts to relate injury type to the roadway engineering characteristics of urban intersections, as well as the use of insurance claims data in roadway safety analysis and efforts to relate insurance claims to the roadway engineering characteristics of urban intersections.

Chapter 3 describes the databases and analysis tools used in the research. The collision databases, geographic information system, and collision rate methodology are summarized.

Chapter 4 compares and contrasts collision data from insurance claims and police-reported collisions. Collisions based on insurance claims are compared with police-reported collisions for the Province of Manitoba, for intersection collisions in the City of Winnipeg, and for high-collision frequency intersections in Winnipeg.

Chapter 5 examines the temporal and geographic characteristics of collisions at intersections in terms of collision frequency, collision rate, and collision cost, as well as the characteristics of injuries at intersections using insurance claims data. From these investigations, the type of intersections where safety is of greatest concern are identified.

Chapter 6 identifies the specific intersections for consideration in relationship development. The geometric and operational roadway engineering characteristics of these intersections are identified, and the characteristics which are most suitable for relationship development for these intersections are identified.

Chapter 7 investigates relationships between injury type and incurred collision costs as a function of the engineering characteristics of the identified intersections.

Chapter 8 presents conclusions and discussion of the research and identifies further research opportunities.

1.6 TERMINOLOGY

The following terms are used in this research:

Bodily injury collision: This is a motor vehicle collision resulting in an injury of any type, including non-fatal and fatal injuries.

Fatal collision: This is a motor vehicle collision resulting in one or more fatally injured persons. For police-reported collisions in Manitoba, a death caused by injuries from a collision must occur within 30 days for the collision to be considered fatal (MTGS, 2003). There is no similar reporting deadline for Manitoba Public Insurance; a collision is considered fatal if a death occurs as a result of injuries from a collision regardless of the time elapsed from the collision event occurrence. In addition to fatalities, injuries and/or physical damage to vehicles may occur as a result of fatal collisions.

Incurred cost: This is the sum of all direct compensation paid on a claim to date by Manitoba Public Insurance. The incurred cost from injury claims are not in many cases final costs, as claims which are still open may continue to accrue cost. Incurred injury costs were unmodified, as provided by Manitoba Public Insurance, in this research and thus do not represent final incurred injury costs.

Injury collision: This is a motor vehicle collision resulting in a non-fatal injury to one or more persons. Physical damage to vehicles may result from injury collisions, but fatal injuries may not.

Property damage only collision: This is a motor vehicle collision where no bodily injuries occur—only physical damage to the vehicle (s).

Reportable collision: This is any motor vehicle collision where there is a bodily injury and/or the combined property damage cost exceeds $1000. This is the reporting threshold for police-reported collisions in Manitoba (MTGS, 2003).

CHAPTER 2

RELATING INJURY TYPE TO THE ENGINEERING CHARACTERISITICS OF INTERSECTIONS USING INSURANCE CLAIMS DATA

This chapter investigates and summarizes previous efforts relating injury type to the engineering characteristics of intersections using insurance claims data. The use of insurance claims as a data source for road safety analysis, efforts to relate insurance claims to the roadway engineering characteristics of intersections, and efforts to relate injury type to the roadway engineering characteristics of intersections based on insurance claims were investigated.

2.1 INSURANCE CLAIMS AS COLLISION DATA SOURCE FOR ROADWAY SAFETY ANALYSIS

The most widely used and available source of collision data in roadway safety analysis is police-reported collision data. Insurance claims have had limited use in roadway safety analysis by engineers. There has been, however, an increase in the number of cases using insurance claims as a means of estimating collision occurrence and severity in recent years. Insurance claims are also perceived by some as being somewhat more reliable than police reports for collision analysis.

de Leur and Sayed (2001) indicate that police collision data is often suspect, and thus looked at insurance claims data from the Insurance Corporation of British Columbia

(ICBC) as a possible source for safety evaluation. Ogden (1996) notes that police collision reports are "the best and only form of basic data generation on accidents in most jurisdictions". However, he also points out that police accident reports are invariably imperfect due to report quality inconsistencies. Collisions reported to or by the police are also limited in their representation of total collisions, as an incident cost threshold must be met before inclusion and that not all reportable collisions are necessarily reported. Hauer (1997) notes that police miss some 20 percent of injuries requiring hospitalization, up to 50 percent of injuries which do not require hospitalization, and some 60 percent of reportable property damage only collisions.

According to Murphy and Johnson (1999), insurance claims data have the potential to increase the quantity and quality of collision data in road safety evaluation. They noted 55,000 vehicle insurance claims were made whilst only 5,000 collisions were reported to police annually for collisions taking place in British Columbian parking lots. In this case, insurance claims provided 11 times the quantity of vehicle collisions, and thus a more robust dataset.

The potential for using insurance claims in road safety analysis was identified by Malfetti (1993), who conducted a study for AAA Foundation for Traffic Safety to evaluate and address the issue of the large traffic safety problem relating to drivers aged 16 to 24. He made use of insurance data from eight AAA insurance companies, and concluded that there "probably is no better data base on young drivers than the records of insurance companies".

Insurance claims have been used in intersection safety analysis, as a means of identifying high-collision intersections. Zein and Navin (2000) found that insurance claims have been used to identify high-collision intersections by the Transport Accident Commission in Victoria, Australia, by a coalition of private auto insurers in Alberta, and by AAA Michigan and State Farm auto insurance agencies in the United States. Manitoba Public Insurance began recording location information for collisions for located within Winnipeg in 2002. This has been done in order to more accurately understand and quantify collision claim trends and to assist in the development of more targeted countermeasures. Preliminary results for the period between June 2002 and November 2003 showed that the top 50 high-collision intersections accounted for 19 percent of all intersection claims and 15 percent of all intersection collision costs (Mwanza, 2004).

2.2 RELATING INSURANCE CLAIMS AND THE ROADWAY ENGINEERING CHARACTERISTICS OF INTERSECTIONS

Insurance claims have been used in relating collisions with the roadway engineering characteristics of intersections.

The Insurance Corporation of British Columbia (ICBC) used claims data for evaluating the cost of collisions at intersections as a part of their Road Improvement Program. Insurance claims were used in the analysis of selected intersections, which involved estimating the expected cost savings due to reduced collision frequency and severity from the implementation of safety features. ICBC would then invest in road safety improvements if the ratio between the expected reduction in insurance claims and the cost of improvements was shown to be at least 2:1, where an investment return period of two years was typically applied. For any intersections where investments were made, follow-up evaluation was conducted comparing the actual post-treatment insurance claims to expected insurance claims without treatment. According to Zein and Navin, cost savings have attained an average ratio of 8:1. As such, collision frequency and cost were related to selected roadway engineering safety treatments at intersections (Zein and Navin, 2000).

Feber, Feldmeier, and Crocker (2000) indicate that AAA Michigan modelled their road improvement program after ICBC's model, in the following manner. AAA Michigan and Southeast Michigan Council of Governments identified high-collision signalized intersections. Test project intersections were then implemented with a safety treatment application, for which AAA Michigan provided partial funding. Insurance claims from post-treatment implementation were compared to the expected number of claims had there been no treatment. Results indicate a reduction in collision severity and frequency at intersections from the modernization of traffic signals, upgrading signal lens sizes from 8 inches to 12 inches in diameter, and installing left-turn lanes.

2.3 RELATING INJURY TYPE AND THE ROADWAY ENGINEERING CHARACTERISTICS OF INTERSECTIONS

The literature is silent on relationships between specific injury types from motor vehicle collisions and the roadway engineering characteristics of intersections. The lack of literature with specific injury type is likely due to the difficulty in obtaining injury information from collision data sources, whether it be difficulty in obtaining access to the actual data (as may be the case for insurance claims), or absence of injury information from the most commonly available collision data sources (such as police-reported collision data). Specific injury type is not usually available from police-reported collision data, but injuries are often catalogued in the dataset based on severity. For this reason, research into relationships between injuries and the roadway engineering characteristics of intersections has generally been limited to investigations of injury severity, where injury severity levels are defined by the level of incapacitation resultant from an injury. These injuries, however, are not distinctly specified by type except for fatal injuries. There are a number of instances where injury severity has been used in investigations of relationships with the roadway engineering characteristics of intersections.

CHAPTER 3

DATABASES AND ANALYSIS TECHNIQUES USED IN THE RESEARCH

This chapter describes the data and the analysis methodologies used for the research. The collision datasets, the geographic platform, and the collision rate methodology are described. Seven different data sources were used for this research: (1) insurance claims data from Manitoba Public Insurance; (2) collision statistics from the Division of Driver and Vehicle Licensing (DDVL) of Manitoba Transportation and Government Services; (3) collision data from the City of Winnipeg Public Works Department Transportation Division; (4) the geographical platform from the City of Winnipeg Public Works Transportation Division; (5) traffic flow estimates from the City of Winnipeg Public Works Transportation Division; (6) orthophotos from the University of Manitoba Transport Information Group; and (7) the City of Winnipeg spatial footprint.

3.1 COLLISION DATASETS USED IN THE RESEARCH

3.1.1 Manitoba Public Insurance Claims Data

Two types of data were provided by Manitoba Public Insurance. The first type consisted of collision information for each individual claim, for all claims from the Province of Manitoba for the years 2000, 2001, 2002, and 2003. These datasets include the following information: incident number, date, time, collision severity, injury type, victim type (road user), collision with wildlife, restraint/protection device use, vehicle type, vehicle model/year, vehicle liability (the amount of fault assigned to a claim for a given incident, in percent), driver age, driver sex, victim age, victim sex, claims centre, and incurred cost per claim. There are 481,238 total collision claims records from the four years in this dataset.

The second type of data is comprised of collision location information for each individual claim, for intersections in Winnipeg from July 2002 to December 2003. This dataset includes incidents, claims, date, time, location, incurred cost of claim, and claim type (property damage or bodily injury). There are 41,545 intersection collision claims records in this dataset.

3.1.2 Manitoba Transportation Collision Statistics

DDVL collision information is provided in the form of annual collision statistics. The most current year of available information at the time of this research is 2001 (MTGS, 2003). This information shows all reported collisions within Manitoba for that year, as well as historical statistics for the previous 10 years. DDVL traffic collision statistics are comprised of reportable collision totals from all law enforcement agencies within Manitoba, including the City of Winnipeg. These statistics present information totals for various collision attributes, including annual total collisions by severity type, total victims and vehicles involved, summaries by month, day of week, and time of day, urban vs. rural, road surface condition, weather, impact configuration type, vehicle type, driver age, driver gender.

3.1.3 City of Winnipeg Collision Data

The Transportation Division of the City of Winnipeg Public Works Department provided a collision dataset which is comprised of information for collisions in Winnipeg for 2003. Information in this dataset includes date, time, impact configuration type, environment/weather conditions, lighting, traffic control at location, collision severity type (property damage only, injury, fatal injury), number of vehicles involved, number of persons injured, number of pedestrians injured, street name(s), and geographic identifier. There are 16,365 total collision records in this dataset, of which 11,254 are intersection collision records.

3.2 GEOGRAPHIC PLATFORM

The geographical platform used in this research was provided by the University of Manitoba Transport Information Group (UMTIG) and the City of Winnipeg Public Works Department Transportation Division. This platform incorporates the geo-locations of all intersections and streets in the City of Winnipeg.

3.2.1 City of Winnipeg Streets Network

Two layers of the City of Winnipeg streets network were used in the research, namely the streets layer and the intersections layer. The intersections layer was directly used for collision information linking and presentation, while the streets layer provided a background spatial context. Figure 3.1 shows the network used in the research, with Winnipeg's regional street network highlighted.

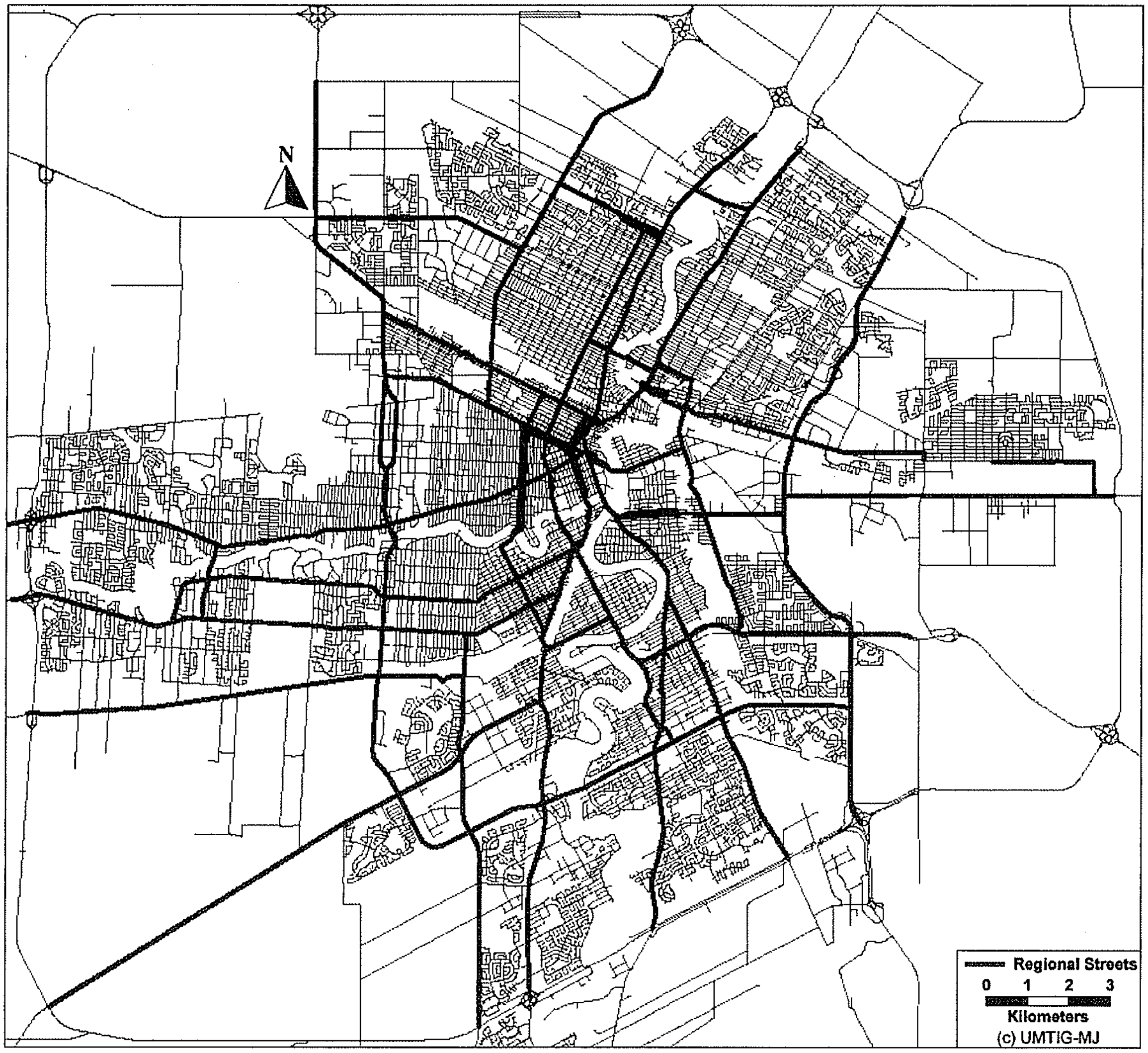

Figure 3.1: Winnipeg Streets Platform Used in the Research

3.2.2 Spatial Linking of Collision Datasets

The two collision data sets with intersection location information (City of Winnipeg collision data and MPI claims data) were linked to the intersections layer for 2003 data. Collision records in the City of Winnipeg collision database have a map identifier, which is assigned based on the intersection or road segment where the incident took place. This map identifier can be directly linked to the intersections layer, allowing for the geographical presentation of collision information.

The MPI intersection location claims data did not originally include a map identifier, but did include the intersection name in text. In order to link the data to the map, a map identifier was assigned to each claim by matching intersection names from the Winnipeg intersections GIS layer to the intersection name on the claim and attaching the associated map identifier. Manipulation of intersection text names of claims was required for linking compatibility, and for certain intersections manual assignment of map identifiers was required. There were two circumstances where it was not possible to assign a map identifier to a claim, because of intersection location ambiguity. This occurred for offset T-intersections (where the offset streets have the same name) or where a circuitous road intersects twice with one street (such as a bay or crescent). This resulted in 470 collisions with an incurred cost of $2.3 million from 166 ambiguously located collisions in 2003 (based on insurance claims) being omitted from GIS analyses. This represents 3 percent of both the total number of collisions (15,655) and the total incurred collision cost ($85.4 million) of all intersections in 2003. While these intersections were not represented in geographical analyses, they were included in tabular analyses. The addition of the map identifier to the claims database allowed for geographic analysis of features unique to the insurance claims dataset, namely incurred cost and collisions by injury type (in addition to collision frequencies and collision rates).

3.2.3 Orthophotos and City of Winnipeg Footprint

Digital orthophotos of the City of Winnipeg were used in the identification of intersection characteristics and the visual portrayal of intersection characteristics. These images are geo-corrected and have a resolution of 20 cm. The City of Winnipeg footprint provides an outline of infrastructure features in Winnipeg, with layers for streets, driveways, back lanes, and sidewalks. For this research, the streets layer was used, and was overlaid onto the orthophotos using AutoCAD.

3.3 COLLISION RATE ANALYSIS APPROACH

3.3.1 Traffic Flow Data

Traffic flow estimates were obtained from the Transportation Division of the City of Winnipeg Public Works Department. The information provided average weekday daily traffic (AWDT) estimates on major Winnipeg streets in 2003, which was the most current available information at the time of this research. Figure 3.2 shows the 2003 traffic volume flows in Winnipeg.

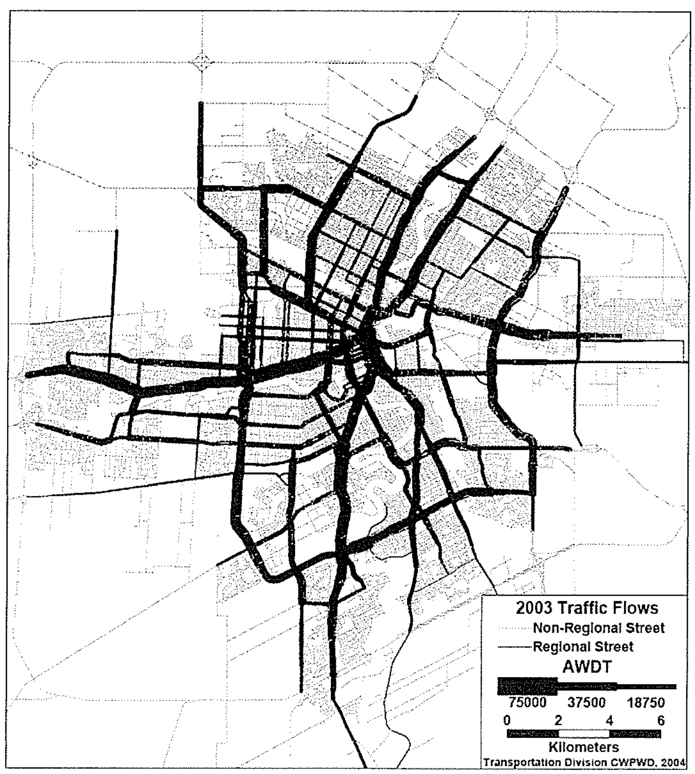

Figure 3.2: 2003 Traffic Flows in Winnipeg
Source: Transportation Division, City of Winnipeg Public Works Department
Note: AWDT is Average Weekday Daily Traffic

3.3.2 Collision Rate Calculation

Collision rates were calculated based on the number of collisions for a given exposure to traffic of an intersection, where exposure was defined in terms of the daily total vehicular activity entering an intersection. For two-way roads, the entering traffic volume was assumed to be half of the two-way volume of the approach leg. Daily vehicular traffic volumes used were based on AWDT values.

Collision rates were calculated using equation 3.1 shown below. For this research, the calculated collision rates were multiplied by 1,000,000 thus giving collision rate units of collisions per million entering vehicles (MEV).

$$CollisionRate = \frac{C \times 1{,}000{,}000}{EnteringAWDT \times (days / year)} \quad \text{(eq. 3.1)}$$

where: C – Number of collisions at the intersection in one year
AWDT – Average Weekday Daily Traffic

Traffic volumes are generally only estimated on major routes in Winnipeg, thus calculating collision rates for every intersection was not feasible. Collision rates were therefore estimated at the highest-ranking intersections in terms of collision frequency in 2003. Collision rates from these intersections represent cases of greater road safety concern than intersections with a small number of collisions and low traffic volumes which may nonetheless have high collision rates.

Of the highest-ranking collision frequency intersections, a number had one or two approach legs without a traffic volume estimate. Entering traffic volumes were used as available; as such, intersections without estimates on all approach legs were assigned lower total entering vehicle traffic volumes than are actually experienced. This resulted in collision rates at these intersections which were overestimated. While this is of some concern in terms of the consistency of intersection collision rates, the road segments without traffic volume estimates are generally collector or local in nature with lower traffic volumes than the approaches with traffic volume estimates. Despite the overestimation, the collision rates at these intersections were comparable to collision rates at other intersections with similar collision totals where all approach legs had traffic estimates.

