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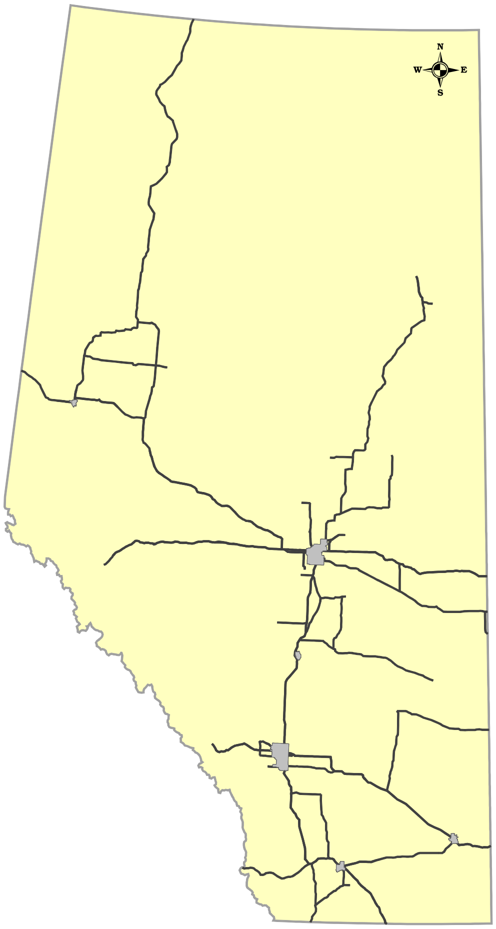
Long Combination Vehicle (LCV) Safety Performance in Alberta: 1999–2005



Alberta
INFRASTRUCTURE AND
TRANSPORTATION

Alberta Infrastructure and Transportation
Policy and Corporate Services Division

Long Combination Vehicle (LCV)
Safety Performance in Alberta: 1999-2005

Final Report

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The findings of this report do not represent the views of any individual, party, or organization that commissioned or contributed information for the analysis. The independent consulting team of Montufar & Associates used the best available data within the time and budget constraints for the study. Readers are responsible for fully understanding any limitations of this study and exercising any caution that may be warranted as a result of the methodologies used when applying the results.

EXECUTIVE SUMMARY

The safety performance of large trucks is a critical issue for transportation agencies in North America. With the increasing use of larger vehicles, combined with longer travel distances, it is essential to understand their safety performance to remain competitive in regional and international markets.

To assist in improving the understanding about the safety impact of large vehicles in the province, Alberta Infrastructure and Transportation (AIT) Policy and Corporate Services Division commissioned Montufar & Associates to undertake an analysis of the safety performance of long combination vehicles (LCVs) operating on Alberta's LCV network, relative to the safety performance of other vehicle types operating on the same network. This improved understanding will help define future truck size and weight policy for Alberta highways, and provide information to policy makers in Alberta and its trading partners concerning LCV safety.

Safety performance is defined in terms of collision frequency and collision rate.

Collision rate is a function of traffic exposure.

Long combination vehicles operate in Alberta and other provinces and states under special permit. In the Canadian Prairie Region, LCVs consist of a tractor and two or three semitrailers or trailers exceeding the basic length limitation of 25 meters specified by provincial truck size regulatory schemes. The three types of LCVs are Rocky Mountain doubles (RMDs), Turnpike doubles (TPDs), and triple trailer combinations (triples).

Specific objectives of this study are to:

- Conduct an environmental scan (literature review and jurisdictional survey) of recent developments involving LCV safety in North America.
- Examine in detail all collision reports involving a double trailer combination on the LCV network or in urban areas, and to contact the corresponding motor carriers to determine the type of truck involved in the collision (Rocky Mountain double, Turnpike double, or other type of double trailer combination).
- Conduct a comprehensive analysis of collisions occurring on Alberta's LCV network for the years 1999 to 2005, inclusive.
- Analyze LCV collisions occurring in urban areas from 1999 to 2005, inclusive.
- Develop exposure estimates on Alberta's LCV network by vehicle type, recognizing changes in the network during the study period.
- Develop collision rates by vehicle type for the LCV network.