An example of collision rate sensitivity is shown as follows. The intersection of Lagimodiere Blvd and Dugald Rd has a traffic volume estimate for three of four approach legs. In 2003, the two-way AWDT volumes were 48,000 vehicles per day (vpd) on the north approach, 40,000 vpd on the south approach, and 23,000 vpd on the east approach. Also, there were 54 collisions based on insurance claims data, which gives a collision rate of 2.67 collisions per million entering vehicles. The approach leg without an estimated traffic flow volume is internally classified as a collector on the City of Winnipeg streets network, suggesting that this leg is in fact the lowest volume traffic leg of the four at the intersection. It is also not unrealistic to assume that, in general, the un-estimated traffic leg has a daily traffic volume less than or equal to the lowest-volume estimated leg. If the 23,000 vehicles from the lowest-volume estimated roadway are applied as a 'worst-case' scenario to the non-estimated leg, the resulting collision rate is 2.21, which is 17 percent lower than the computed rate of 2.67. If the non-estimated leg is assumed to have a traffic volume of half the lowest volume (i.e. 11,500 vpd), then the collision rate becomes 2.42 collisions/mev, which is nine percent lower than the identified collision rate. Intersections where collision rates were not based upon AWDT values from all approach legs were noted.

CHAPTER 4

COLLISION ANALYSIS BASED ON INSURANCE CLAIMS VERSUS POLICE-REPORTED INFORMATION

This chapter presents the results of a comparative analysis of collisions using insurance claims data and police-reported data. The purpose of this chapter is to obtain an understanding about the nature and magnitude of the differences in collision totals by severity from these data sources, to assess the potential utility of insurance claims data in intersection collision analysis as compared to the typically used police-reported collision data. Data sources are compared for collisions in Manitoba, for collisions at all intersections in Winnipeg, and for high-collision frequency intersections in Winnipeg.

4.1 COMPARISON OF DATASETS FOR COLLISIONS IN MANITOBA

Manitoba Public Insurance (MPI) claims data and Manitoba Transportation Division of Driver and Vehicle Licensing (DDVL) statistics were compared for the Province of Manitoba. Table 4.1 shows the total number of collisions based on MPI information and DDVL statistics. These collisions were compared for the years 2000 and 2001, the most recent years for which collision information was available for both sources.

There were more than twice as many total collisions represented in the insurance claims dataset than were reported by DDVL. This is not unexpected, as the insurance claims database includes all collisions, not just those with a minimum $1000 combined damage total cost. When considering reportable collisions, as defined by police reporting criteria, (i.e., PDO collisions with a minimum $1000 total claim cost or occurrence of bodily injury) there were still more collisions in the insurance claims dataset. For these collisions there were 52 percent more total collisions, with 57 percent more PDO, 35 percent more injury, and 34 percent more fatal collisions documented in the insurance claims dataset than in the DDVL summary report. The number of vehicles, injuries, and fatalities represented by these collision totals are presented by source in Table 4.2.

Table 4.1: Total Number of Collisions in Manitoba, 2000 – 2001

	Based on Manitoba Public Insurance		Based on DDVL
	Based on all insurance data	Based on PDO collisions with combined insurance claims > $1000 OR where bodily injury occurred*	
PDO	127,435	75,701	48,211
Injury	18,410	18,410	13,587
Fatal	234	234	174
Total:	146,079	94,345	61,972

Source: Analysis conducted using raw data provided by Manitoba Public Insurance and DDVL summary statistics
* This is the reporting threshold for police-reported collisions

There were more than twice as many vehicles reported to have been involved in collisions in the insurance claims dataset than were reported by DDVL. When considering collisions as defined by police reporting criteria, there were 39 percent more vehicles, 32 percent more persons injured, and 31 percent more fatalities represented in the insurance claims dataset than were reported by DDVL. The difference in the number of fatalities and fatal collisions may be due to different definition of fatality used for the data sources. For a collision to be considered fatal for DDVL, a death caused by injuries from a collision must occur within 30 days; for Manitoba Public Insurance, however, a collision is considered fatal for any death caused by injuries from a collision, regardless of the time elapsed.

Table 4.2: Total Vehicles, Persons Injured, and Fatalities Involved in Collisions in Manitoba, 2000 – 2001

	Based on Manitoba Public Insurance		Based on DDVL
	Based on all insurance data	Based on PDO collisions with combined insurance claims > $1000 OR where bodily injury occurred*	
Vehicles	213,692	144,570	103,933
Injured	24,492	24,492	18,487
Fatalities	269	269	205

Source: Analysis conducted using raw data provided by Manitoba Public Insurance and DDVL summary statistics

* This is the reporting threshold for police-reported collisions

As shown in Tables 4.1 and 4.2, insurance claims data provide a more robust collision dataset than police-reported collisions as presented by DDVL traffic statistics. Insurance claims yield a higher number of collisions of all types, in particular PDO collisions. When considering collisions based on an equivalent definition of a collision, there was still a greater number of collisions of all types represented by insurance claims data. Insurance claims also represent a greater number of vehicles, injured persons, and fatalities.

4.2 COMPARISON OF DATASETS FOR COLLISIONS IN WINNIPEG

Similar to the investigation of provincial data, collision information from both MPI and City of Winnipeg Public Works Department were compared for the year 2003 for collisions taking place at intersections in Winnipeg.

The collision total by severity type for this period is presented in Table 4.3. This table shows MPI collisions based on insurance claims for which location information is available.

Table 4.3: Total Number of Collisions at Intersections in Winnipeg, 2003

	Based on Manitoba Public Insurance		Based on City of Winnipeg data
	All insurance claims	Based on PDO collisions with combined insurance claims > $1000 OR where bodily injury occurred*	
PDO	12,413	9,281	8,480
Injury	3,233	3,233	2,755
Fatal	9	9	14
Total	15,655	12,523	11,249

Source: Analysis conducted using raw data provided by Manitoba Public Insurance and the City of Winnipeg Public Works Department
* This is the reporting threshold for police-reported collisions

There were more total collisions based on insurance claims than from City of Winnipeg collision data (this is when comparing all claims with reported collisions). There were 46 percent more PDO and 17 percent more injury collisions reported based on insurance data. There were, however, 75 percent more fatal collisions reported in the City of Winnipeg database (14 versus 9). When considering the number of collisions based on MPI data which meet the police-reporting threshold, there are 9 percent more PDO collisions. The percent difference in these collision totals, however, is less than the difference between insurance claims and DDVL for the entire province of Manitoba. Part of the reason for this may be that this table only shows collisions from MPI claims for which location information is available. The difference in fatal collisions is unexpected, as the number of injuries reported by insurance claims data is higher than police-reported data, and the number of fatal injury collisions is greater for province-wide insurance claims than for province-wide DDVL collision statistics. One possible reason for this may be that a claim may be reported at any time within four years of the incident occurring, hence the number of fatal injuries from intersection collisions may increase in the future for MPI collision data.

In discussions with Manitoba Public Insurance officials, they stated that the location data collection process is in its infancy, and that the collection of location information by MPI staff is not mandatory. Therefore, the quantity of incidents with location information attached was expected to increase in the future. There have also been some system difficulties in adequately cataloguing segment collisions, and possibly intersection collisions (Mwanza, 2004).

Figures 4.1 and 4.2 show the geographical distribution of intersection collisions based on insurance claims and City of Winnipeg data for 2003. The map illustrating the distribution of collisions based on insurance claims shows the collisions that fall under police-reporting criteria (i.e., $1,000 or more in property damage or personal injury). This makes the comparison feasible with the City of Winnipeg data, which only includes police-reported collisions. Many intersections have different collision totals for these two maps. Also, the highest collision-frequency intersections based on insurance claims data which meet police-reporting criteria have more collisions than the highest collision-frequency intersections based on City of Winnipeg collision data.

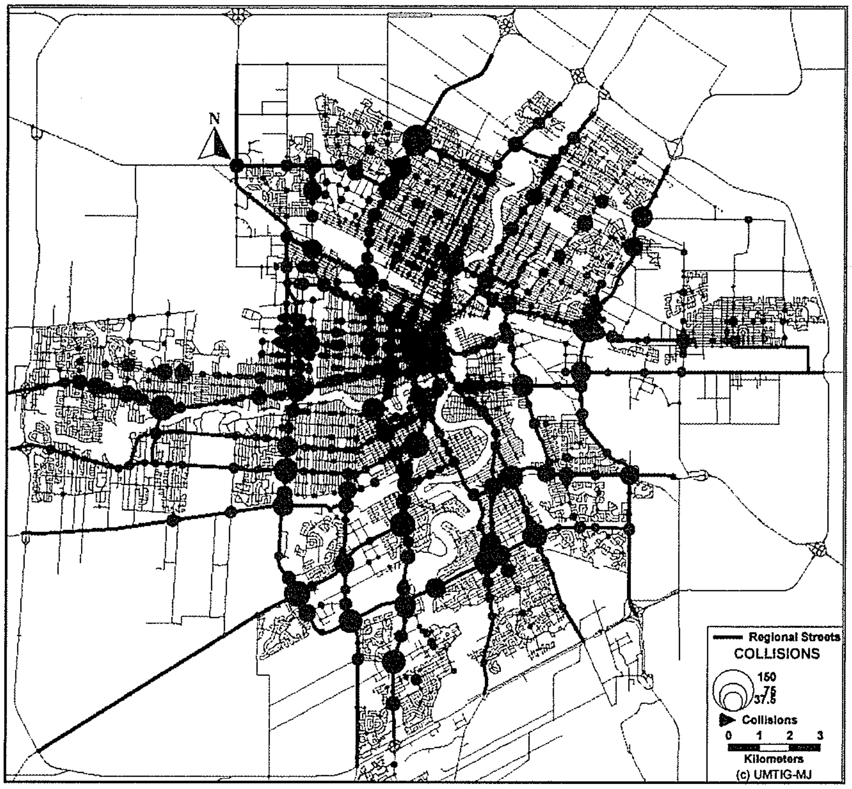

Figure 4.1: Intersection Collision Frequency based on Insurance Claims Meeting Police Reporting Criteria (Injury or Incurred PDO > $1,000), 2003

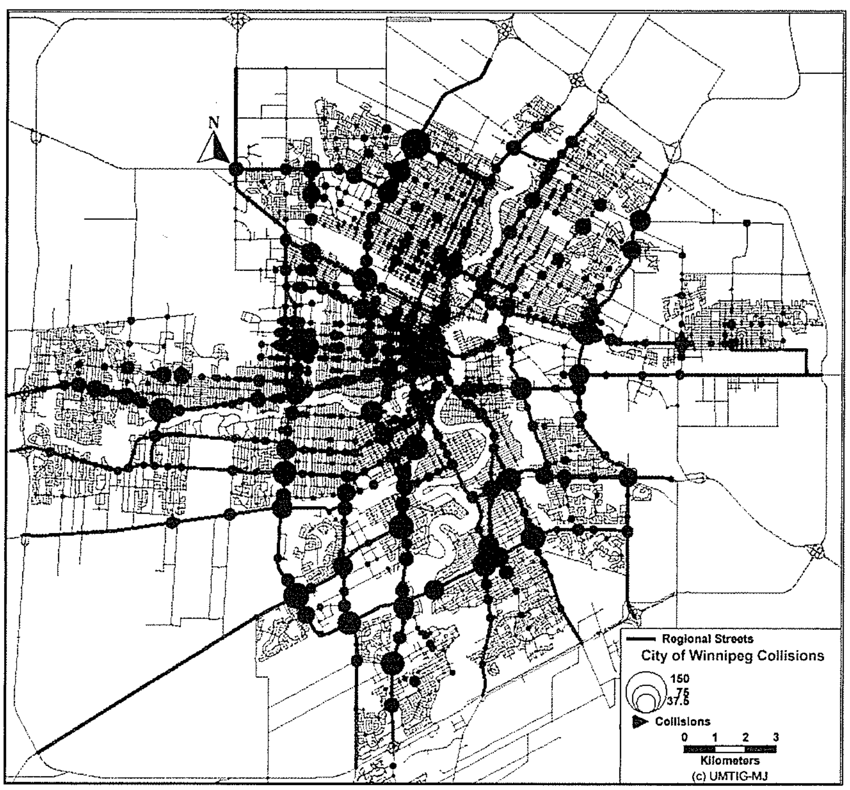

Figure 4.2: Intersection Collision Frequency based on City of Winnipeg Collision Data, 2003

The number of vehicles and injuries for each dataset are presented in Table 4.4. From this table, it can be seen that when all claims are considered there are more vehicles (58 percent) and injuries (15 percent) represented from insurance claims collisions than from data maintained by the City of Winnipeg. When considering collisions from insurance claims which meet police-reporting criteria, there were 31 percent more vehicles represented by Manitoba Public Insurance collisions.

Table 4.4: Total Number of Vehicles and Injuries at Intersection Collisions in Winnipeg, 2003

	Based on Manitoba Public Insurance		Based on City of Winnipeg data
	All insurance claims	Based on PDO collisions with combined insurance claims > $1000 OR where bodily injury occurred*	
Vehicles	26,722	22,158	16,912
Bodily Injuries	4,190	4,190	3,648

Source: Analysis conducted using raw data provided by Manitoba Public Insurance and the City of Winnipeg Public Works Department
*This is the reporting threshold for police-reported collisions

The comparison of common collisions in both databases was done by comparing collisions for each date and time, at each location. The greatest difficulty in matching up which collisions are included in both datasets is due to the time of incident occurrence. In inspecting the two datasets, there are a number of collisions which match by date and street names, but differ in time of occurrence by a range of a few minutes to many hours. It would seem, therefore, that many of these collisions are indeed the same incident in both datasets and that some of these collisions are genuinely separate incidents. This research attempted to identify matching collisions under the following scenarios; (1) collisions for which the hour of incidence matched; (2) collisions for which the hour of incidence was within ±1 hour; (3) collisions for which the hour of incidence was within ±3 hours; and (4) collisions for which the hour of incidence was within ±12 hours. Additionally, in all scenarios the month, day(s), and map intersection node identification code were required to match in order to deem a particular collision as being the same event.

The analysis found that there were 4,767 collisions in common with the same incident time listed; 5,135 collisions in common within ±1 hour; 5,342 collisions in common within ±3 hours; and 6,052 collisions in common within ±12 hours. Percentage-wise, this represents between 32 and 41 percent of the 14,806 collisions with unique location descriptions with a known map identification value from all insurance claims and between 43 and 52 percent of collisions from the City of Winnipeg dataset. With no more than 52 percent of collisions found to be in both datasets, the total number of actual collisions was therefore underreported, in both datasets, by at least one third.

In cataloguing intersection collisions based on MPI data, multiple intersections which have the same name were not given a map node identifier. Such intersections occur either from a bay intersecting the same street twice, or from two T intersections where two of the approach legs are offset (generally with the major through route). There were 470 collisions at 166 multi-named intersections where map node identifiers could not conclusively be applied. As such, it is not possible to know if these collisions are also reported in City of Winnipeg collision data; conversely, there are collisions in the City of Winnipeg collision dataset which may or may not be represented by MPI collision claims data at these intersections. The 470 collisions represent 3 percent of the total number of collisions from MPI collision claims, and thus do not greatly affect the MPI data versus City of Winnipeg data collision comparison results.

4.3 HIGH COLLISION FREQUENCY INTERSECTIONS

Further comparison was conducted for high collision frequency intersections. This was done by examining the 20 highest collision frequency intersections based on insurance claims meeting police-reporting criteria and City of Winnipeg collision data for 2003. This number of collisions was selected for comparison as they represent a relatively large percentage of the total number of collisions for a small percentage of the total number of intersections, while retaining a manageable number of intersections for comparison.

Tables 4.5 and 4.6 show the intersection rankings based on: (1) insurance claims that fall under the police-reporting threshold; and (2) City of Winnipeg data. The 1,153 collisions based on insurance claims represent nine percent of the 12,182 total collisions with unique location descriptions with a known map identification value which meet the police-reporting threshold while the 910 collisions based on City of Winnipeg data represent eight percent of the total 11,249 collisions at less than 0.25 percent of the 8000+ intersections in Winnipeg. Figure 4.3 displays the geographical distribution of the 20 highest collision frequency intersections based on police-reporting criteria using both Manitoba Public Insurance records and City of Winnipeg data.

Table 4.5: 20 Highest Collision Frequency Intersections Based on Insurance Claims Meeting Police-Reporting Criteria, 2003

Rank	Intersection	Num. of Collision
1	*Leila Ave & McPhillips St*	85
2	*McGillivray Blvd & Kenaston Blvd*	65
3	*Grant Ave & Pembina Hwy*	64
4	*Moray St & Portage Ave*	63
4	*McGillivray Blvd & Pembina Hwy*	63
6	*Logan Ave & McPhillips St*	61
6	*Lagimodiere Blvd & Regent Ave W*	61
8	*Bishop Grandin Blvd & St Anne's Rd*	60
9	*Bishop Grandin Blvd & St Mary's Rd*	59
10	*Grant Ave & Kenaston Blvd*	56
10	*Fermor Ave & St Anne's Rd*	56
12	*Pembina Hwy & Bison Dr*	55
13	*Bishop Grandin Blvd & Waverley St*	54
13	*Main St & Redwood Ave*	54
15	*Ellice Ave & St James St*	53
16	*Academy Rd & Stafford St*	52
17	*McPhillips St & Jefferson Ave*	49
17	*Archibald St & Marion St*	49
19	*Main St & Portage Ave*	48
20	*3 Intersections**	46
	Total	1,153

Source: Manitoba Public Insurance Data
**These intersections are:*

- *Inkster Blvd & McPhillips St*
- *Dakota St & St. Mary's Rd*
- *Lagimodiere Blvd & Springfield Rd*

Table 4.6: 20 Highest Collision Frequency Intersections Based on City of Winnipeg Collision Data, 2003

Rank	Intersection	Num. of Collision
1	*Bishop Grandin Blvd & St Mary's Rd*	58
2	*Bishop Grandin Blvd & Dakota St*	56
3	*Moray St & Portage Ave*	53
4	*McGillivray Blvd & Kenaston Blvd*	49
4	*Logan Ave & McPhillips St*	49
4	*Bishop Grandin Blvd & St Anne's Rd*	49
4	*Lagimodiere Blvd & Regent Ave W*	49
8	*Dakota St & St Mary's Rd*	46
9	*Dugald Rd & Lagimodiere Blvd*	45
10	*Archibald St & Marion St*	44
11	*Pembina Hwy & Bison Dr*	43
11	*Bishop Grandin Blvd & River Rd*	43
11	*Lagimodiere Blvd & Grassie Blvd*	43
14	*Leila Ave & McPhillips St*	42
14	*Fermor Ave & St Anne's Rd*	42
16	*Kenaston Blvd & Wilkes Ave*	40
16	*Ellice Ave & St James St*	40
16	*Pembina Hwy & University Cres*	40
16	*Fermor Ave & Lagimodiere Blvd*	40
20	*Main St & Redwood Ave*	39
	Total	910

Source: City of Winnipeg Data

From these tables it can be seen that, at the 20 highest collision frequency intersections, there were more collisions based on insurance claims data than on City of Winnipeg data per intersection for a given rank. As such insurance claims presented a more acute intersection safety assessment of the highest collision frequency intersections as compared to police-reported collision data. It is also observed that many of the intersections with the 20 highest frequencies of collisions differ between these datasets; this is shown in Figure 4.3. Nine intersections are in the top 20 collision frequency intersections for MPI data only, and seven intersections are in the top 20 collision frequency intersections for City of Winnipeg data only (note that there are actually 22 intersections shown in this figure, as three intersections share the 20th highest collision frequency ranking based on MPI data with 46 collisions). The intersections with the highest collision frequencies based on insurance data were located throughout the city. There were no high collision frequency intersections through the centre of the city based on City of Winnipeg collision data (i.e., on Pembina Highway north of Bishop Grandin Blvd or downtown). All of the top 20 intersections save one were on at least one regional street, indicating that certain intersections on major roads are of greatest safety concern.

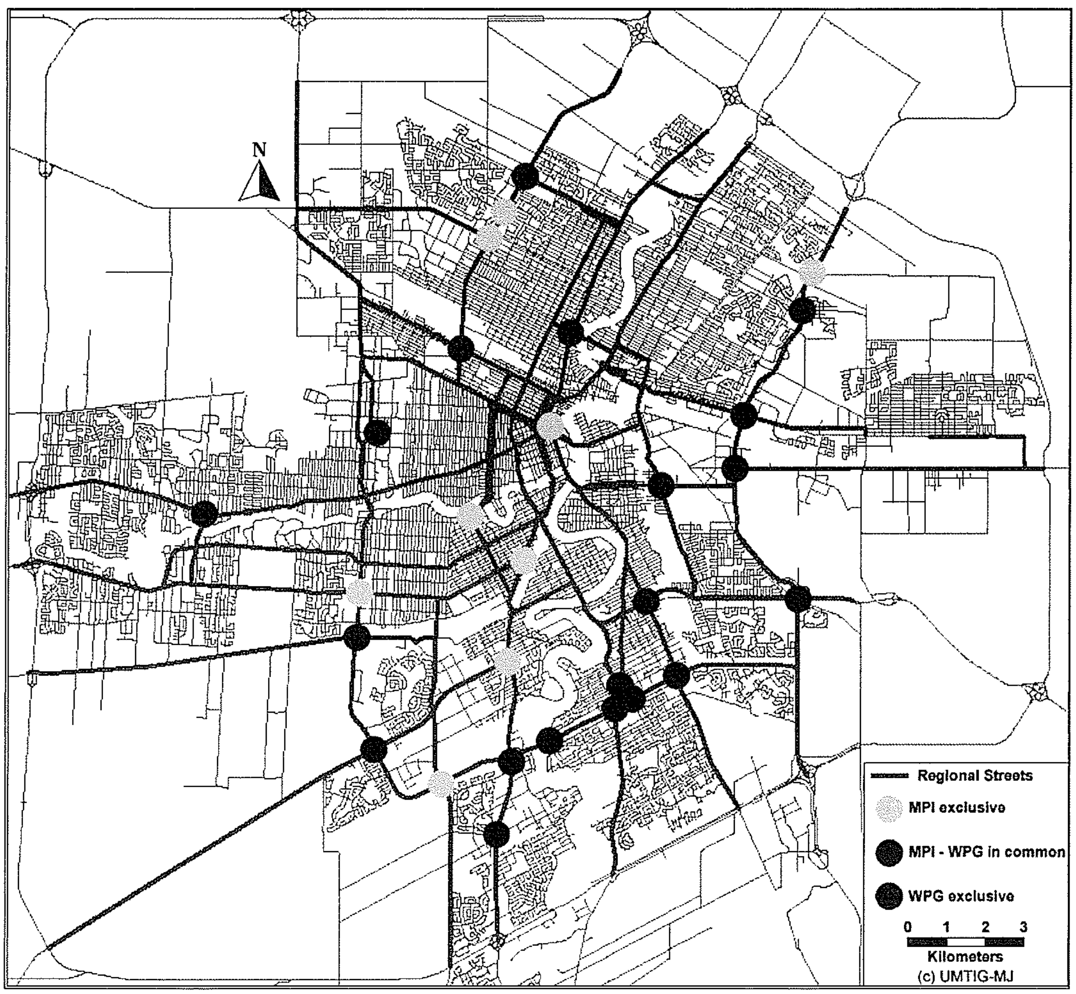

Figure 4.3: Intersections with 20 Highest Collision Frequencies, MPI and City of Winnipeg, 2003

CHAPTER 5

CHARACTERISTICS OF INTERSECTION COLLISIONS IN WINNIPEG

This chapter investigates the characteristics of collisions at intersections in Winnipeg in 2003. Temporal and spatial characteristics of collisions are investigated in terms of collision frequency, collision rate, incurred collision cost, and injury type. Collision frequency, incurred cost, and injury type are also investigated as occurring based on intersection traffic control. Manitoba Public Insurance claims data were used for all analysis in this chapter.

5.1 INTERSECTION COLLISIONS IN WINNIPEG

The frequency and incurred costs from all intersection collisions in Winnipeg in 2003 are presented in Table 5.1. Collisions are presented by collision type (PDO, injury, or fatal), with the incurred costs broken down into property damage (PD) and injury incurred claims costs. The total and average collision costs are also shown.

Table 5.1: Collisions and Incurred Costs at Winnipeg Intersections, 2003

	Number of Collisions	PD Cost (millions)	Injury Cost (millions)	Total Cost (millions)	Average Total Collision Cost
PDO	12,371	$42.5	-	$42.5	$3,400
Injury	3,275	$20.2	$20.9	$41.1	$12,500
Fatal	9	$0.1	$1.7	$1.8	$203,900
Total	15,655	$62.8	$22.6	$85.4	$5,500

Source: Manitoba Public Insurance data

The majority of collisions were PDO (79%), with injury collisions accounting for most other collisions (21%); fatal collisions represented less than 0.1% of all intersection collisions in 2003. Despite having nearly four times as many total collisions, PDO collisions accounted for almost the same total incurred collision cost as injury collisions ($42.5 million vs. $41.1 million). The average incurred cost for an injury collision was nearly four times that of a PDO collision, with $12,500/collision vs. $3,400/collision. Fatal collisions had the highest average incurred collision cost at $203,900/collision (60 times the average PDO collision cost and 16 times the average injury collision cost). For injury collisions, half of the incurred cost was attributed to injury cost ($20.9 million) and the other half to property damage cost ($20.2 million). The average PD cost was greater for injury collisions than for PDO collisions ($6,200/collision vs. $3,400/collision); the average PD cost was higher yet for fatal collisions ($10,700/collision). Therefore, bodily injury collisions were associated with higher property damage costs in addition to having incidence of injury.

5.2 TEMPORAL CHARACTERISTICS

The temporal characteristics of collisions at intersections in Winnipeg were examined in regards to collision frequency and incurred collision cost. Incurred cost was characterized by month, day of week, and time of day.

Figure 5.1 shows the incurred cost of intersection collisions by season in 2003, where seasons were defined as follows: winter – December to February; spring – March to May; summer – June to August; and fall – September to December. The number of collisions at intersections was greatest in winter, with over 34 percent of collisions. Spring, summer, and fall had 23, 19, and 24 percent of collisions respectively. The average cost per collision, however, was lowest in winter ($4,600/collision), with the average collision cost being slightly higher spring and fall ($4,800/collision each) and greatest in the summer ($6,100/collision). Therefore the winter had the highest collision frequency while the summer had the highest average collision cost severity.

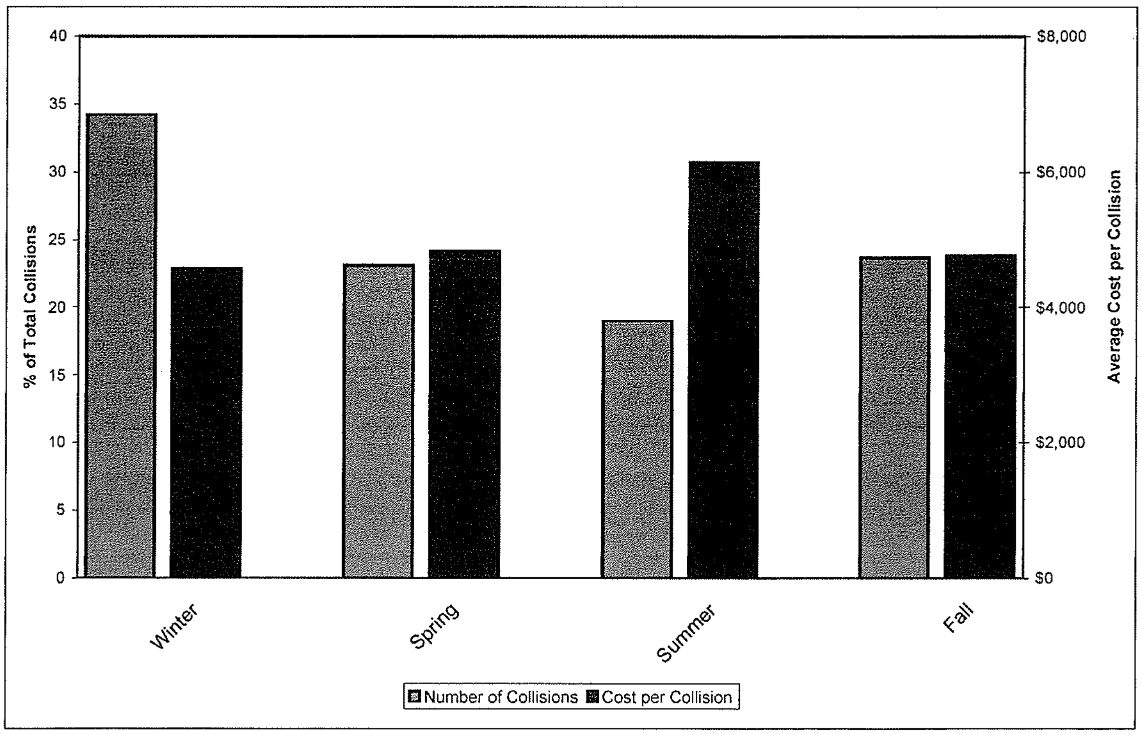

Figure 5.1: Frequency and Average Incurred Cost of Intersection Collisions by Season, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 were excluded from this figure (three collisions with an incurred cost of $7,400,000)

Table 5.2 shows the incurred cost of intersections collisions by day of week. The frequency of collisions at intersections was highest on Thursdays and Fridays, and lowest on Sundays. The average incurred collision cost was highest on Friday and Saturday and lowest from Tuesday through Thursday. The average cost per collision for any day of the week does not vary by more than $500 from the overall average of $5,000; as such the average incurred cost by day of week is generally consistent. In contrast, the total incurred cost on Friday is 2.5 times that of Sunday; the other weekdays have total costs around $10 million.

Table 5.2: Frequency and Incurred Cost of Intersection Collisions by Day of Week, 2003

Day of Week	Number of Collisions	Total Incurred Cost (millions)	Average Cost per Collision
Sunday	1,238	$6.1	$5,000
Monday	2,355	$12.0	$5,100
Tuesday	2,463	$11.5	$4,700
Wednesday	2,245	$10.7	$4,800
Thursday	2,654	$12.3	$4,700
Friday	2,905	$15.4	$5,300
Saturday	1,792	$9.9	$5,500
Total	15,652	$78.0	$5,000

Note: Collisions with an incurred cost in excess of $1,000,000 were excluded from this table (three collisions with an incurred cost of $7,400,000)

Figure 5.2 shows the number of collisions at intersections by time of day. The average number of collisions is lowest in the overnight hours from midnight to 6AM. The number of collisions per hour increases from 7AM to 4PM (with an A.M. peak at 8AM), then decreases until midnight. The majority of collisions (88%) occurred between 7AM and 8PM. The average cost of collisions did not vary considerably for different hours of the day and, for most hours, the average is below the average collision cost of $5,000 but within $1,000 of this value. Collisions with high incurred cost values greatly impact the average cost values of certain hours (especially some of the overnight hours when collision frequency is low); as such average collision cost values by hour are not shown.

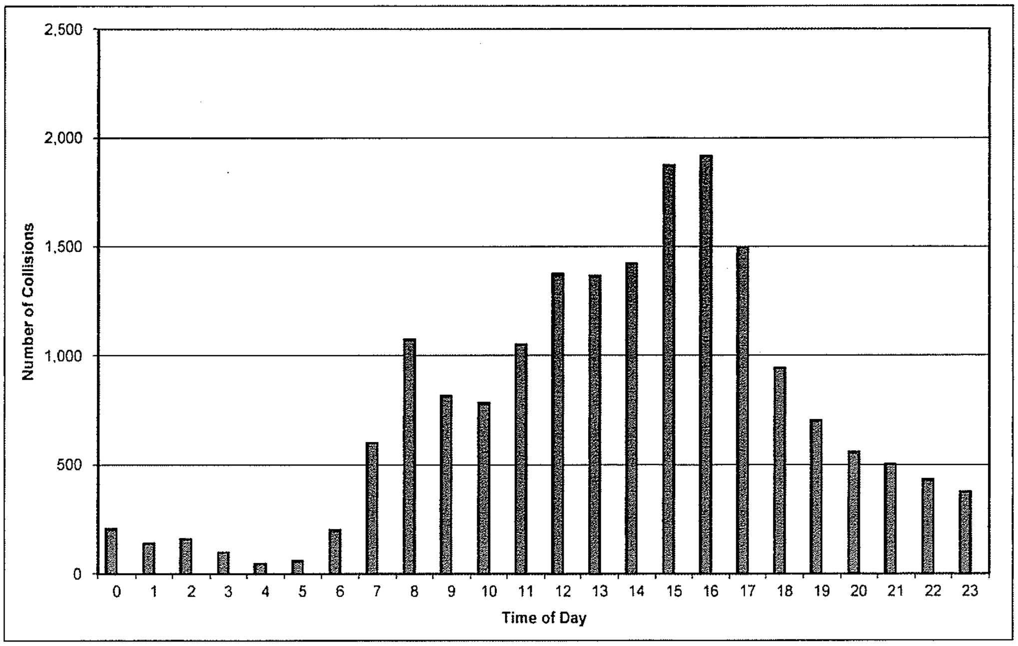

Figure 5.2: Collision Frequency at Intersections by Time of Day, 2003
Note: Collisions with an incurred cost in excess of $1,000,000 were excluded from this figure (three collisions with an incurred cost of $7,400,000)

5.3 GEOGRAPHIC DISTRIBUTION

The geographic characteristics of intersection collisions in Winnipeg were investigated in terms of collision frequency, incurred collision cost, and collision rate. Collision frequency was further investigated based upon the type of intersection traffic control.

5.3.1 Geographic Distribution at All Intersections

Figure 5.3 shows intersection collisions by frequency and Figure 5.4 shows the total incurred cost by intersection, for all intersections in Winnipeg. The intersections with the highest collision frequencies and incurred costs were generally located on regional streets or in the downtown area (centre area of the figures). While many intersections with noticeable collision frequencies and incurred costs were located in the downtown, most of the highest frequency and incurred cost intersections were on radial or suburban regional routes outside the downtown area. There are 14,806 collisions with a total incurred cost of $73.6 million at 2,675 intersections represented in these figures.

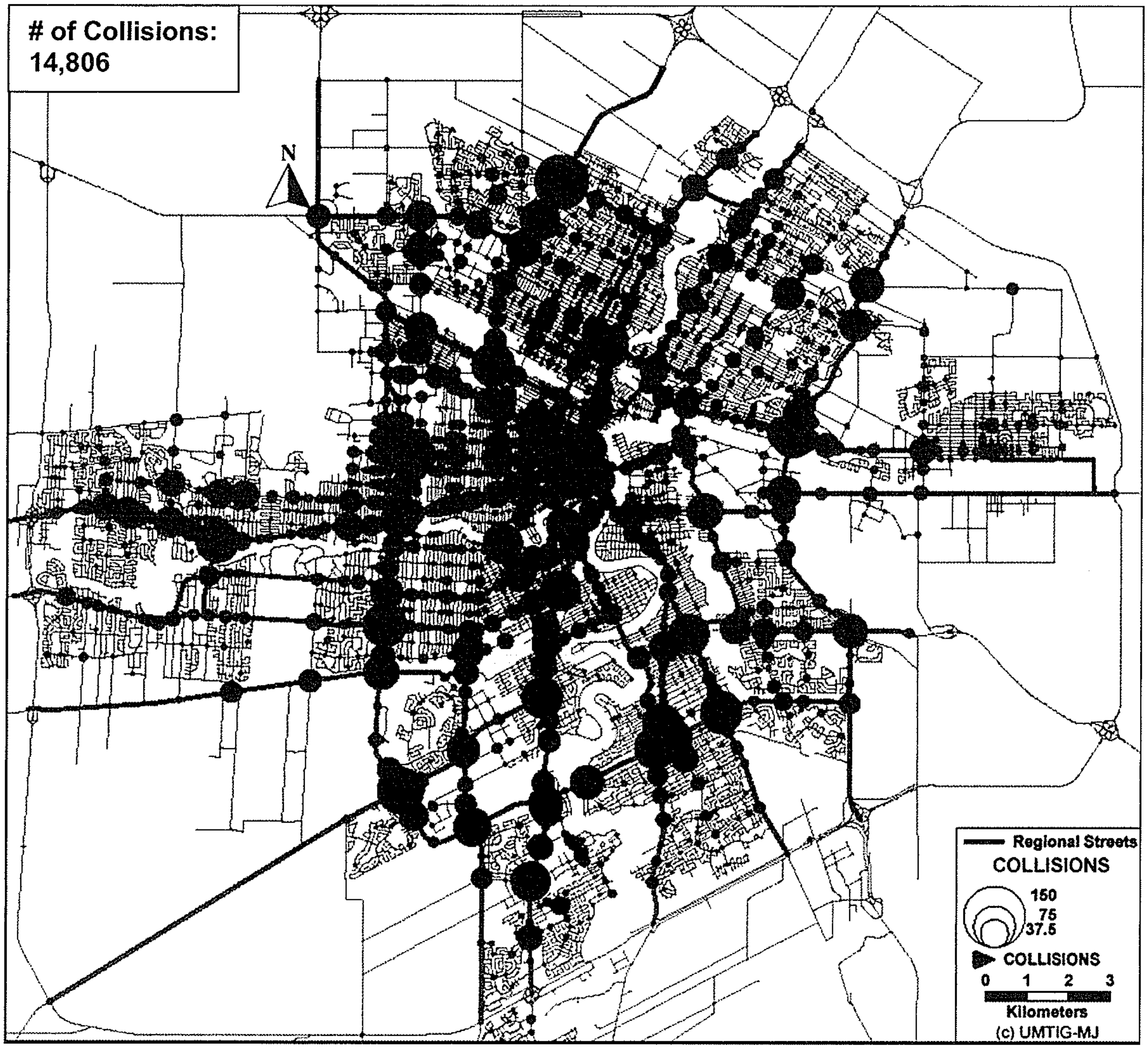

Figure 5.3: Intersection Collisions by Frequency, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

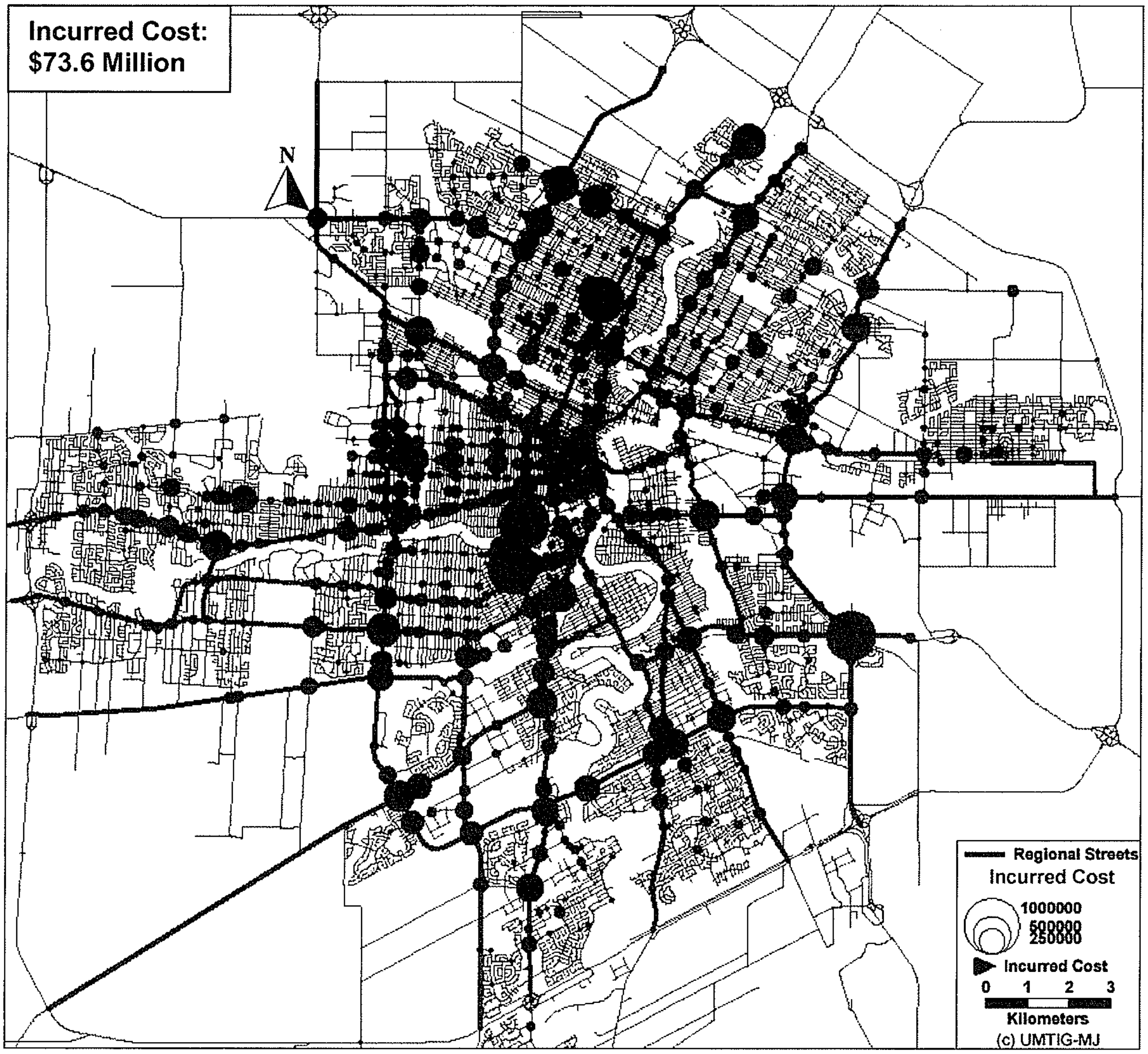

Figure 5.4: Intersection Collisions by Incurred Cost, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

Figure 5.5 shows the collision rate for the 50 highest collision frequency intersections in 2003, which had 42 or more collisions. These intersections were selected as the estimation of collision rate is only possible for intersections which have traffic estimates, and they represent a large portion of all collisions and incurred cost (2,962 collisions with an incurred cost of $12.9 million, or 19 percent of all collisions and 16 percent all incurred cost, at 0.6 percent of the total number of intersections).