The following are identified as urban areas: Calgary, Edmonton, Lethbridge, Red Deer, Medicine Hat, Fort McMurray, and Grande Prairie.

LCV network routes through other towns in the study area (e.g., Hinton, Fort McLeod, Peace River, Valleyview, Athabasca, and others) are included in the comprehensive safety analysis of vehicles operating on the LCV network.

This report is divided into four chapters. Chapter 1 provides background information about the study, discusses the LCV network in Alberta, identifies the types of vehicles used, and data sources.

Data sources for exposure analysis

No single data source is available to develop exposure estimates by vehicle type on Alberta's LCV network for the study period. As such, a methodology was developed that utilizes a variety of data sources and integrates them using a hierarchical scheme. The following data sources were used in the exposure analysis:

- Average daily traffic volumes provided by AIT by traffic control section for five vehicle classes on the LCV network for each year in the study period.
- Raw data from five weigh-in-motion (WIM) stations on the Alberta LCV network for 2005.
- A specialized vehicle length survey conducted on Highway 63 in 2005.
- Raw data from three WIM stations in Saskatchewan for 2005 and 2006.
- Interviews conducted with several AIT Commercial Vehicle Enforcement Branch officers.
- Specialized 12-hour vehicle classification counts conducted by AIT at selected locations on the Alberta LCV network in 2007.
- Short-term vehicle classification counts conducted by Montufar & Associates at selected locations on the Alberta LCV network in 2007.
- Fleet mix data (provided by AIT) derived from the 1999 Canadian Council of Motor Transport Administrators (CCMTA) National Roadside Survey (NRS).

Vehicle type definitions

The vehicles of interest to this study are:

- Passenger vehicles
- Straight trucks and bobtails
- Tractor semitrailers
- Legal-length tractor double trailers
- Rocky Mountain doubles
- Turnpike doubles
- Triple trailer combinations

Chapter 2 presents a summary of findings from an environmental scan (literature review and jurisdictional survey) about the latest developments (1995 and later) regarding the safety of LCVs in North America.

Environmental scan

- Of all CANAMEX corridor states and Canadian Prairie Region jurisdictions, Alberta is the only jurisdiction that has specifically evaluated the safety performance of LCVs by determining collision rates for LCVs compared to other vehicle types.
- Studies about LCV safety performance (as measured by collision frequency and collision rates) show disparate results. Some studies indicate that LCVs are safer than other truck configurations, and some studies conclude that LCVs pose a detriment to road safety.
- LCV driver standards and training requirements contribute positively to the safety performance of LCVs. Some studies indicate that LCVs are involved in fewer collisions because of the strict operating restrictions placed on their use, and the special driver training requirements. Alberta is one of the most stringent jurisdictions along the CANAMEX corridor and the Canadian Prairie Region regarding driver training and qualifications requirements for LCV operations.
- Most jurisdictions along the CANAMEX corridor and the Canadian Prairie Region do not specifically record LCVs as a distinct vehicle class in their collision reporting system. This poses a barrier to analyzing the extent and nature of LCV collisions in these jurisdictions.

Chapter 3 presents the findings from a comprehensive analysis of the safety performance of LCVs relative to other vehicle types operating on the LCV network and urban areas.

Chapter 4 presents conclusions based on this study.

The safety performance of LCVs in Alberta

- There were 106 LCVs involved in 106 collisions on the Alberta LCV network and in urban areas over the study period. These accounted for 0.02 percent of all collisions in the study area (106 of 490,956). Sixty percent of these (65 of 106) took place on the LCV network and 40 percent (41 of 106) in urban areas.