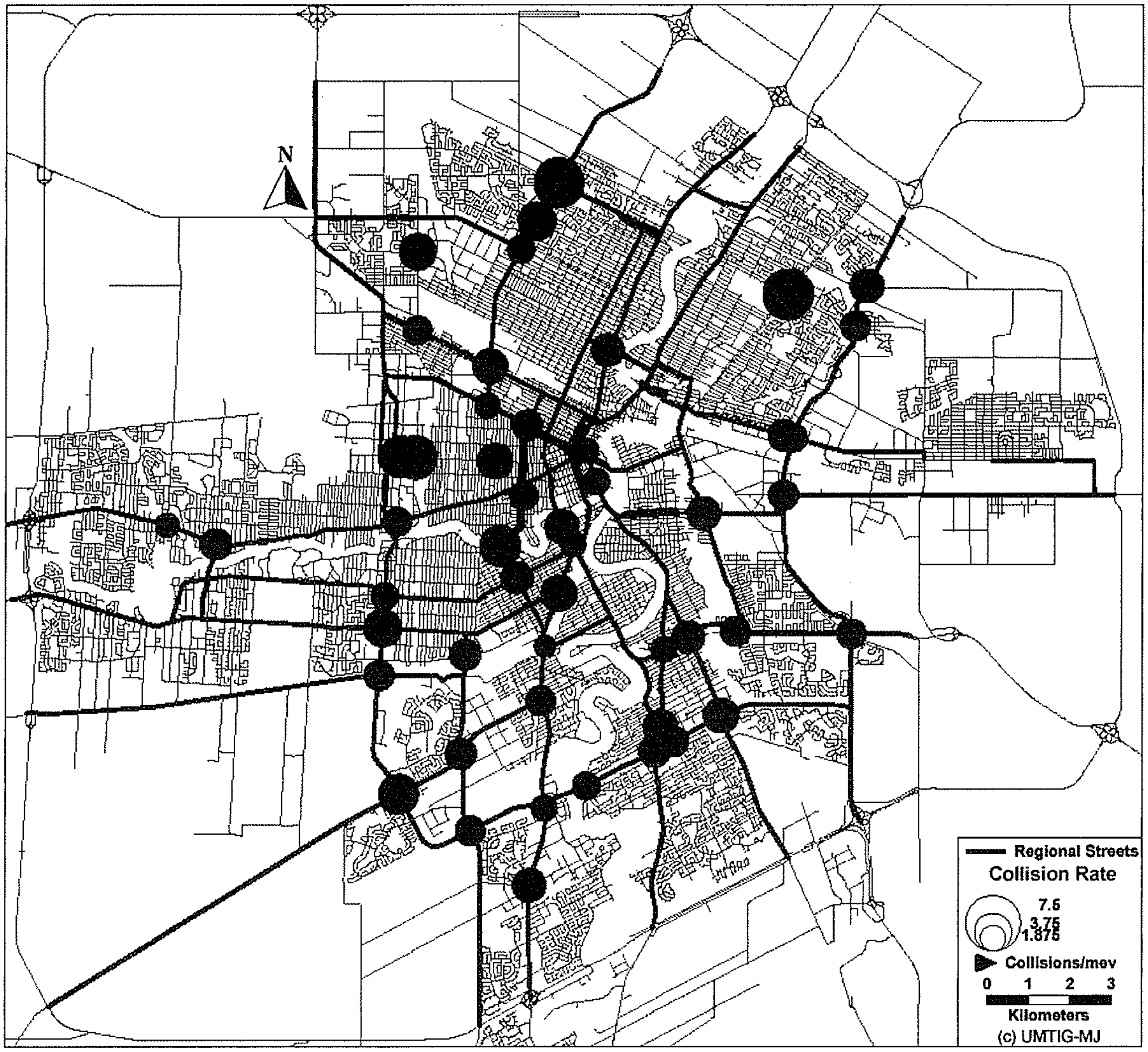

Figure 5.5: Collision Rate (in Collisions per MEV) at Intersections with the Top 50 Highest-Ranking Collision Frequencies, 2003
Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

The comparison of Figures 5.3, 5.4, and 5.5 reveals that many of the intersections feature prominently in terms of high collision frequency, large incurred costs, and high collision rate (10 intersections rank in the top 20 for all three figures). There are also intersections which feature prominently in one figure only, however. The difference in total incurred cost between the largest incurred cost intersections and other high-ranking cost intersections is relatively greater than the difference in total collisions between the highest collision frequency intersections and other high-ranking collision frequency intersections and than the difference in collision rate values between the highest collision rate intersections and other high-ranking collision rate intersections.

5.3.2 Geographic Distribution by Intersection Traffic Control

This section investigates the nature of collisions at signalized and unsignalized intersections in Winnipeg. Figure 5.6 shows intersection collision frequency at signalized and unsignalized intersections in 2003. It is observed that the number of collisions at signalized intersections nearly always exceeds the number of collisions at unsignalized intersections. The signalized intersections shown in Figure 5.6 account for 9,470 collisions and $46 million in incurred cost from 568 intersections, while unsignalized intersections account for 5,336 collisions and $28 million in incurred cost from 2,107 intersections. Therefore signalized intersections are of greater safety concern for the total number of collisions, the total incurred cost, and the average number of collisions and incurred cost per intersection than unsignalized intersections.

For signalized intersections, the intersections between arterial streets, as defined in the GIS intersections layer, had 5,092 collisions with an incurred cost of $23 million at 244 intersections in 2003. This accounts for 53 percent of collisions and 50 percent of incurred collision cost at 43 percent of signalized intersections. As approximately half of the collisions and half of the incurred cost occur at less than half of signalized intersections, intersections between arterial roads are, on average, of greater safety concern than signalized intersections which involve at least one non-arterial approach.

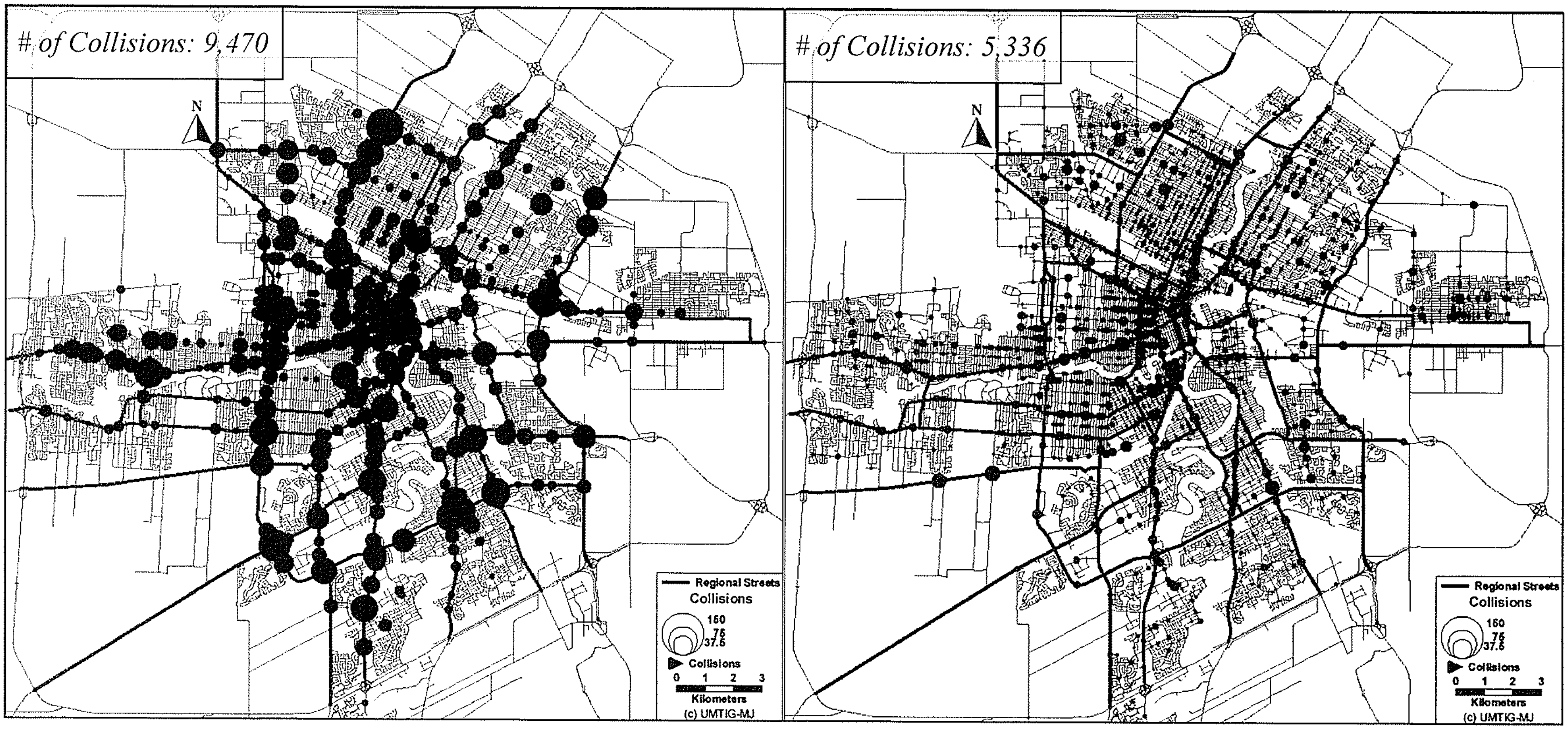

Figure 5.6: Intersection Collisions by Frequency at Signalized (Left) and Unsignalized (Right) Intersections, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

5.4 ANALYSIS OF INJURIES AT INTERSECTIONS

This section investigates injuries occurring from intersection collisions in Winnipeg in 2003. Figures 5.7 and 5.8 show the number of claims by injury type and total incurred claims cost by injury type from intersection collisions, respectively. Whiplash injuries dominated the injury claims dataset for intersections, with 88 percent of all claims being of this type. Whiplash claims also had the highest total incurred cost of any injury type with 37 percent of the total incurred claims cost, followed by brain and fatal injuries (32 percent) and broken bone injuries (24 percent). Brain and fatal injuries, however, accounted for less than half a percent of the total number of injury claims while broken bone injuries accounted for three percent. As such brain and fatal injuries are the most severe injury types in the dataset, followed by broken bone injuries. Claims for all other injury types combined represented 9 percent of injury claims and 7 percent of total incurred injury claims cost. With the highest number of claims and highest total incurred cost of any injury type, whiplash injuries are a road safety concern, especially in terms of frequency of occurrence. Brain and fatal injuries are of concern in terms of severity and cost, but occur infrequently. Broken bone injuries occur more frequently than brain or fatal injuries, but similar to those injury types, are more of a concern in terms of severity and cost than frequency.

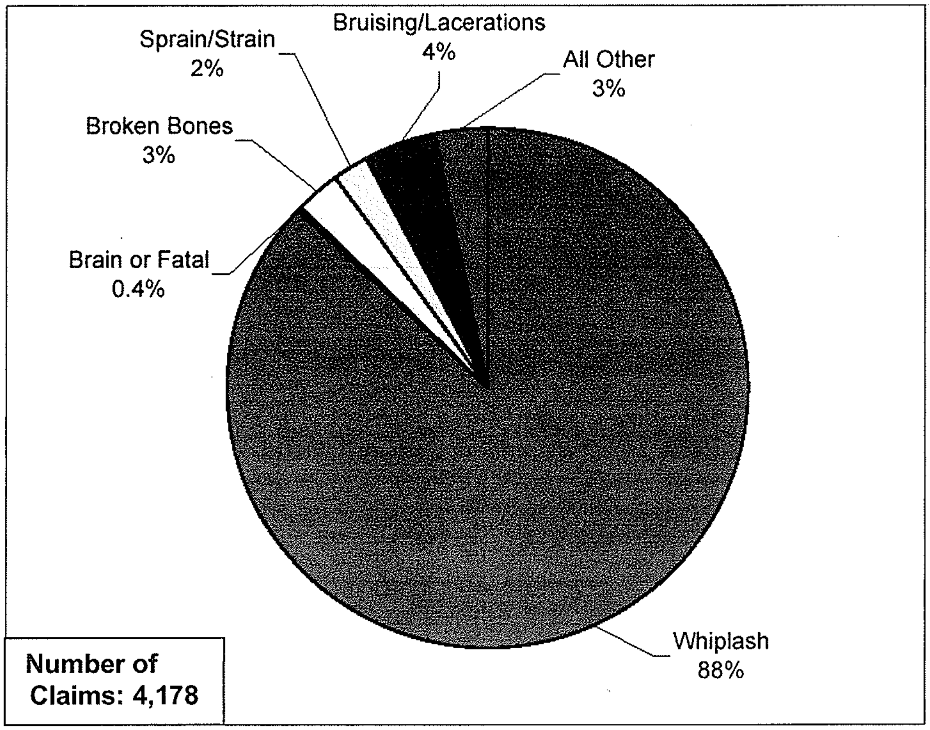

Figure 5.7: Number of Claims by Injury Type from Intersection Collisions in Winnipeg, 2003

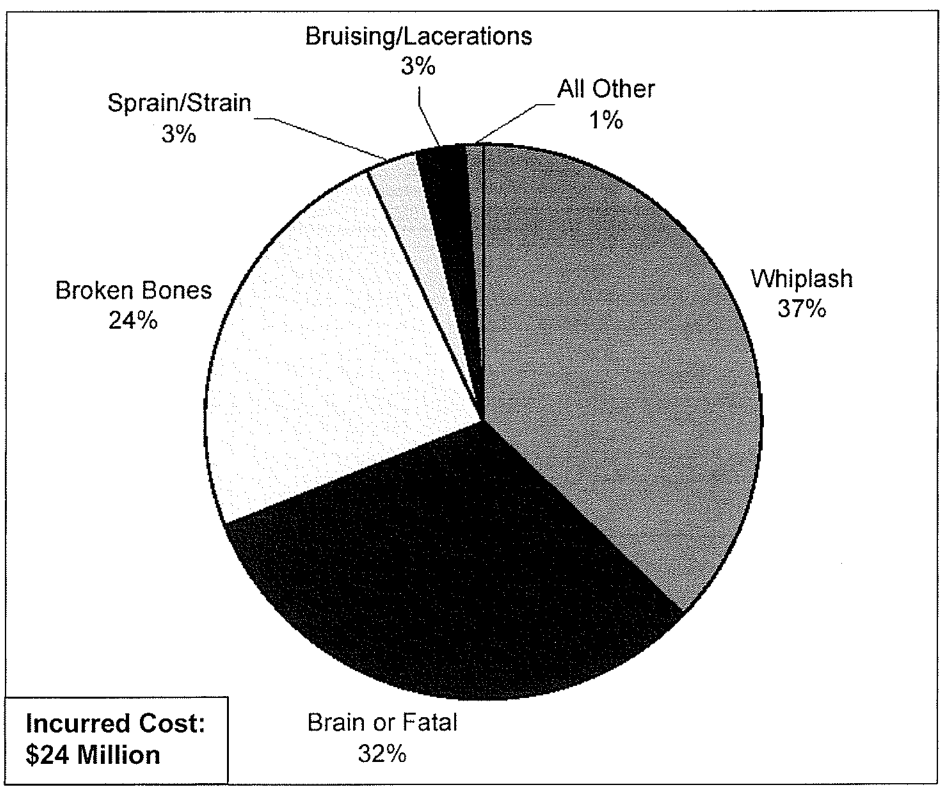

Figure 5.8: Cost of Claims by Injury Type from Intersection Collisions in Winnipeg, 2003

5.4.1 Injury Collisions by Geographic Distribution

Geographic characteristics of injury collisions by type were investigated. Figures 5.9, 5.10, 5.11, and 5.12 show the number of injury collisions and incurred injury costs at Winnipeg intersections for whiplash injuries, broken bone injuries, brain and fatal injuries, and all other injury types combined in 2003.

Whiplash injury collisions were the most numerous in frequency of occurrence at individual intersections, with up to 22 whiplash injury collisions at a given intersection. Whiplash injury collisions also occurred at the greatest number of different intersections (1,125). Broken bone injuries occurred at 104 different intersections, brain and fatal injuries occurred at 14 intersections, and all other injury types occurred at 290 different intersections. Whiplash injuries had the highest total incurred injury cost of the plotted intersections, at $7.3 million. Broken bone injuries had $3.8 million in incurred cost plotted (plus $1.2 million from one unplotted collision), brain and fatal injuries had $1.8 million in incurred cost (plus $4.7 million from one unplotted brain and one unplotted fatal injury collision), and all other injuries had $1.4 million in incurred cost. The majority of collisions where broken bone injuries resulted occurred at intersections involving one or more regional streets, while almost half of brain and fatal injury collisions (6 of 14) occurred at intersections between non-regional streets. The incurred cost by injury type was found to be consistently small on a per intersection basis for whiplash injuries, variable between low and high cost for broken bone, brain, and fatal injuries, and generally low cost for all other injuries.

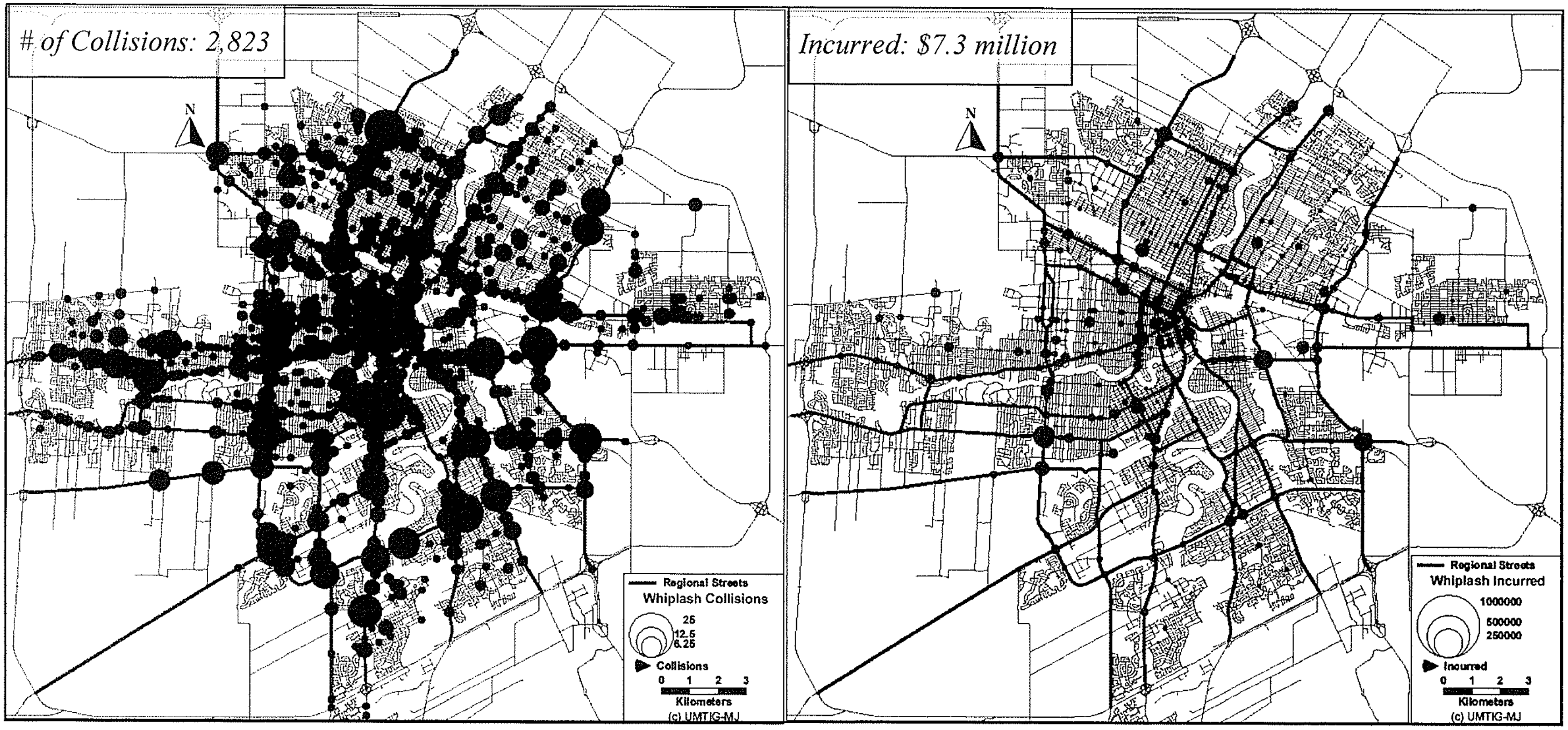

Figure 5.9: Number of Whiplash Injury Collisions (Left) and Incurred Whiplash Injury Cost (Right) by Intersection, 2003

Note: Collisions with an incurred cost in excess of \$1,000,000 (three collisions with an incurred cost of \$7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of \$4,400,000) were excluded from this figure

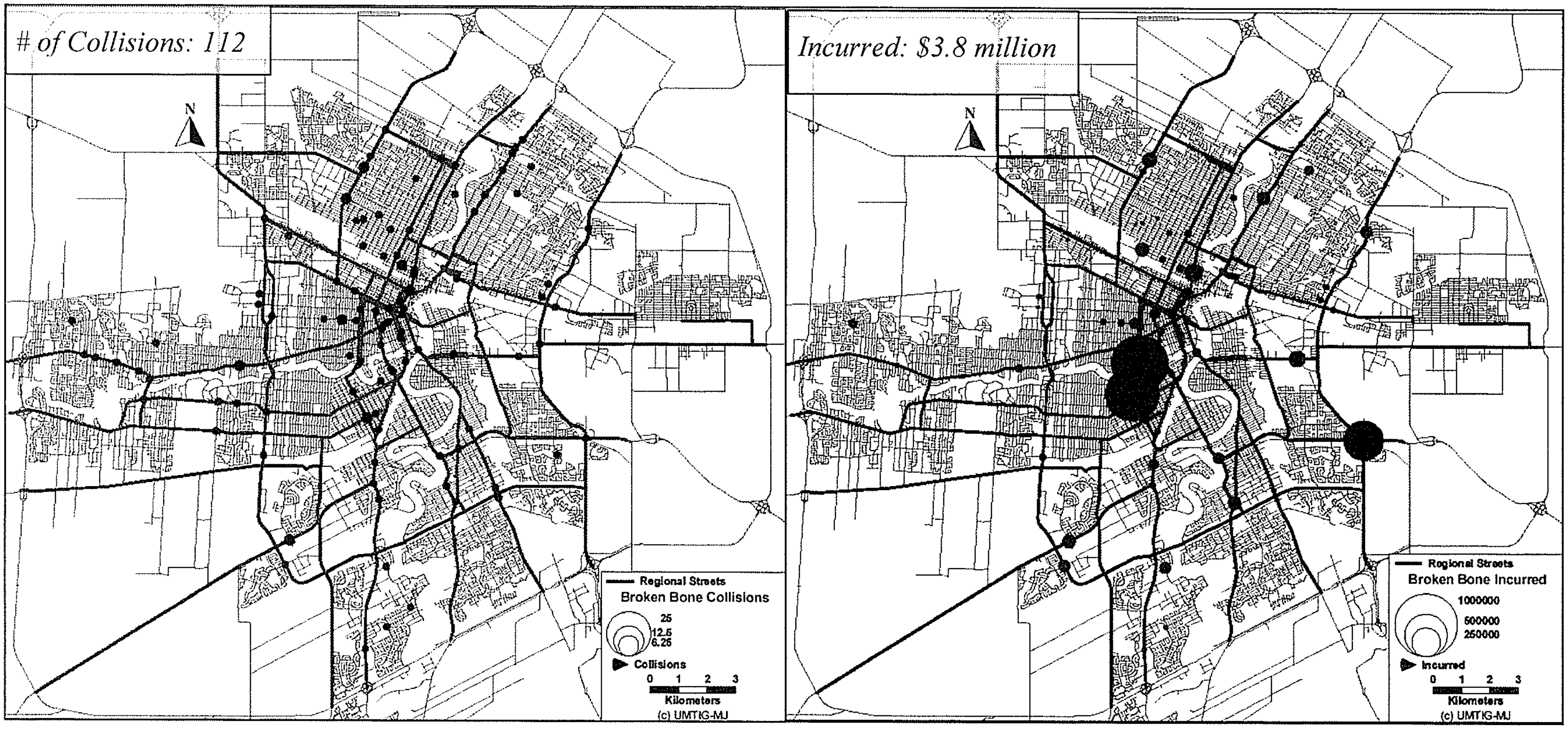

Figure 5.10: Number of Broken Bone Injury Collisions (Left) and Incurred Broken Bone Injury Cost (Right) by Intersection, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

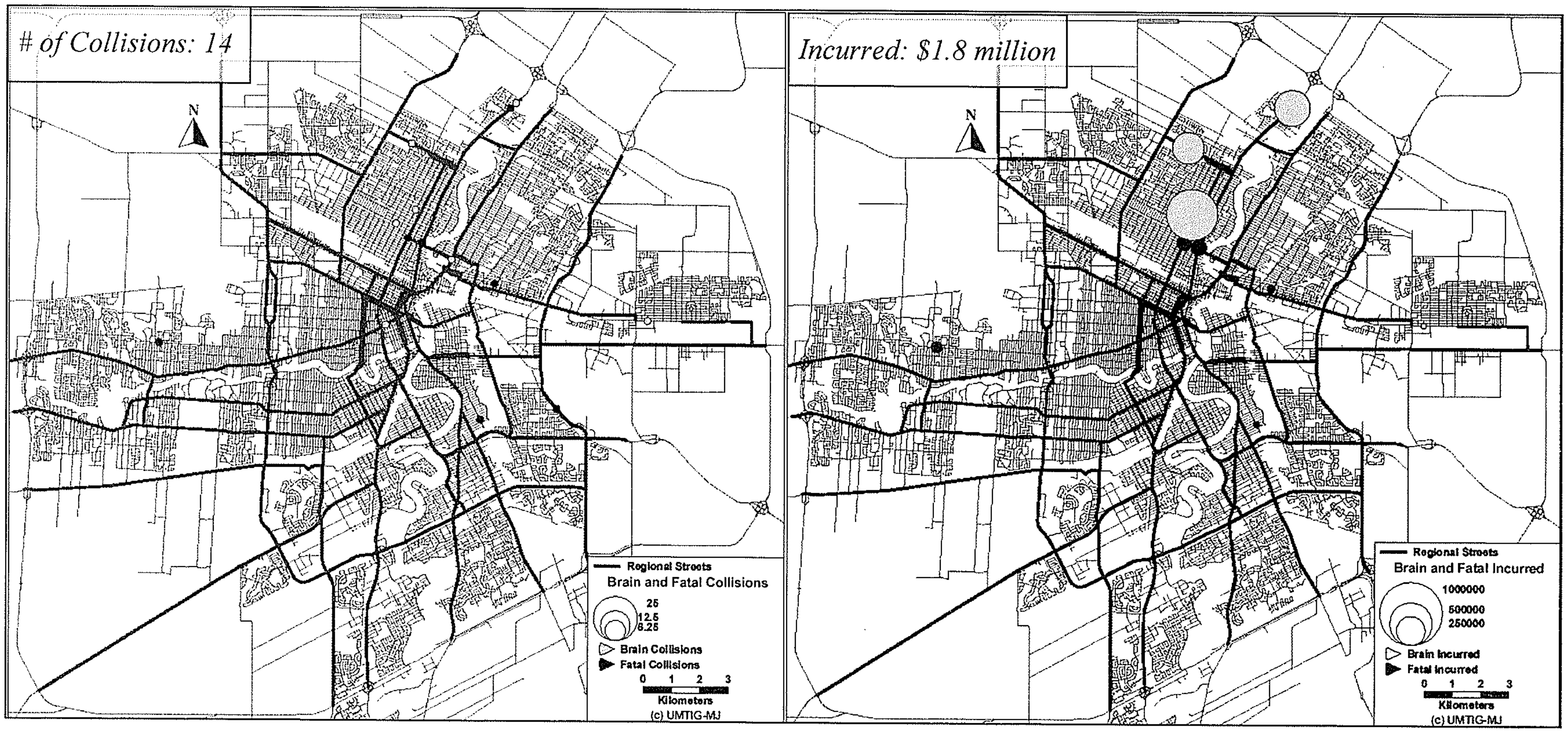

Figure 5.11: Number of Brain and Fatal Injury Collisions (Left) and Incurred Brain and Fatal Injury Cost (Right) by Intersection, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

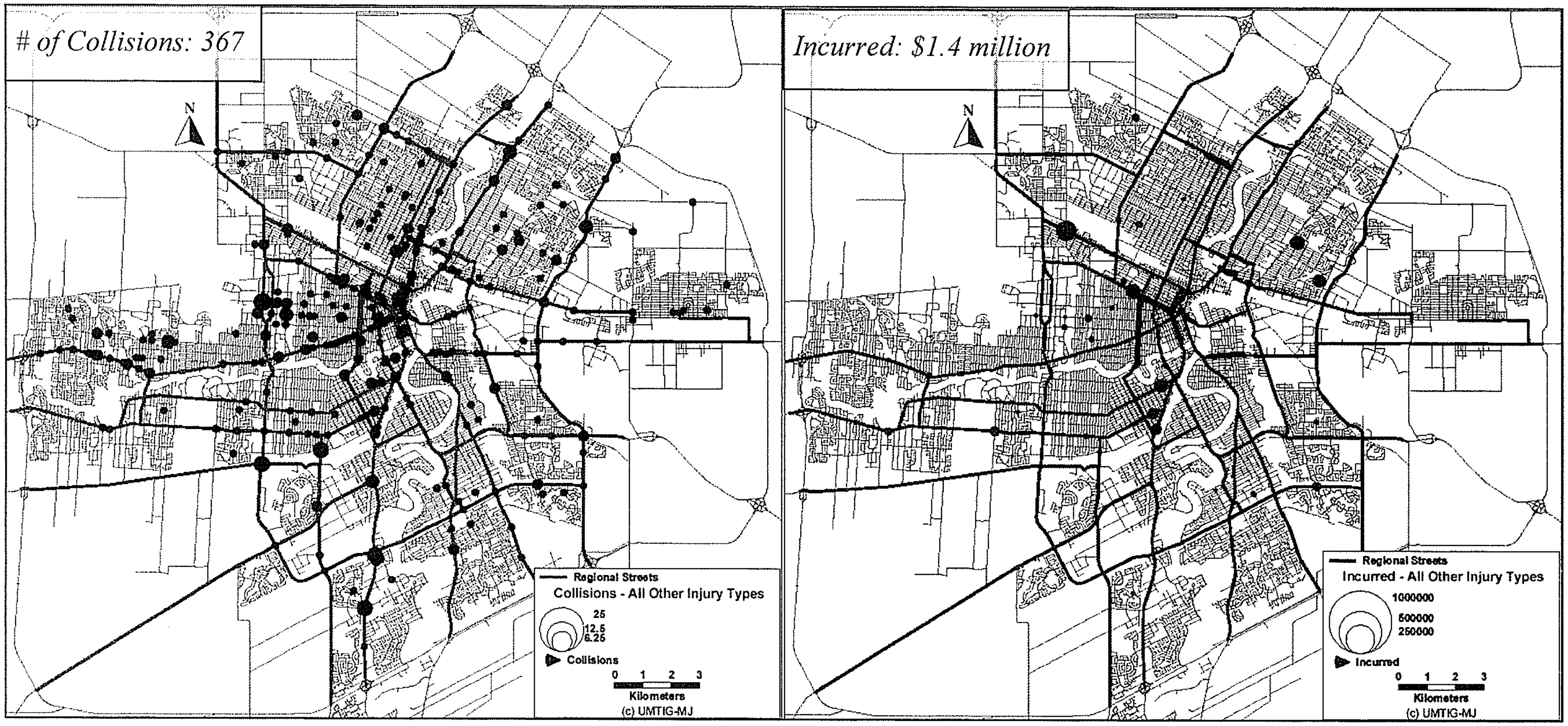

Figure 5.12: Number of Collisions (Left) and Incurred Injury Cost (Right) by Intersection, All Other Injury Types, 2003

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this figure

5.4.2 Injury Collisions and Intersection Traffic Control

Collisions by injury type were investigated based on intersection traffic control. Table 5.3 shows the number of injury collisions and incurred claims cost of those injury claims for signalized and unsignalized intersections in 2003.

Table 5.3: Collisions and Incurred Cost by Injury Type, by Intersection Traffic Control, 2003

	Whiplash Collisions	Whiplash Incurred	Broken Bone Collisions	Broken Bone Incurred	Brain / Fatal Collisions	Brain / Fatal Incurred	All Other Collisions	All Other Incurred
Signalized	1876	$4,847,000	79	$3,431,000	6	$419,000	231	$816,000
Unsignalized	947	$2,432,000	33	$349,000	8	$1,351,000	136	$604,000
Total	2823	$7,279,000	112	$3,780,000	14	$1,770,000	367	$1,420,000

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this table

There were nearly twice as many whiplash collisions with nearly double the incurred whiplash injury cost at signalized intersections as at unsignalized intersections. As there are only 605 signalized intersections compared to over 8,000 unsignalized intersections, the average number of whiplash collisions and average incurred whiplash injury cost per intersection by traffic control is greater for signalized intersections. There were more than twice as many broken bone collisions at signalized intersections as at unsignalized intersections, with more than 10 times the incurred broken bone cost ($3.4 million vs. $0.35 million). Brain and fatal injury collisions occurred with almost equal frequency at signalized and unsignalized intersections in 2003. The incurred cost of brain and fatal injuries was greater at unsignalized intersections. It should be noted, however, that the incurred cost of broken bone, brain, and fatal injuries varies greatly (as shown in Figures 5.10 and 5.11), and therefore inferences about the average and total incurred costs by intersection traffic control should be interpreted with caution for these injury types. Considering that whiplash and broken bone injury collisions occurred most frequently with the majority of their incurred injury cost at signalized intersections and that less than 10 percent of intersections in Winnipeg are signalized, signalized intersections are of greater concern in addressing the occurrence of these injury types than unsignalized intersections.

CHAPTER 6

IDENTIFICATION AND CHARACTERISATION OF INTERSECTIONS FOR ANALYSIS

This chapter identifies intersections used for the development of relationships between injury type and incurred collision cost as a function of roadway engineering characteristics of intersections. Geometric and operational roadway engineering features of the intersections are considered for suitability for further investigations, and specific features for further investigation in this thesis are identified.

6.1 IDENTIFICATION OF INTERSECTIONS FOR ANALYSIS

It was identified in Chapter 5 that collision frequencies, collision rates, and incurred costs were highest at signalized intersections on regional routes and at intersections between arterial roadways. Whiplash and broken bone injury collisions were also found to be more common at signalized intersections than at unsignalized intersections. As such signalized intersections between arterial roadways are of particular interest in the potential development of collision relationships, as they represent intersections with greater overall safety concerns. An intersection set comprised of signalized intersections between arterial roadways which have a base of common geometric and operational characteristics was therefore considered, so that relevant comparative analysis between different roadway engineering features could be conducted. The intersection selection criteria used is outlined as follows:

- The intersection must be signalized. This is because the majority of collisions, incurred collision costs, and whiplash and broken bone injury collisions are associated with the relatively small number of intersections which are signalized.

- The approach roadways must exhibit arterial roadway characteristics. Intersections on regional routes and intersections between arterial roadways were identified as having large collision frequencies, rates, and incurred costs. By examining only the intersection of arterial roadways, intersections with similar operational characteristics in terms of approach roadway functionality are compared, which reduces the potential for comparison of intersections having differing safety performance due to inherent operational differences.

- The approach roadways must have bi-directional traffic. This is to ensure vehicle entry and exit opportunities at the intersection for all approach legs.

- The intersection must have four approach legs. This is to ensure the intersections have equivalent through movements.

The identification of intersections using the preceding criteria does not strictly identify all worst case intersections in terms of collision frequency, rate, and incurred cost. Nonetheless, intersections identified from this criteria provide a sample of intersections with a base of similar geometric and operational characteristics which have been highlighted as intersections of overall greater safety concern.

According to the Transportation Association of Canada (TAC) Geometric Design Guide, arterial roadways exhibit the following key characteristics: (1) traffic movement is the major consideration; (2) access to the road is limited to some degree; (3) typical traffic volumes between 5,000 and 30,000 vehicles per day; (4) vehicle running speeds between 40 km/h and 90 km/hr; and (5) accommodates all vehicle types (TAC, 1999). Local streets are typically not given access to arterials; in Winnipeg, however, there are frequent instances of local streets intersecting arterial routes. There are also many intersections where three of four approach legs are designated as truck routes, but the fourth approach leg still exhibits all other arterial traffic characteristics. Therefore, for this thesis, roads which meet the following definition are considered as arterials:

- primarily serves non-local traffic, while additionally serving local traffic
- posted speed limit from 50 to 80 km/h
- traffic volume is estimated on at least 3 of 4 approach legs
- truck route designation of at least 3 of 4 approach legs
- non-truck-route and/or non-traffic-volume estimated leg must otherwise exhibit arterial characteristics (lane balance with oncoming roadway, does not act as a local/collector street)

The City of Winnipeg Department of Public Works Transportation Division does not have an official designation of arterial roads. However, many roads are classified internally, as part of the streets network, based on their functionality as arterial, minor arterial, collector, or local. These classifications were used to identify the majority of intersections between arterial roads. There are other routes which are not internally classified as arterials which nonetheless exhibit arterial characteristics, as well as routes which are classified as arterials which operate in a manner more accurately described by a collector description. Based on the consultation of Winnipeg road maps, the 2001 Truck Route Map of the City of Winnipeg, and local knowledge of the characteristics of Winnipeg streets potential arterial – arterial intersections, which were not initially listed as arterial-arterial intersections, were identified. Further, intersections initially identified as arterial – arterial which in fact are not accurately described by this definition were removed from the arterial – arterial dataset.

There were 64 intersections which met the selection criteria and where all approach roadways met the arterial definition used for this research. These intersections accounted for 2,707 collisions and $12.4 million in incurred cost in 2003, or 17 percent of all intersection collisions and 15 percent of the total incurred cost at less than 1 percent of the total number of intersections in the City of Winnipeg. Figure 6.1 shows the location of the 64 identified intersections; a complete list of the intersections can be found in the Appendix A.

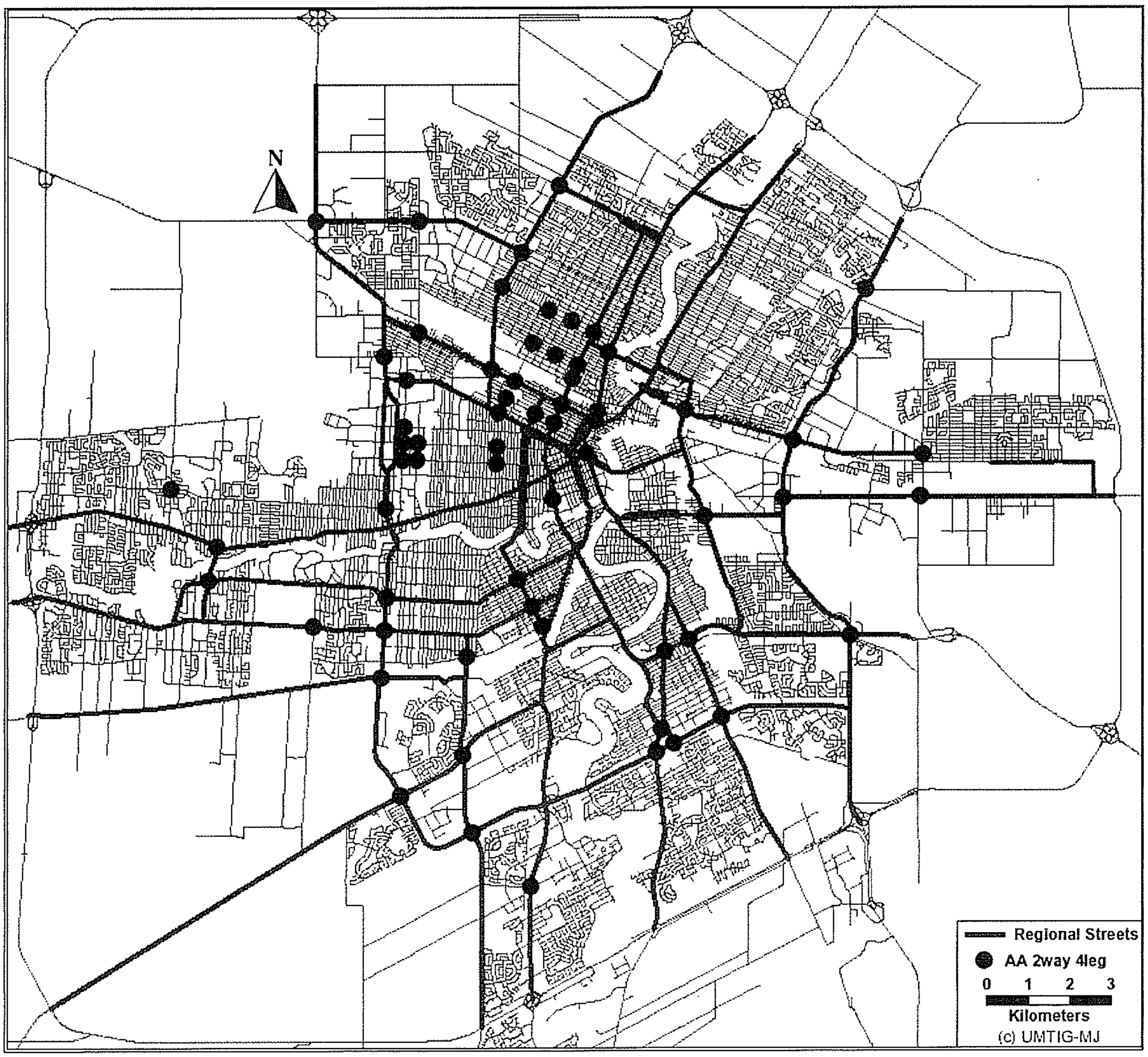

Figure 6.1: The 64 Intersections Identified as Four-Leg Two-Way Arterial-Arterial

6.2 CHARACTERIZATION OF IDENTIFIED INTERSECTIONS

Geometric and operational characteristics of the identified intersections were summarized for subsequent investigations between these characteristics and injuries by type and incurred collision cost. The intersection characteristics were identified through site visits and consultation of orthophotos of Winnipeg.

6.2.1 Geometric Characteristics of Identified Intersections

Major geometric characteristics of the 64 intersections were identified, and were assessed for suitability in the subsequent development of relationships. The following geometric characteristics were identified for the intersections:

- approach roadway median presence
- number of through lanes by approach
- number of left turn lanes by approach
- presence of right turn treatment by approach (cutoff and/or right turn lane)
- intersection skew

6.2.1.1 Approach Roadway Median Presence

Physical medians serve to separate opposing traffic streams, and by doing so can affect the safety of an intersection. The presence or absence of roadway medians on the approach roadways at the identified intersections was recorded, from which the intersections were assigned one of the following three designations:

- divided versus divided roads (DD)
- divided versus undivided roads (DU)
- undivided versus undivided roads (UU)

The DD intersections have divided roadways for all four approach legs at the intersection, DU intersections have at least one undivided approach leg at the intersection, and UU intersections have no divided approaches at the intersection. For an approach leg to be considered as divided for this research, the roadway may be divided through the entire length or a raised median separation may be introduced in advance of an intersection on an otherwise undivided roadway. Examples of DD, DU, and UU intersections are shown in Figures 6.2, 6.3, and 6.4 respectively. Orthophotos were combined with the City of Winnipeg Streets footprint for the example intersections shown. The DD intersection shown is from Leila Avenue and McPhillips Street, the DU intersection shown is from Logan Avenue (undivided from left to right in Figure 6.3) and McPhillips Street (divided from top to bottom in Figure 6.3), and the UU intersection shown is from Archibald Street and Marion Street. Table 6.1 summarizes collision frequency, incurred cost, and the number of intersections by approach roadway median presence for the identified intersections.