- The severity outcome of LCV collisions on the LCV network was lower than that of other vehicle types. LCVs accounted for one percent of all trucks (articulated and non-articulated) in fatal collisions, one percent of all trucks in injury collisions, and one percent of all trucks in property damage only (PDO) collisions. Other articulated units (tractor semitrailers and legal-length tractor double trailers) accounted for nearly two-thirds of trucks in fatal collisions, 57 percent of trucks in injury collisions, and 43 percent of trucks in PDO collisions. Taking traffic exposure into consideration, LCVs have a lower fatality, injury, and PDO rate per 100 million VKT than other vehicle types.

- LCVs were over-represented in collisions on the LCV network in winter (December, January and February) and spring (March, April and May), relative to the corresponding seasonal traffic volume distribution. Winter accounted for 30 percent of LCV collisions and for 24 percent of LCV traffic. Spring accounted for 25 percent of LCV collisions and 17 percent of LCV traffic. Other articulated combinations also showed similar collisions-to-traffic proportions in winter and spring.

- Driver action and environmental condition were the main contributing factors listed for LCVs involved in collisions on the LCV network and in urban areas. Driver action was particularly associated with Turnpike doubles operating in urban areas. Improper turning and improper lane change were cited as contributing factors in 40 percent of TPD collisions in urban areas.

- Adverse road surface conditions (wet, slush, snow, or ice) accounted for about 40 percent of all LCVs involved in collisions on the LCV network. This proportion was similar for other truck types but smaller for passenger vehicles. Comparatively, adverse road surface conditions accounted for one-quarter of all LCVs involved in collisions in urban areas. The same proportion was experienced by other vehicle types.

- Four highways accounted for 75 percent of collisions involving LCVs: Highway 2 between Edmonton and Calgary (20 of the 65 collisions), Highway 35 north of Peace River (10 of 65 collisions), Highway 1 east of Calgary (9 of 65 collisions) and Highway 43 between Edmonton and Grande Prairie (9 of 65). Most Rocky Mountain doubles were involved in collisions along Highways 35 and 43 northwest of Edmonton.

- From a collision rate perspective, LCVs as a group had the best safety performance of all vehicle types with 25 collisions per 100 million vehicle-kilometers traveled (VKT) on the LCV network. The collision rates for other vehicle types in descending order of performance were: tractor semitrailers—42 collisions per 100 million VKT, legal-length tractor doubles—44 collisions per 100 million VKT, passenger vehicles—83 collisions per 100 million VKT, and straight trucks and bobtails—123 collisions per 100 million VKT.

- Turnpike doubles had the lowest collision rate of all individual vehicle types (16 collisions per 100 million VKT), followed by Rocky Mountain doubles (32 collisions per 100 million VKT). The collision rate for triple trailer combinations was 62 collisions per 100 million VKT.

- LCVs were under-represented in terms of collision frequency with respect to traffic exposure. They accounted for 0.1 percent of all collisions on the LCV network, and for 0.4 percent of all traffic exposure. Other vehicle types that were also under-represented were tractor-semitrailers and legal-length tractor doubles. Straight trucks and bobtails, as well as passenger vehicles, were over-represented in terms of collision frequency with respect to traffic exposure.

- A sensitivity analysis revealed that a 10 percent decrease in LCV VKT, combined with a 10 percent increase in non-LCV articulated truck VKT, still results in a lower rate (in terms of vehicles in collisions per 100 million VKT) for all LCVs than for all non-LCV articulated trucks. Assuming that there is no change in the number of collisions, one of the following events would need to occur for these rates to be equal: (1) the VKT for all non-LCV articulated trucks increases by 75 percent and there is no change in LCV exposure; or (2) the VKT for all LCVs decreases by 42 percent and there is no change in non-LCV articulated truck exposure.

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GLOSSARY OF ACRONYMS

AADT	Annual average daily traffic
AADTT	Annual average daily truck traffic
ACIS	Alberta Collision Information System
AIT	Alberta Infrastructure and Transportation
ATR	Automatic traffic recorder
AVC	Automatic vehicle classifier
CCMTA	Canadian Council of Motor Transport Administrators
CFR	Code of Federal Regulations
CMV	Commercial motor vehicle
DOT	Department of Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GAO	General Accounting Office
GIS	Geographic information system
GVW	Gross vehicle weight
ISTEA	Intermodal Surface Transportation Efficiency Act
LCV	Long combination vehicle
MIT	Manitoba Infrastructure and Transportation
MOU	Memorandum of Understanding
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
NN	National Network
NPO	Net passing opportunity
NRS	National Roadside Survey
PDO	Property damage only
PTH	Provincial Trunk Highway
RMD	Rocky Mountain double
STAA	Surface Transportation Assistance Act
TAC	Transportation Association of Canada
TPD	Turnpike double
VKT	Vehicle-kilometers of travel
WAADT	Weighted annual average daily traffic
WIM	Weigh-in-motion
WWC	Winter Weather Command

1. INTRODUCTION

1.1. BACKGROUND

The safety performance of large trucks is a critical issue for transportation agencies in North America. With the increasing use of larger vehicles, combined with longer travel distances, it is essential to understand their safety performance to remain competitive in the regional and international markets.

Alberta's strategy to increase international trade relies, in part, on harmonizing commercial truck sizes, weights, operating practices and enforcement, to access U.S. and emerging Mexican markets located along the CANAMEX Trade Corridor. While CANAMEX is vital to ensuring North America's competitiveness in the international marketplace, the current lack of information on the safety, productivity and infrastructure impact of large vehicles in some areas of the highway network in North America impedes the adoption of standardized large vehicles to travel the full length of the CANAMEX Trade Corridor from Alaska to Mexico City.

To assist in improving the understanding of the safety impact of large vehicles in the province, Alberta Infrastructure and Transportation (AIT) Policy and Corporate Services Division commissioned Montufar & Associates to undertake an analysis of the safety performance of long combination vehicles (LCVs) for the period from 1999 to 2005. This study is the second of its kind in Alberta as there was a previous study conducted in 2001 by Woodrooffe and Associates to undertake an in-depth review of LCVs in Alberta for the period from 1995 to 1998.

The purpose of this study is to help improve the understanding about the safety performance of LCVs relative to the safety performance of passenger vehicles, straight trucks and bobtails, tractor semitrailers, and legal-length tractor double trailers operating on the LCV network and urban areas. This improved understanding will help define future truck size and weight policy for Alberta highways, and provide information to policy makers in Alberta and its trading partners concerning LCV safety.

Long combination vehicles operate in Alberta and other provinces and states under special permit. In the Canadian Prairie Region, LCVs consist of a tractor and two or three semitrailers or trailers that exceed the basic length limitation of 25 meters specified by provincial truck size regulatory schemes. Figure 1 shows typical configurations and trailer dimensions of three common types of LCVs operating in the Canadian Prairie Region: (1) Rocky Mountain doubles (RMDs); (2) Turnpike doubles (TPDs); and (3) triples or triple trailer combinations (Regehr and Montufar, 2007).