Table 6.1: Collision Frequency, Total Incurred Cost, and Average Collision Rate of Four-Leg Two-Way Arterial Intersections in Winnipeg by Median Type, 2003

Median Type	Number of Intersections	Number of Collisions	Total Incurred Cost (millions)
Divided - Divided	32	1,614	7.35
Divided - Undivided	13	523	2.45
Undivided - Undivided	19	570	2.85
Total	64	2,707	12.64

Note: Collisions with an incurred cost in excess of $1,000,000 (three collisions with an incurred cost of $7,400,000) and with uncertain intersection locations (846 collisions with an incurred cost of $4,400,000) were excluded from this table

Figure 6.2: DD Intersection Between Leila Ave and McPhillips St
Source: UMTIG

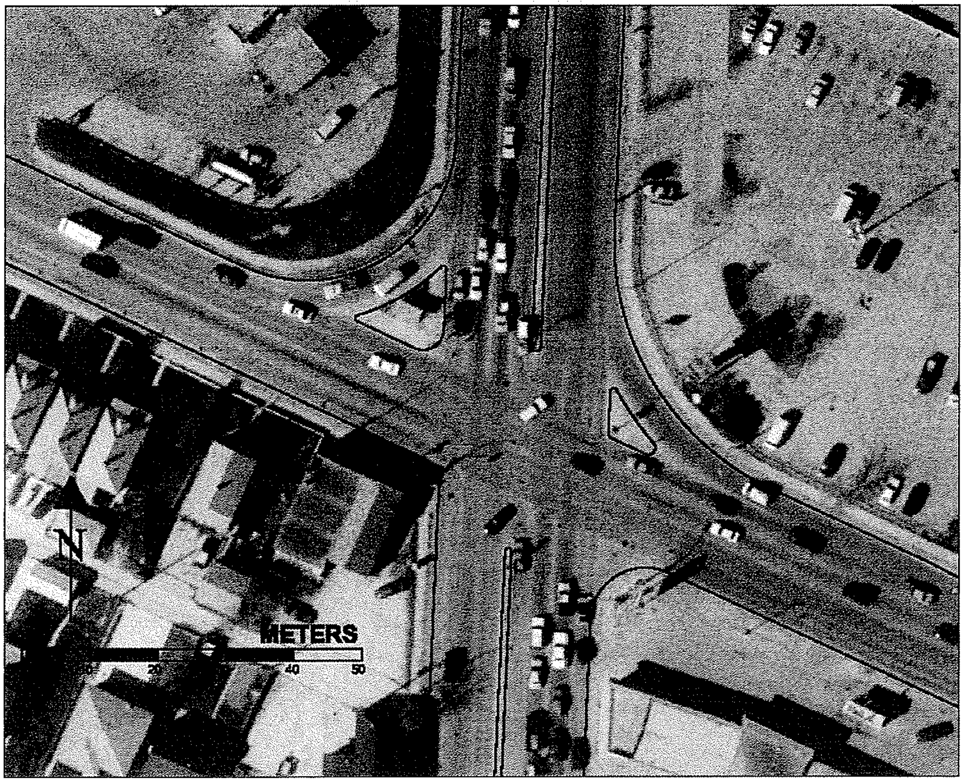

Figure 6.3: DU Intersection Between Logan Ave & McPhillips St
Source: UMTIG

Figure 6.4: UU Intersection Between Archibald Rd and Marion St
Source: UMTIG

Half of the identified intersections are divided for all approach roadways at the intersection; these DD intersections accounted for over half of all collisions and incurred collision cost (60 and 58 percent respectively) from all identified intersections. Twenty percent of the identified intersections were designated DU, which accounted for 19 percent of both the total number of collisions and the total incurred cost. Thirty percent of the intersections were designated as UU, but accounted for a smaller percentage of the total number of collisions (21 percent) and incurred cost (23 percent).

Figure 6.5 shows the intersections by approach median presence type. From this figure it can be seen that intersections with the same median presence type are generally located in similar areas of the city. UU intersections are generally found in the central part of the city where streets follow a grid pattern, and are often not located on regional routes. DU intersections are generally located in the central sections of the city on regional routes, while DD intersections are generally found in suburban areas.

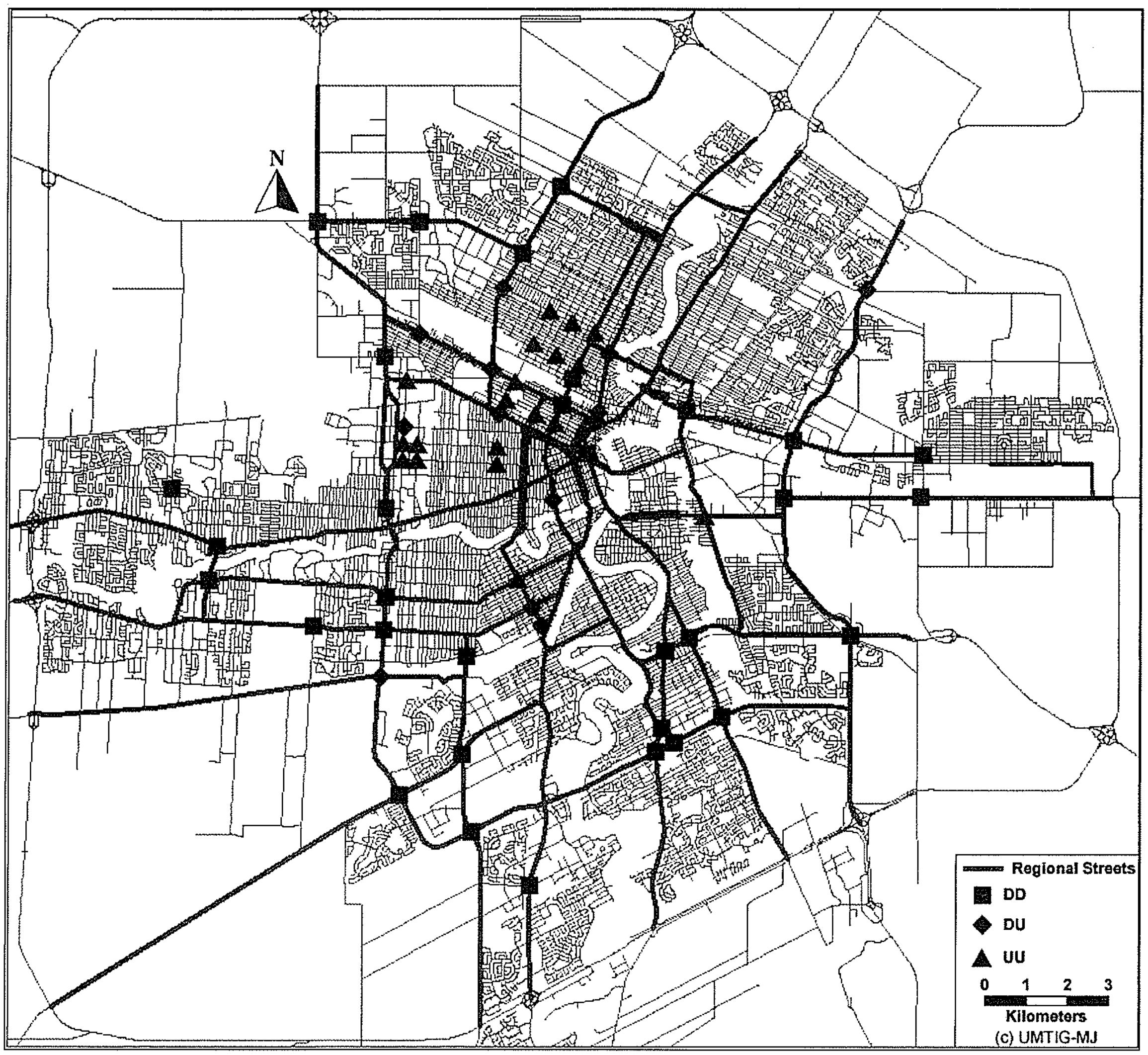

Figure 6.5: The Identified Intersections by Median Presence (DD, DU, or UU)

6.2.1.2 Number of Through Lanes

The number of through lanes by approach roadway was recorded for the identified intersections. The number of lanes affects the capacity of a given roadway, and therefore roadways with different lane totals may affect the safety of an intersection due to different operating characteristics. Table 6.2 summarizes approaches by number of through lanes for intersections by median presence.

Table 6.2: Number of Intersections by Number of Through Lanes of Intersecting Roadways, by Median Presence

	Through Lanes by Intersecting Roadways		
	4 vs 2, or 3 vs 2	***2 vs 2***	***2 vs 1***
DD	7	23	2
DU	5	6	2
UU	0	16	3

All of the identified intersections had at least one four-lane through roadway, two lanes in each direction, and most had two lanes in each direction for all four approaches. There were seven DD intersections which had one or two approaches with three or four through lanes in each direction and two DD intersections with one or two approaches with one through lane. There were five DU intersections which had one or two approaches with three or four through lanes in each direction and two DU intersections which had one or two approaches with one through lane. There were no UU intersection approaches with more than two through lanes, and there were three UU intersections with one or two approaches with one through lane in each direction. As the majority of intersections had two through lanes per approach in each direction, the number of through lanes was not investigated as a variable in relationship development.

6.2.1.3 Left Turn Lanes

Left turn lanes provide channelization, removing left-turning traffic from the leftmost through lane of a roadway at an intersection, enhancing safety and traffic mobility. The presence of exclusive left turn lanes at the identified intersections was recorded for each approach, and is summarized in Table 6.3 by intersection median presence. It should be noted that some intersections have unique left turn lane attributes (such as an approach with an exclusive left turn lane plus a combined left turn / through lane); these attributes are not differentiated in the table below.

Table 6.3: Left Turn Lane Presence by Intersection Type for the Identified Intersections

	Left Turn Lane Presence		***No left turn lane***
	All approaches	*3, 2, or 1 approaches*	
DD	28	4	0
DU	0	11	2
UU	0	0	19

DD intersections generally have at least one left turn lane per approach, DU intersections generally have at least one left turn lane per divided roadway approach (i.e. left turn lane on two approaches), and UU intersections do not in any case have exclusive left turn lanes. As left turn lane presence is generally associated with median presence for the identified intersections, it would be difficult to discern the difference in effect from left turn lanes and median presence in investigations of possible relationships with injury type/incurred collision cost. Therefore further investigations will focus on median presence at intersections, but left-turn lanes may accentuate the safety effect of medians at intersections. Left turn lanes will not be explicitly considered in relationship analysis.

6.2.1.4 Right Turn Treatment

Right turn treatments can impact the safety of an intersection. Right turn cutoffs improve the mobility of turning and through traffic by lowering the turning impedance. Through traffic mobility may be further improved if there is a right turn lane associated with the cutoff. Right turn lanes can eliminate potential vehicular conflict by removing right-turning vehicles from the rightmost through lane at an intersection. For this research, the presence of right turn cutoffs and right turn lanes was noted for each approach leg of the identified intersections. Table 6.4 summarizes the number of intersections by approaches with right turn cutoffs or lanes by median presence.

Table 6.4: Number of Intersections by Approaches with Right Turn Treatment by Median Presence

	Right Turn Lane or Cutoff		
	All approaches	*3, 2, or 1 approaches*	*No approaches*
DD	19	11	2
DU	0	11	2
UU	1	1	17

There were 19 DD intersections with cutoffs on all four approaches, 11 intersections with one to three approaches with cutoffs, and two intersections with no cutoffs (only one of which had no right turn lanes). There were six DU intersections with one or two approaches with right turn cutoffs and two intersections with one or two right turn lanes but no cutoffs. There were always, however, at least two approaches at every DU intersection with no right turn cutoffs or lanes. The other six DU intersections had no right turn treatments. There were only two UU intersections with any right turn cutoffs, and no other intersections with right turn lanes.

For the eleven DD and six DU intersections with one to three right-turn cutoffs, the placement of the cutoffs was varied. In some cases a cutoff would be found for each approach of one road only, and in other cases two cutoffs were found on the same side of the intersection (for example, two cutoffs were on the south side of the intersection and hence served eastbound and northbound approaches). The result is that there are not many of the intersections with similar combinations of right turn cutoff locations, and thus the consideration of these intersections based on cutoff location would be difficult. As nearly all DD intersections have some right turn treatment, nearly all UU intersections have no right turn treatment, and DU intersections have a range of right turn treatment scenarios, the presence of right turn treatment is varied between intersections by approach roadway median presence but is not as varied within each median presence category. Therefore right turn treatments are not investigated as a variable in relationship development.

6.2.1.5 Intersection Skew

Intersection skew angle can impact the safety of an intersection by impairing sight distances for certain intersection approaches and movements. The TAC Geometric Design Guide for Canadian Roads indicates that intersections where the angles between approach roadways are less than 70° or greater than 110° are not desirable and may pose safety concerns (TAC, 1999). Investigation of the identified intersections revealed that there were 5 skewed and 2 partially skewed intersections at more than 20° degrees from perpendicular. However, as only 7 of the 64 intersections are skewed, this geometric roadway feature is not pursued in relationship investigations.

6.2.2 Operational Characteristics of Identified Intersections

Just as geometric characteristics of an intersection impact the safety performance of that intersection, the operational features (from a civil engineering perspective) of an intersection affect traffic operations and possibly safety. Strategies to improve intersection signalization operations have been identified as a means of reducing frequency and severity of intersection conflicts by the National Cooperative Highway Research Program, and operating speeds were identified as impacting signalization timing which in turn can impact intersection safety (NCHRP, 2004). Therefore the following two operational characteristics of intersections were considered for this research:

- speed limits of the approach roadways
- signalization schemes

6.2.2.1 Approach Roadway Posted Speed Limits

Vehicle speeds may affect the nature of collisions, particularly the severity. The posted speed limit for each approach leg at the intersection was recorded for the identified intersections. Table 6.3 shows the number of approaches for each possible posted speed limit (50 km/hr, 60 km/hr, 70 km/hr, or 80 km/hr) for the identified intersections by roadway median presence.

Table 6.3: Number of Approaches for Posted Speed Limit Values at the Identified Intersections

	Number of Approaches Per Roadway Speed Limit				
	50 km/hr	*60 km/hr*	*70 km/hr*	*80 km/hr*	*Total*
DD	29 (23%)	53 (41%)	19 (15%)	27 (21%)	118
DU	31 (59%)	15 (29%)	3 (6%)	3 (6%)	52
UU	60 (79%)	16 (21%)	0	0	76
Total	120 (47%)	84 (33%)	22 (9%)	30 (12%)	256

UU intersections had a posted speed limit of 50 km/hr for the majority of approaches (79 percent of the 76 approaches), and some at 60 km/hr (21 percent) but none at higher speeds. DU intersections also had a majority of approaches with a posted speed limit of 50 km/hr (59 percent of 52 approaches), with some at 60 km/hr (29 percent) and a few with 70 km/hr or 80 km/hr (6 percent each). DD intersections had more approaches at 60 km/hr than at other speeds (41 percent of the 128 approaches), with a similar number of approaches having posted speed limits of 50 km/hr, 70 km/hr, and 80 km/hr (23 percent, 15 percent, and 21 percent respectively). As DD intersections are the only median presence configuration with a number of approaches at different speed limits, DD intersections are of greatest interest in the consideration of posted speed limits in relationship investigation.

6.2.2.2 Intersection Signalization

Signalization schemes affect the operation and coordination of vehicle movements through intersections, which may potentially affect safety. For a given intersection, each approach leg often has unique signalization schemes, setups, and signal timing patterns; further, signal timing patterns often vary throughout the day. The signalization characteristics between intersections are therefore often different, where differences are further compounded by the fact that many intersections have unique signalization setups to accommodate site-specific needs (such as signalization to accommodate lanes which double to serve both through and left-turning traffic). The cataloguing and summarization of signalization attributes for all of the identified intersections would therefore be very difficult, and therefore signalization characteristics are not considered in the development of intersection relationships.

CHAPTER 7

INJURY TYPE AND INCURRED COST AS A FUNCTION OF ROADWAY ENGINEERING CHARACTERISTICS OF INTERSECTIONS

This chapter investigates possible relationships between injury type and incurred collision cost as a function of the roadway intersection features. Whiplash and broken bone injury collisions were investigated, as they were the injury types identified in Chapter 5 as candidates for further investigation. The roadway characteristics identified for investigation in Chapter 6 were approach roadway median presence and approach roadway posted speed limits. Investigations looked at relationships where injury collisions and incurred cost were dependent upon the total number of collisions, the daily traffic exposure, and the approach roadway speed limit.

7.1 WHIPLASH INJURY RELATIONSHIPS

Whiplash injury collisions were investigated as they may relate to selected roadway engineering characteristics of the identified intersections. The total number of whiplash injury collisions versus the total number of collisions by roadway median type, versus the entering vehicle traffic by median type, and versus the average approach roadway posted speed limit for four lane DD intersections was explored.

7.1.1 Whiplash Injury Collisions and Total Collision Frequency

The number of whiplash injury collisions occurring for a given total number of collisions at the identified intersections was investigated by approach roadway median presence. This investigation was performed to see how median presence might affect the number of whiplash injury collisions as a function of the total number of collisions. The analysis examined several model forms; linear, logarithmic, exponential, and power. The power equation gave the highest R^2 value, and was therefore considered to be the best representative form. Figure 7.1 shows the relationship between the number of whiplash injury collisions and the total number of collisions at all of the identified intersections by approach roadway median presence.

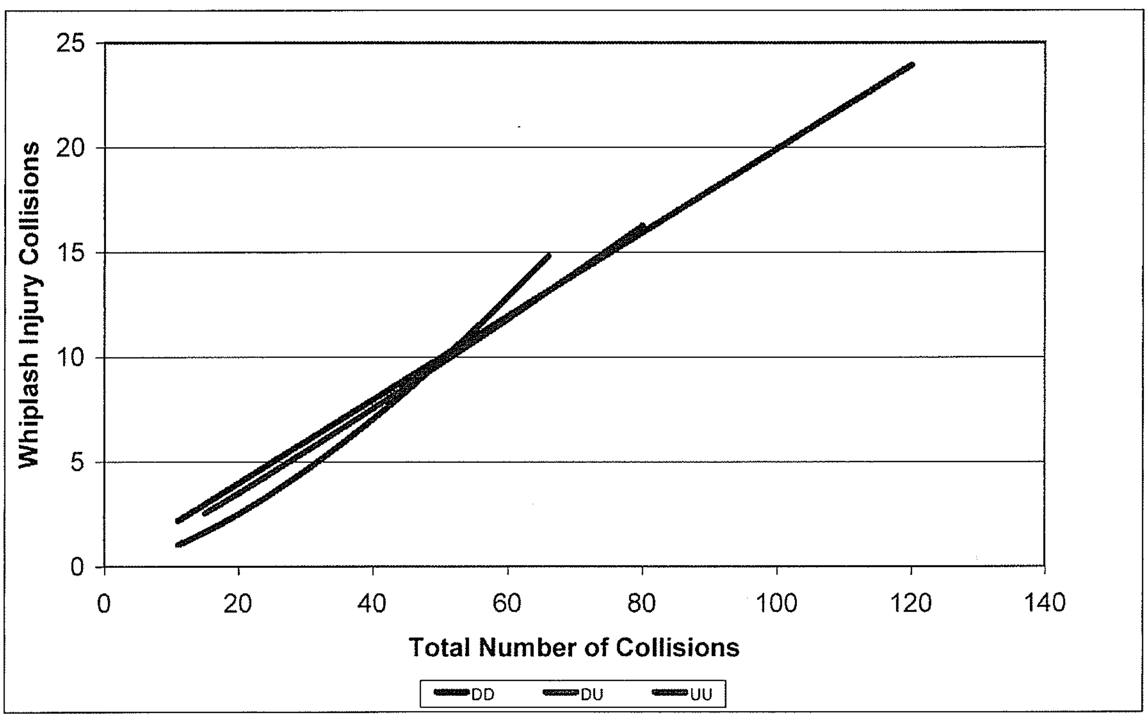

Figure 7.1: Whiplash Injury Collisions vs. All Collisions for DD, DU, and UU Intersections, 2003

The equations of these relationships by intersection median presence are:

DD:	$I_w = 0.20 * C^{1.00}$	$R^2 = 0.81$	(eq. 7.1)
DU:	$I_w = 0.13 * C^{1.11}$	$R^2 = 0.77$	(eq. 7.2)
UU:	$I_w = 0.03 * C^{1.49}$	$R^2 = 0.68$	(eq. 7.3)

Where: I_w = number of whiplash injury collisions
C = number of total collisions

The R^2 values for the DD, DU, and UU equations respectively are 0.81, 0.77, and 0.68. The DD equation is in fact a linear relation, and is closely matched in form by the DU equation; the UU equation has a higher power of 1.49. Despite different coefficients, from Figure 7.1, it can be seen that all three equations predict a similar number of whiplash collisions from a given total number of collisions (with about one whiplash injury collision in every five total collisions).

These equations were tested against collision claims data from July 2002 to December 2002 using collisions at the identified intersections. The collection of location information by MPI began in July 2002, and therefore only six months of data not used in the creation of the equations was available for comparison. The equations were tested by comparing the difference between the predicted number of whiplash collisions and the actual number experienced for a given intersection. Table 7.1 summarizes the number of intersections where the difference between predicted and actual whiplash collisions was one or zero, was two or three, or was greater than three.

Table 7.1: Difference in Predicted Vs. Actual Whiplash Collisions at the Identified Intersections from Equations 7.1, 7.2, and 7.3, Jul 2002 – Dec 2002

	Difference in Predicted from Actual		
	0 or |1|	|2| or |3|	>= |4|
DD (eqn 7.1)	20	9	3
DU (eqn 7.2)	9	2	2
UU (eqn 7.3)	11	8	0

All three equations predict within one the number of whiplash collisions for more than half of the intersections. Equations 7.1 and 7.2 have several predicted whiplash collision totals which varied by four or more, however. Nonetheless, the equations closely predict the actual number of whiplash collisions for many intersections.

7.1.2 Whiplash Injury Collisions and Traffic Exposure

The relationship between the number of whiplash injury collisions and the daily traffic exposure of an intersection was investigated by approach roadway median presence. This investigation was performed to see how presence or absence of roadway medians might affect the number of whiplash collisions for a given total daily traffic volume of an intersection. Hauer, Ng, and Lovell (1988) note that some have suggested that the number of collisions at intersections may be related to the sum of roadway traffic flows, while others have suggested that relating collisions to the product of traffic flows is more appropriate. For this investigation the sum of daily traffic volumes was used because information about which traffic flow stream a collision belongs to is not available, the investigation is simplified over the investigation of traffic flows by product, and the investigation of collision rate in previous sections of this thesis employed the sum of traffic volumes. Furthermore, this investigation is exploratory in purpose, and does not purport to identify the definitive relation or relational form. Figure 7.2 shows a relationship between the number of whiplash injury collisions and the average daily traffic exposure (defined in terms of entering average weekday daily traffic (AWDT)) at the identified intersections based on approach roadway median presence.

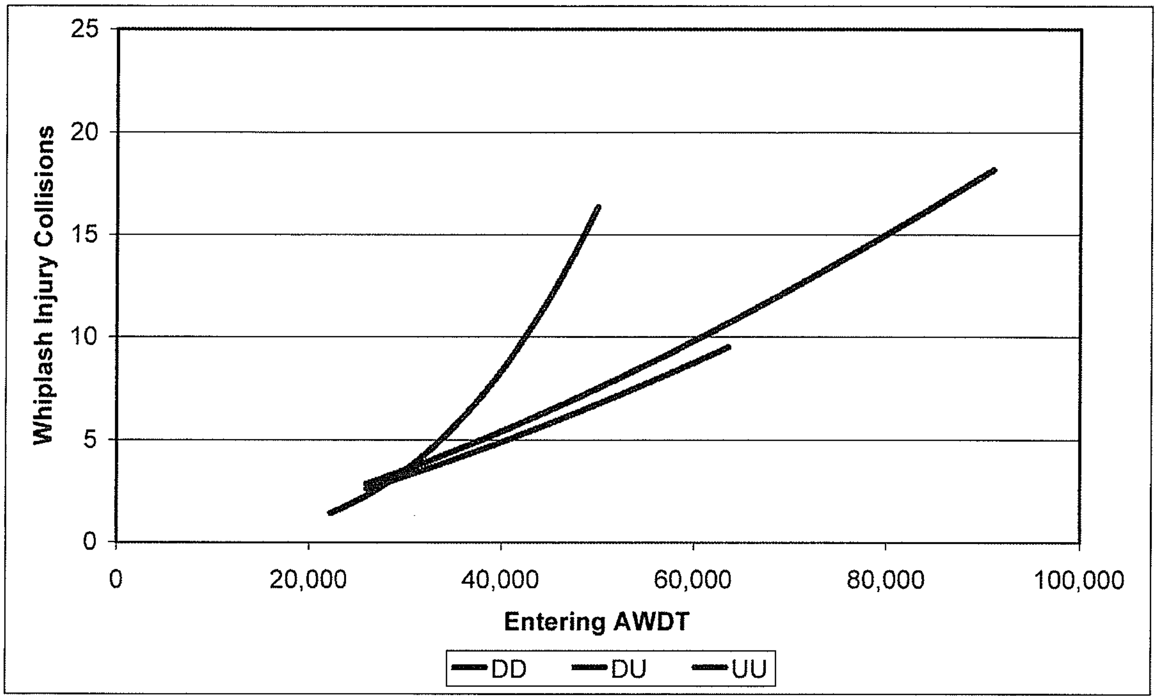

Figure 7.2: Whiplash Injury Collisions vs. Entering AWDT for DD, DU, and UU Intersections, 2003

The equations of these relationships are:

DD: $I_w = 8.9*10^{-7} * \text{enteringAWDT}^{1.47}$ $R^2 = 0.35$ (eq. 7.4)
DU: $I_w = 1.1*10^{-6} * \text{enteringAWDT}^{1.44}$ $R^2 = 0.32$ (eq. 7.5)
UU: $I_w = 1.3*10^{-13} * \text{enteringAWDT}^{3.00}$ $R^2 = 0.53$ (eq. 7.6)

Where: I_w = number of whiplash injury collisions / year
AWDT = Average Weekday Daily Traffic

The DD and DU equation trend lines are similar in shape, with an increase in the number of whiplash injury collisions with an increase in the entering AWDT. The UU equation trend line increases at a greater rate than do the DD and DU equations, and predicts a greater number of whiplash collisions for entering AWDT values greater than about 30,000 vpd than do the other equations. None of these equations are as strong in R^2 value as equations 7.1, 7.2, and 7.3.

As with equations 7.1, 7.2, and 7.3 these equations were tested against collision claims data from July 2002 to December 2002 using collisions at the identified intersections. Equations 7.4, 7.5, and 7.6 predict the number of whiplash collisions in a year, and therefore the predicted values were divided by half the year in order to compare the predicted to the actual values. There may therefore be temporal and random effects which may impact the difference between the predicted and actual values. Table 7.2 summarizes the number of intersections where the difference between predicted and actual whiplash collisions was one or zero, was two or three, or was greater than three.

Table 7.2: Difference in Predicted Vs. Actual Whiplash Collisions at the Identified Intersections from Equations 7.4, 7.5, and 7.6, Jul 2002 – Dec 2002

	Difference in Predicted from Actual		
	0 or |1|	**|2| or |3|**	**>= |4|**
DD (eqn 7.4)	11	13	8
DU (eqn 7.5)	4	8	1
UU (eqn 7.6)	10	8	1

The DD equation predicts a similar number of intersections with a difference of one or less, two or three, or greater than three whiplash collisions. The DU equation predicts a difference of two or three whiplash collisions for about two-thirds of the intersections, but only one intersection with a larger difference. The UU equation predicts within one whiplash collision for about half of the intersections and a difference of greater than three for one intersection. As with the equations based on the total number of collisions, equations 7.4, 7.5, and 7.6 predict within one the number of whiplash collisions for certain intersections. The DD and DU equations based on entering AWDT, however, do not predict as many intersections within one whiplash collision as the equations based on the total number of collisions.

7.1.3 Whiplash Injury Collisions and Approach Roadway Speed Limit

Relationships between whiplash injury collisions and approach roadway posted speed limit were investigated. For the identified intersections, 4 X 4 DD intersections (where 4 X 4 stands for the intersection of two four-lane roads) were considered. This is because DD intersections have similar median presence for all approaches (as do UU intersections), but unlike UU intersections many DD intersections have different approach roadway posted speed limits as shown in Table 6.4 (most UU approach roadways have posted speed limits of 50 km/hr and a few at 60 km/hr, while DD approach roadways have posted speed limits from 50 to 80 km/hr). The average of the approach roadway speeds was used in the analysis. Figure 7.3 shows the relationship between the number of whiplash injury collisions and the average posted speed limit of an intersection in 2003. The equation of this relationship is:

$$I_w = 0.0011*(\text{AvgPostedSpeedLimit})^{2.18} \qquad R^2 = 0.30 \qquad \text{(eq. 7.7)}$$

Where: I_w = number of whiplash injury collisions / year

The equation predicts an increase in the number of whiplash injury collisions as the average approach roadway posted speed limit increases, with five whiplash collisions at 50 km/hr and fifteen whiplash collisions at 80 km/hr.

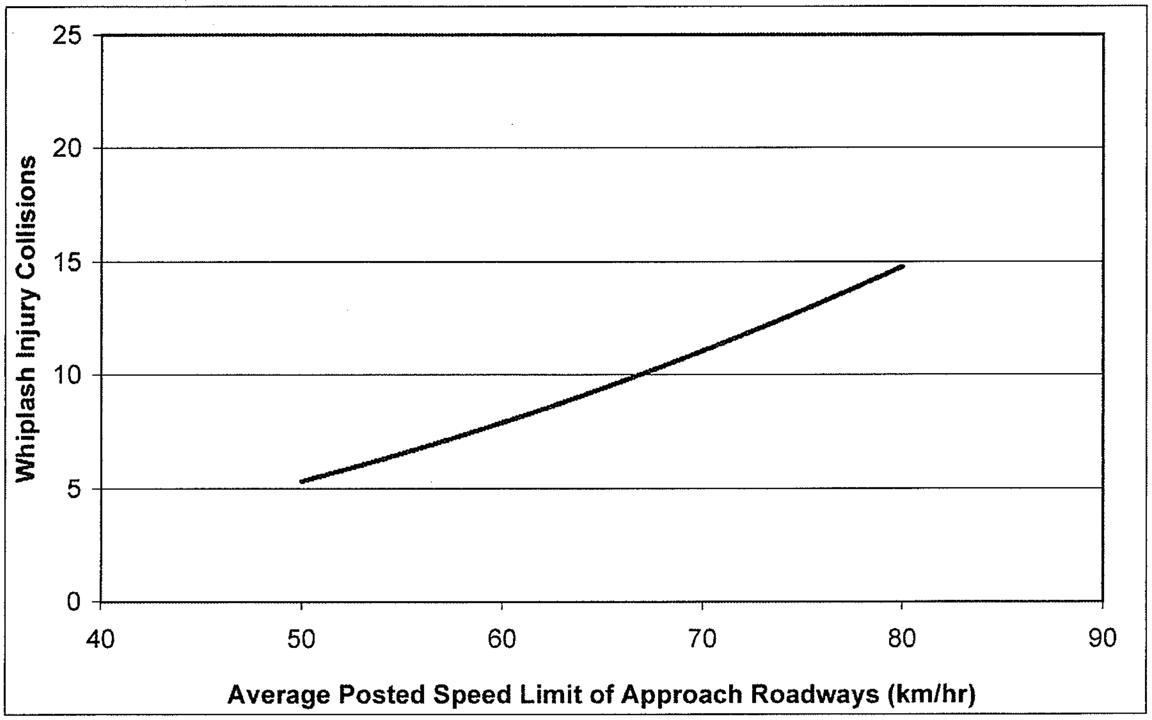

Figure 7.3: Whiplash Injury Collisions at DD Intersections of Four Lane Roadways, 2003

This equation was tested against collision claims data from July 2002 to December 2002 using collisions at the identified DD intersections between four-lane roads. This equation predicts the number of whiplash collisions in a year, and therefore the predicted values were divided by half the year in order to compare the predicted to the actual values. There may therefore be temporal and random effects which may impact the difference between the predicted and actual values. The number of intersections by difference in predicted and actual whiplash collisions is as follows: (1) difference of zero or one – seven intersections; (2) difference of two or three – eight intersections; and (3) difference greater than three – five intersections. There are roughly the same number of intersections in each category listed above. There are therefore a number of intersections where the predicted number of collisions matches closely, but also many intersections where the number of whiplash collisions is not well predicted.

7.2 BROKEN BONE INJURY COLLISIONS

Broken bone injury collisions were investigated as they occurred at the identified intersections. Table 7.3 shows the summary total of intersections by number of broken bone injury collisions at the identified intersections by approach roadway median presence in 2003.

Table 7.3: Number of DD, DU, and UU Intersections with 0, 1, or 2 Broken Bone Injury Collisions, 2003

	Number of Intersections with:		
	0 Broken Bone Collision	***1 Broken Bone Collision***	***2 Broken Bone Collisions***
DD	23 (72%)	9 (28%)	0
DU	9 (69%)	1 (8%)	3 (23%)
UU	16 (84%)	2 (11%)	1 (5%)
Total:	48 (75%)	12 (19%)	4 (6%)

Of the 64 intersections, 12 had one broken bone injury collision and 4 had two broken bone injury collisions. There were no more than two broken bone collisions, and no more than one broken bone injury per collision, at any of the intersections. The proportion of intersections without any broken bone collisions was similar for intersections based on approach roadway median presence, with UU intersections having more intersections (84 percent) without a broken bone collision than DD (72 percent) and DU (69 percent). DU intersections also had three of the four intersections with two broken bone collisions in one year.

As broken bone collisions occurred at less than half of the intersections, and where they did occur there were only one or two incidents, broken bone injuries would be described as being isolated incidents, which would require a more comprehensive dataset to attempt to establish any trends with the roadway engineering characteristics of intersections. As there are few broken bone collisions available for comparison, and the majority of intersections experienced no broken bone injuries at all in 2003, relationships relating broken bone injury collisions and the roadway engineering characteristics of intersections are not investigated further.

7.3 INCURRED COST RELATIONSHIPS

Incurred cost from collisions at the identified intersections was investigated as it may relate to selected roadway intersection engineering characteristics. As with whiplash injury collision investigation, the total incurred cost versus the total number of collisions by roadway median type, versus the entering vehicle traffic by median type, and versus the average approach roadway posted speed limit for four-lane DD intersections was explored.

7.3.1 Incurred Cost and Collision Frequency

The incurred collision cost resulting from a given total number of collisions at the identified intersections was investigated by approach roadway median presence. This investigation was performed to see how median presence might affect the incurred cost as a function of the total number of collisions. The analysis examined several model forms; linear, logarithmic, exponential, and power. The power equation gave the highest R^2

value, and was therefore considered to be the best representative form. Figure 7.4 shows power relationships between the incurred collision cost and the total number of collisions at all of the identified intersections by approach roadway median presence. In the examination of the incurred cost by the total number of collisions, there was one intersection that had a total incurred cost of nearly double the next most costly intersection ($810,000 vs. $450,000), where more than half the cost of the highest-cost intersection was attributable to one collision. This resulted in a data point which noticeably deviated from all others. Therefore this intersection was omitted from the analysis. As this outlier was omitted due to a high-cost collision incident, the investigated relationships only represent lower cost collisions.

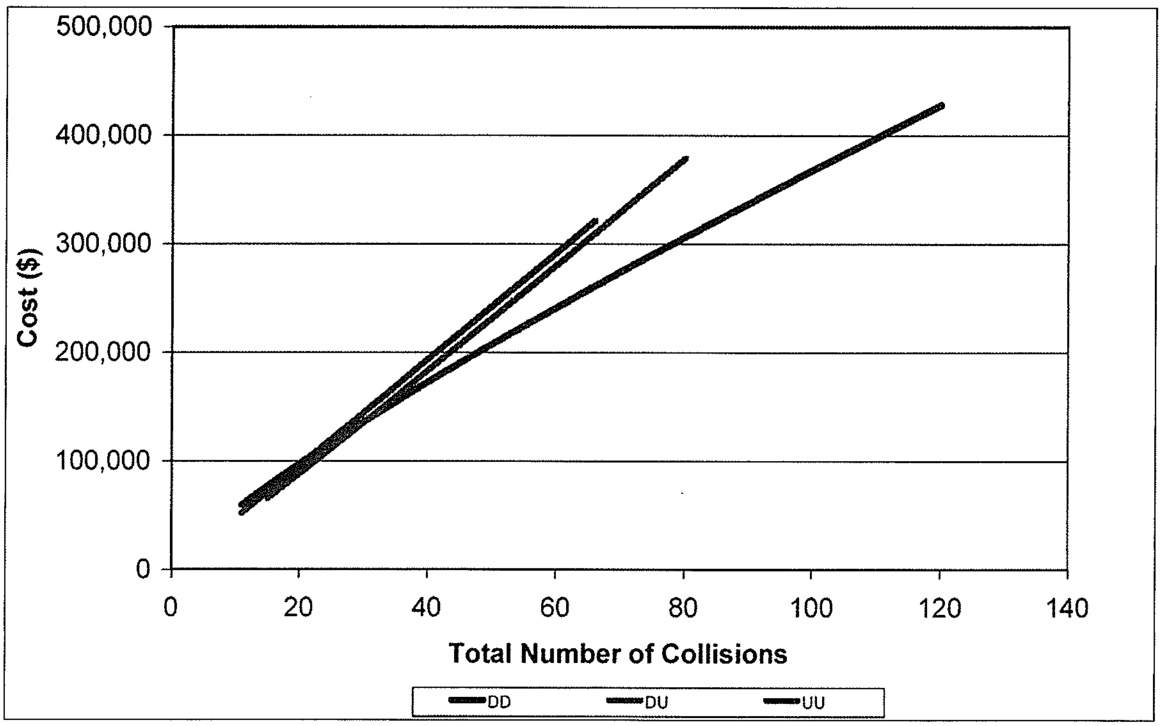

Figure 7.4: Incurred Cost vs. Collision Frequency for DD, DU, and UU Intersections, 2003

Note: One DD intersection with a total incurred cost of $810,000 was excluded from this figure

The equations of these relationships by intersection median presence are:

DD:	$I_\$ = 8{,}120 * C^{0.83}$	$R^2 = 0.73$	(eq. 7.8)
DU:	$I_\$ = 3{,}810 * C^{1.05}$	$R^2 = 0.80$	(eq. 7.9)
UU:	$I_\$ = 4{,}560 * C^{1.02}$	$R^2 = 0.76$	(eq. 7.10)

Where: $I_\$$ = total incurred collision cost
C = number of total collisions

The DU and UU equations predict similar incurred cost values. At lower collision totals (about 40 or less), the DD equation also predicts a similar incurred cost as the DU and UU equations, but for higher collision totals, the DD equation predicts a lower incurred cost than the other equations. Therefore, the intersection of arterial roads may have a lower incurred cost when all approach roadways are divided, although the reduction in cost may be in part due to features associated with medians, such as left turn lanes.

These equations were tested against collision claims data from July 2002 to December 2002 using collisions at the identified intersections. Table 7.4 summarizes the number of intersections where the difference between predicted and actual whiplash collisions was within \$20,000, was between \$20,000 and \$40,000, or was greater than \$40,000.

Table 7.4: Difference in Predicted Vs. Actual Incurred Cost at the Identified Intersections from Equations 7.8, 7.9, and 7.10, Jul 2002 – Dec 2002

	Difference in Predicted from Actual		
	± |\$20k|	>±|\$20k|, <±|\$40k|	>= ±|\$40k|
DD (eqn 7.8)	17	9	6
DU (eqn 7.9)	7	4	2
UU (eqn 7.10)	13	6	0

All three equations predict the incurred cost of collisions within \$20,000 for the majority of intersections. Equations 7.8 and 7.9 have several predicted incurred cost values which were greater than $40,000 from the actual incurred cost, however. Nonetheless, the equations predict reasonably well the incurred cost for many intersections.

7.3.2 Incurred Cost and Traffic Exposure

The incurred collision cost as a function of the daily entering traffic volume at the identified intersections was investigated by approach roadway median presence. This investigation was performed to see how presence or absence of roadway medians might affect the incurred cost for a given intersection daily traffic volume. The analysis examined several model forms; linear, logarithmic, exponential, and power. The power equation gave the highest R^2 value, and was therefore considered to be the best representative form. Figure 7.5 shows a relationship between the incurred collision cost and the average daily traffic exposure (defined in terms of average weekday daily traffic (AWDT)) at all identified intersections based on approach roadway median presence. As with the investigation of incurred cost versus collision frequency, one intersection with a high incurred cost resulting from a particularly costly collision was omitted from the analysis. As this outlier was omitted due to a high-cost collision incident, the investigated relationships only represent lower cost collisions. The equations of these relationships by intersection median presence are:

DD:	$I_\$ = 2.35 * \text{enteringAWDT}^{1.03}$	$R^2 = 0.23$	(eq. 7.11)
DU:	$I_\$ = 0.0030 * \text{enteringAWDT}^{1.65}$	$R^2 = 0.47$	(eq. 7.12)
UU:	$I_\$ = 0.0002 * \text{enteringAWDT}^{1.97}$	$R^2 = 0.55$	(eq. 7.13)

Where: $I_\$$ = total incurred collision cost
AWDT – Average Weekday Daily Traffic

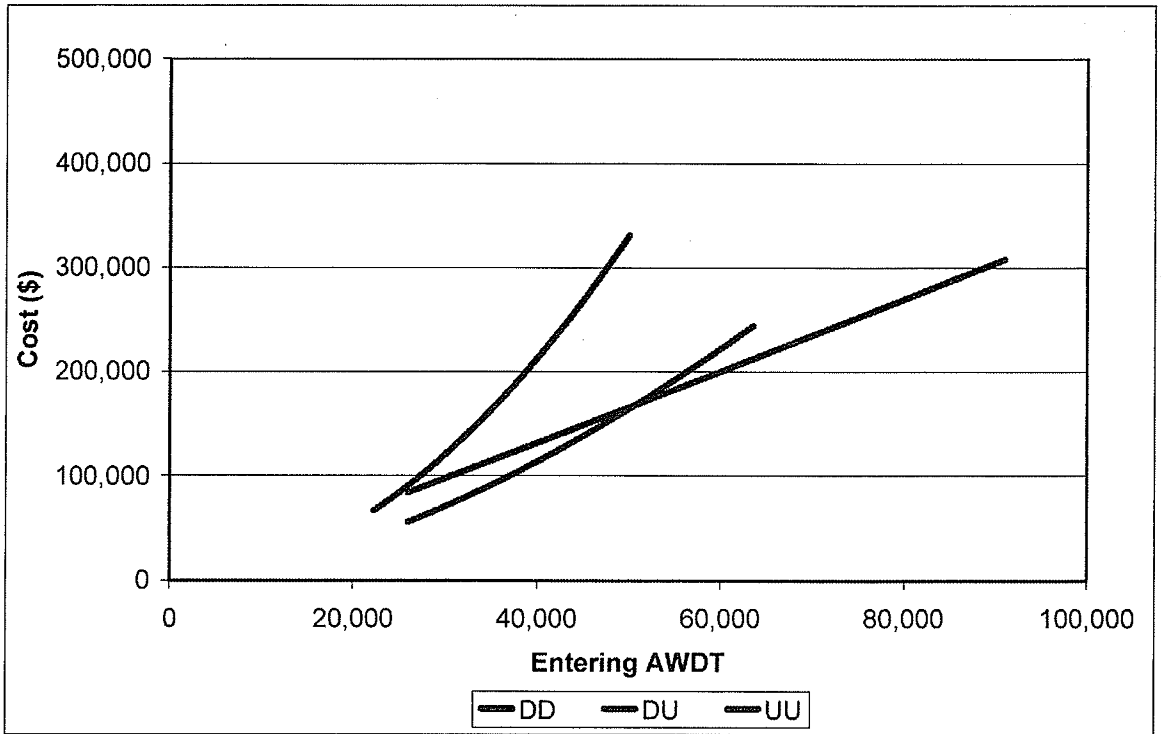

Figure 7.5: Incurred Cost vs. Intersection AWDT for DD, DU, and UU Intersections, 2003

Note: One DD intersection with a total incurred cost of $810,000 was excluded from this figure

The DD and DU equations predict similar incurred cost values, with the DU equation predicting lower incurred cost for entering AWDT's lower than about 50,000 and the DD equation predicting higher values for entering AWDT's greater than about 50,000. The UU equation trend line increases at a greater rate than do the DD and DU equations, and predicts a greater number of whiplash collisions for entering AWDT values greater than about 25,000 vpd than do the other equations. None of these equations are as strong in R^2 value as equations 7.8, 7.9, and 7.10.

These equations were tested against collision claims data from July 2002 to December 2002 using collisions at the identified intersections. These equations predict the total incurred cost in a year, and therefore the predicted values were divided by half the year in order to compare the predicted to the actual values. There may therefore be temporal and random effects which may impact the difference between the predicted and actual values. Table 7.5 summarizes the number of intersections where the difference between predicted and actual incurred cost was less than $20,000, between $20,000 and $40,0000, or was greater than $40,000.

Table 7.5: Difference in Predicted Vs. Actual Incurred Cost at the Identified Intersections from Equations 7.11, 7.12, and 7.13, Jul 2002 – Dec 2002

	Difference in Predicted from Actual		
	± |$20k|	**>±|$20k|, <±|$40k|**	**>= ±|$40k|**
DD (eqn 7.11)	6	12	14
DU (eqn 7.12)	5	3	5
UU (eqn 7.13)	9	5	5

The DD equation predicts a difference of $20,000 for only 20 percent of intersections, compared to 40 percent of intersections from the DU equation and 50 percent of intersections from the UU equation. There are for all equations, however, many intersections which have a difference between predicted and actual incurred cost in excess of $40,000. Therefore, certain intersections are closely predicted, but the equations based on entering AWDT (in particular the DD and DU equations) do not predict the incurred cost as well as the equations based on the total number of collisions.

7.3.3 Incurred Cost and Approach Roadway Posted Speed Limit

Similar to whiplash injury collisions, the incurred cost as a function of approach roadway posted speed limits was investigated. As with the whiplash collision investigation, 4 X 4 DD intersections were considered. The average of the approach roadway speeds was used in the analysis. Figure 7.6 shows the power relationship between the number of whiplash injury collisions and the average posted speed limit of an intersection in 2003.

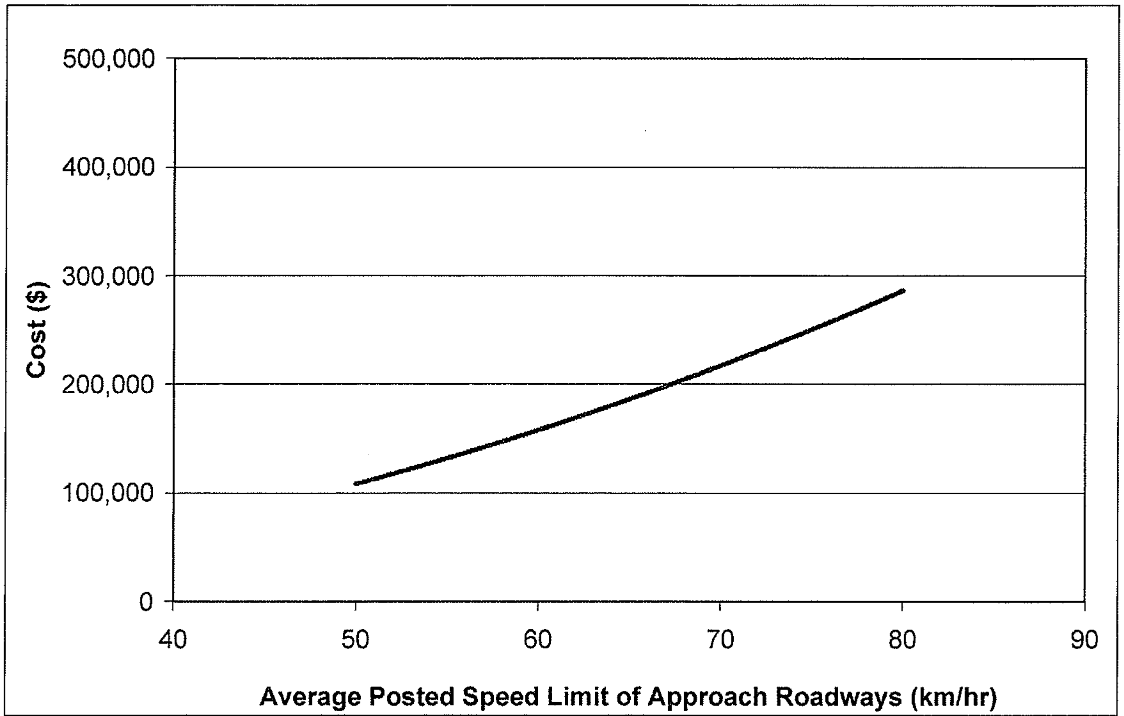

Figure 7.6: Incurred Cost vs. Average Posted Speed Limit for 4 X 4 DD Intersections, 2003

Note: One DD intersection with a total incurred cost of $810,000 was excluded from this figure

The equation of this relationship is:

$$I_{\$} = 33.0*(\text{AvgPostedSpeedLimit})^{2.07} \qquad R^2 = 0.25 \qquad \text{(eq. 7.14)}$$

Where: $I_{\$}$ = total incurred collision cost

The equation predicts an increase in incurred cost as the average approach roadway posted speed limit increases, from about $100,000 for an average posted speed of 50 km/hr to about $300,000 for an average posted speed of 80 km/hr.

This equation was tested against collision claims data from July 2002 to December 2002 using collisions at the identified DD intersections between four-lane roads. This equation predicts the incurred cost in a year, and therefore the predicted values were divided by half the year in order to compare the predicted to the actual values. There may therefore be temporal and random effects which may impact the difference between the predicted and actual values. The number of intersections by difference in predicted and actual incurred cost is as follows: (1) less than $20,000 – six intersections; (2) between $20,000 and $40,000 – six intersections; and (3) greater than $40,000 – nine intersections. There are therefore a number of intersections where the predicted incurred cost matches closely, but also many intersections where the incurred cost is not well predicted.

CHAPTER 8

CONCLUSIONS

The purpose of this research is to investigate the characteristics of motor vehicle collisions at urban intersections using insurance claims data. The results may be useful to roadway engineers and road safety researchers in further understanding the road safety problem in the urban environment.

This chapter presents findings of the comparison of collisions from insurance claims and police-reported collision data, the characteristics of intersection collisions in Winnipeg, and relationships between injury type and incurred collision cost as a function of the roadway engineering characteristics of intersections.

8.1 INSURANCE CLAIMS DATA VERSUS POLICE REPORTED COLLISIONS

Insurance claims data was compared to police-reported collision data in order to understand the nature and magnitude of differences in collision totals from these data sources. For all of Manitoba, insurance claims represented more collisions than police-reported collisions (146,079 vs. 61,972), even when considering collisions from insurance claims which meet police-reporting criteria (94,345 vs. 61,972). Insurance claims represented more collisions at all intersections in Winnipeg, and at high-collision frequency intersections in Winnipeg, for all collisions and those meeting police-reporting criteria, as well. Not only are more total collisions represented, more injury collisions are represented as well. Therefore collisions at intersections based on insurance claims data provide a more robust collision dataset than police-reported collision data, and have the potential for road safety research. The types of information found in these datasets differ, however; insurance claims data includes more driver characteristic information, while police-reported collision data includes more site description information. It is therefore imperative to have a clear understanding about the characteristics of the database being used.

8.2 CHARACTERISTICS OF INTERSECTION COLLISIONS IN WINNIPEG

Based on Manitoba Public Insurance collision claims data, there were 15,665 collisions with an incurred cost of $85.4 million at intersections in the City of Winnipeg in 2003. While representing only 21 percent of collisions, injury and fatal collisions accounted for over 50 percent of incurred cost. Temporal analysis revealed that there was the highest number of collisions but the lowest average collision cost in the winter (Dec-Feb). Conversely, the summer (Jun-Aug) had the lowest number of collisions but the highest average incurred collision cost. Weekends (Saturday and Sunday) had fewer collisions than did weekdays, and average collision costs were highest on Fridays and Saturdays. The majority (88%) of collisions took place between 7AM and 8PM, with 3PM and 4PM having the greatest number of collisions.

Collision characteristics were linked to the Winnipeg streets network for graphical analysis and presentation. Collision frequency and incurred collision cost were presented for all intersections where linking was possible, and collision rate was investigated for the

50 intersections with the highest collision frequency totals. Many intersections had high collision frequencies, rates, and incurred cost, but intersection rankings of these measurements yielded different worst-case intersections. Nonetheless, there were 10 intersections which ranked amongst the highest 20 in terms of collision frequency, rate, and incurred cost. Investigation of intersection collisions by type of traffic control showed that the majority of collisions and incurred collision cost occurred at signalized intersections.

From a total of 4,178 injury claims, 88 percent were for whiplash injuries. Whiplash injury collisions were also found at the greatest number of different intersections, and often occurred multiple times at a given intersection. All other injury types occurred at fewer intersections and with lower frequency at a given intersection. The majority of incurred injury claims cost was attributed to whiplash, brain and fatal, and broken bone injury claims (37, 32, and 24 percent respectively). Whiplash injuries generally had a consistently low incurred injury cost for all intersections. Broken bone injury collisions had variable cost, with a typical broken bone injury having an incurred cost similar to that of all whiplash injuries at a given intersection, with the exception of very high-cost broken bone injuries. The examination of injury collisions by traffic control showed that the majority of whiplash and broken bone collisions and their incurred injury cost occurred at signalized intersections; brain and fatal injury collisions and their injury cost occurred at approximately the same number of signalized and unsignalized intersections. The majority of intersections with broken bone injury collision(s) and a high frequency of whiplash injury collisions occurred on arterial roadways.

Signalized intersections between arterial roads were identified as locations of safety concern which are of interest in the investigation of relationships between injury type and cost as a function of intersection roadway characteristics. Whiplash and broken bone injury collisions were identified as most suitable for relationship investigation.

8.3 INJURY AND INCURRED COST RELATIONSHIPS WITH ROADWAY ENGINEERING CHARACTERISTICS OF THE IDENTIFIED INTERSECTIONS

An investigation of potential relationships between whiplash injury collisions, broken bone injury collisions, and incurred collision cost as a function of the roadway engineering characteristics of the identified intersections was conducted.

Both whiplash injury collisions and incurred collision cost were investigated as they relate to the total number of collisions at the identified intersections by approach roadway median presence, to the daily traffic exposure by approach roadway median presence, and to the average approach roadway posted speed limit for intersections between divided four-lane roadways. In all cases, the power form of the relation was found to provide the strongest statistical fit, and this form was used in all derived equations.

For all of these relationships, there is an increase in either the predicted number of whiplash collisions or the incurred cost with an increase in either the total number of collisions, the daily traffic exposure, or the average approach roadway posted speed limit. Relationships which are a function of the total number of collisions give better predictions of whiplash and incurred cost totals than those which are a function of the daily traffic exposure or of the average approach roadway posted speed limit. The relationships do not, in many cases, accurately predict individual intersections, but rather reflect a general trend amongst all intersections (in particular for the relationships based on daily traffic exposure or average approach roadway speed limit). Relationships which are a function of the total number of collisions do not vary greatly based on approach roadway median presence. The relationships for undivided-undivided roadway intersections which are a function of the daily traffic exposure, however, predict more whiplash injury collisions or a higher incurred cost than the divided-divided and divided-undivided relationships for similar daily traffic exposure values. The developed incurred cost relationships are only applicable for low cost collisions.

The investigation of broken bone injury collisions at the identified intersections revealed that the majority did not experience a broken bone injury collision in 2003, with just 25 percent of the intersections having either one or two broken bone collisions. As there are few broken bone collisions which may be considered, relationships between broken bone collisions and the roadway engineering characteristics of intersections were not pursued.

8.4 FURTHER RESEARCH

The research has identified the following opportunities for further study:

- Investigation of the characteristics of high-cost and severe injury collisions at intersections.
- Consideration of multiple intersection characteristics as variables in relationship development, and consideration of additional characteristics not mentioned in this

thesis, such as pavement markings, obstructions within the vicinity of the intersection, etc.

- Consideration of intersections of concern which were not considered in this research, namely signalized intersections between arterial and non-arterial roads, 3-leg arterial intersections, and arterial intersections involving one-way roads, in relationship investigation.

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APPENDIX A: IDENTIFIED INTERSECTIONS

Arterial Roadway Intersections in Winnipeg
Archibald St & Marion St
Arlington St & Ellice Ave
Arlington St & Mountain Ave
Arlington St & Sargent Ave
Arlington St & Selkirk Ave
Arlington St & William Ave
Bishop Grandin Blvd & Dakota St
Bishop Grandin Blvd & St Anne's Rd
Bishop Grandin Blvd & St Mary's Rd
Bishop Grandin Blvd & Waverley St
Brookside Blvd & Inkster Blvd
Century St & Ness Ave
Corydon Ave & Kenaston Blvd
Corydon Ave & Stafford St
Dakota St & St Mary's Rd
Dublin Ave & St James St
Dufferin Ave & Salter St
Dugald Rd & Lagimodiere Blvd
Dugald Rd & Plessis Rd
Ellice Ave & Empress St
Ellice Ave & St James St
Empress St & Sargent Ave
Fermor Ave & Lagimodiere Blvd
Fermor Ave & St Anne's Rd
Fermor Ave & St Mary's Rd
Grant Ave & Kenaston Blvd
Grant Ave & Shaftesbury Blvd
Grant Ave & Stafford St
Inkster Blvd & Keewatin St
Inkster Blvd & McPhillips St
Isabel St & Logan Ave
Isabel St & William Ave
Kenaston Blvd & Wilkes Ave
King Edward St & Notre Dame Ave
Lagimodiere Blvd & Regent Ave W
Lagimodiere Blvd & Springfield Rd
Leila Ave & McPhillips St
Logan Ave & Arlington St
Logan Ave & Keewatin St
Logan Ave & Main St
Logan Ave & McPhillips St
Main St & Higgins Ave
Main St & Portage Ave
Main St & Redwood Ave
McGillivray Blvd & Kenaston Blvd
McGillivray Blvd & Waverley St
McGregor St & Mountain Ave
McGregor St & Selkirk Ave

Con't...
McPhillips St & Mountain Ave
Moray St & Portage Ave
Moray St & Roblin Blvd
Nairn Ave & Watt St
Ness Ave & Sturgeon Rd
Notre Dame Ave & Arlington St
Osborne St N & Broadway
Pembina Hwy & Bison Dr
Plessis Rd & Regent Ave W
Salter St & Mountain Ave
Salter St & Selkirk Ave
Sargent Ave & St James St
Sherbrook St & William Ave
St James St & Wellington Ave
Stafford St & Taylor Ave
Waverley St & Taylor Ave

DD Intersections	# of Through Lanes				Approaches w/L.T. Lanes	# R.T. Cutoffs	Approaches w/R.T. Lanes	Posted Speed by Approach (km/hr)			
	WB	EB	SB	NB				WB	EB	SB	NB
Bishop Grandin Blvd & Dakota St	2	2	2	2	4	4	4	80	80	60	60
Bishop Grandin Blvd & St Anne's Rd	2	2	2	2	4	4	4	80	80	60	60
Bishop Grandin Blvd & St Mary's Rd	2	2	2	2	4	4	4	80	80	60	60
Bishop Grandin Blvd & Waverley St	2	2	2	2	4	4	4	80	80	80	80
Brookside Blvd & Inkster Blvd	2	2	2	2	4	4	2	70	80	80	80
Century St & Ness Ave	2	2	3	3	3	4	0	60	60	70	70
Corydon Ave & Kenaston Blvd	2	2	2	2	4	0	0	50	50	50	50
Dakota St & St Mary's Rd	2	2	2	2	4	4	0	60	70	60	60
Dufferin Ave & Salter St	2	2	2	2	4	2	0	50	50	50	50
Dugald Rd & Lagimodiere Blvd	2	2	2	2	4	4	4	70	60	80	80
Dugald Rd & Plessis Rd	2	2	1	1	4	3	2	70	70	80	60
Fermor Ave & Lagimodiere Blvd	2	2	2	2	4	4	4	80	80	80	80
Fermor Ave & St Anne's Rd	2	2	2	2	4	4	3	70	70	60	60
Fermor Ave & St Mary's Rd	2	2	2	2	4	2	1	70	70	60	60
Grant Ave & Kenaston Blvd	2	2	2	2	4	4	4	60	60	60	60
Grant Ave & Shaftesbury Blvd	2	2	1	1	4	2	1	60	60	50	50
Inkster Blvd & Keewatin St	2	2	2	2	4	4	1	60	70	60	60
Inkster Blvd & McPhillips St	2	2	3	3	4	0	0	60	50	60	60
Isabel St & Logan Ave	2	2	2	2	4	4	4	50	50	50	50
King Edward St & Notre Dame Ave	2	2	2	2	4	1	0	60	60	70	70
Lagimodiere Blvd & Regent Ave W	3	3	2	2	4	4	4	60	60	80	80
Leila Ave & McPhillips St	2	2	3	2	4	4	2	60	60	60	60
Main St & Portage Ave	2	2	3	3	1	0	3	50	50	50	50
McGillivray Blvd & Kenaston Blvd	2	2	2	2	4	4	4	70	70	80	80
McGillivray Blvd & Waverley St	2	2	2	2	4	4	4	80	80	70	70
Moray St & Portage Ave	4	4	2	2	4	4	2	60	60	50	60
Moray St & Roblin Blvd	2	2	2	2	3	3	3	60	70	70	80
Nairn Ave & Watt St	2	2	2	2	3	2	1	60	50	50	60
Ness Ave & Sturgeon Rd	2	2	2	2	3	3	0	60	50	60	50
Pembina Hwy & Bison Dr	2	2	3	3	4	4	0	60	60	60	60
Plessis Rd & Regent Ave W	2	2	2	2	4	2	2	50	60	50	50
Waverley St & Taylor Ave	2	2	2	2	4	2	0	60	60	50	50

DU Intersections	# of Through Lanes				Approaches w/L.T. Lanes	# R.T. Cutoffs	Approaches w/R.T. Lanes	Posted Speed by Approach (km/hr)			
	WB	EB	SB	NB				WB	EB	SB	NB
Grant Ave & Stafford St	2	2	2	2	2	0	0	60	50	50	50
Kenaston Blvd & Wilkes Ave	1	1	2	2	2	1	2	70	70	60	80
Lagimodiere Blvd & Springfield Rd	1	1	2	2	2	1	2	70	60	80	80
Logan Ave & Keewatin St	2	2	2	2	2	2	0	50	50	60	60
Logan Ave & Main St	2	2	3	4	1	0	1	50	50	50	50
Logan Ave & McPhillips St	2	2	3	3	2	2	2	50	50	60	60
Main St & Higgins Ave	2	2	2	3	1	0	1	50	50	50	50
Main St & Redwood Ave	2	2	4	4	2	2	1	50	50	60	60
McPhillips St & Mountain Ave	2	2	2	2	2	1	0	50	50	60	60
Notre Dame Ave & Arlington St	3	3	2	2	2	0	0	60	60	50	50
Osborne St N & Broadway	2	2	2	2	2	0	0	50	50	50	50
St James St & Wellington Ave	2	2	2	2	0	0	0	50	50	60	60
Stafford St & Taylor Ave	2	2	2	2	0	0	0	50	50	50	50

UU Intersections	# of Through Lanes				Approaches w/L.T. Lanes	# R.T. Cutoffs	Approaches w/R.T. Lanes	Posted Speed by Approach (km/hr)			
	WB	EB	SB	NB				WB	EB	SB	NB
Archibald St & Marion St	2	2	2	2	0	4	1	60	60	60	60
Arlington St & Ellice Ave	2	2	2	2	0	0	0	50	50	50	50
Arlington St & Mountain Ave	2	2	2	2	0	0	0	50	50	50	50
Arlington St & Sargent Ave	2	2	2	2	0	0	0	50	50	50	50
Arlington St & Selkirk Ave	2	2	2	2	0	0	0	50	50	50	50
Arlington St & William Ave	2	2	2	2	0	0	0	50	50	50	50
Corydon Ave & Stafford St	2	2	2	2	0	0	0	50	50	50	50
Dublin Ave & St James St	2	2	2	2	0	0	0	60	60	60	60
Ellice Ave & Empress St	2	2	1	1	0	0	0	50	50	60	60
Ellice Ave & St James St	2	2	2	2	0	0	0	50	50	60	60
Empress St & Sargent Ave	2	2	1	1	0	0	0	50	50	60	60
Isabel St & William Ave	2	2	2	2	0	0	0	50	50	50	50
Logan Ave & Arlington St	2	2	1	1	0	1	1	50	50	50	50
McGregor St & Mountain Ave	2	2	2	2	0	0	0	50	50	50	50
McGregor St & Selkirk Ave	2	2	2	2	0	0	0	50	50	50	50
Salter St & Mountain Ave	2	2	2	2	0	0	0	50	50	50	50
Salter St & Selkirk Ave	2	2	2	2	0	0	0	50	50	50	50
Sargent Ave & St James St	2	2	2	2	0	0	0	50	50	60	60
Sherbrook St & William Ave	2	2	2	2	0	0	0	50	50	50	50