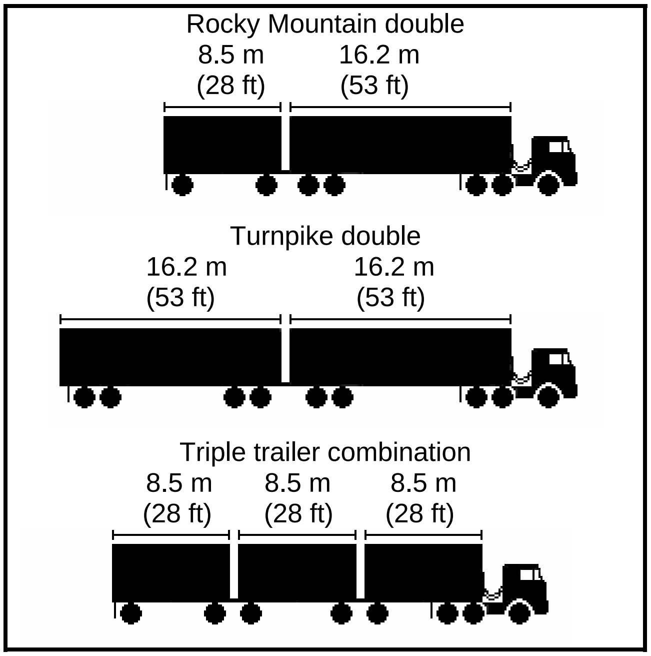


Figure 1: Routinely permitted LCVs in the Canadian Prairie Region
Source: Regehr and Montufar, 2007

Canadian commercial vehicle size and weight limitations are defined by provincial regulatory agencies. Table 1 summarizes basic length and gross vehicle weight (GVW) limitations for LCVs in the region. These vehicles offer increased cubic capacity, but do not allow additional gross vehicle or axle weight relative to standard configurations.

Table 1: Length and GVW limitations for LCVs in the Prairie Region

Configuration	**Alberta**		**Saskatchewan**		**Manitoba**	
	Length (m)	GVW (kg)	Length (m)	GVW (kg)	Length (m)	GVW (kg)
Rocky Mountain doubles [a]						
A Converter Dolly	31	53,500	31	53,500 [e]	31.5	53,500 [d]
B Converter Dolly	31	63,500	31	62,500 [f]	31.5	62,500 [d]
C Converter Dolly	31	60,500	31	60,500 [g]	31.5	60,500 [d]
Turnpike doubles [b]						
A Converter Dolly	38	63,500 [d]	38	62,500 [h]	38.5	62,500 [d]
B Converter Dolly	38	63,500 [d]	38	62,500	38.5	62,500 [d]
C Converter Dolly	38	63,500 [d]	38	62,500	38.5	62,500 [d]
Triple trailer combinations [c]						
A Converter Dolly	35	53,500	38	N/A [i]	35	53,500
B Converter Dolly	38	53,500	38	53,500	35	53,500
C Converter Dolly	35	53,500	38	53,500	35	53,500

Source: Regehr and Montufar, 2007

Notes:
[a] RMDs are made up of one 16.2-m (53-ft) trailer and one 8.5-m (28-ft) trailer (maximum)
[b] TPDs are made up of two 16.2-m (53-ft) trailers (maximum)
[c] Triples are made up of three 8.5-m (28-ft) trailers (maximum)
[d] For eight or more axles
[e] Ranges from 41,000 kg (90,200 lbs) to 53,500 kg (117,700 lbs) depending on axle arrangement
[f] Ranges from 54,600 kg (120,120 lbs) to 62,500 kg (137,500 lbs) depending on axle arrangement
[g] Ranges from 46,000 kg (101,200 lbs) to 60,500 kg (133,100 lbs) depending on axle arrangement
[h] Except for 9-axle single dolly converters, for which the maximum GVW is 54,600 kg (120,120 lbs)
[i] Not allowed

The economic and environmental advantages of LCVs compared to other major truck combinations are well documented in many provinces and states. In addition to environmental benefits, LCVs offer economic efficiencies through productivity increases, lower unit costs to transport products, and reduced fuel consumption. However, there is inconclusive knowledge regarding their safety performance.

1.2. OBJECTIVES AND SCOPE

Specific objectives of this study are to:

- Conduct an environmental scan (literature review and jurisdictional survey) of recent developments involving LCV safety in selected North American jurisdictions.
- Examine in detail all collision reports involving a double trailer combination on the LCV network or in urban areas, and to contact the corresponding motor carriers to determine the type of truck involved in the collision (Rocky Mountain double, Turnpike double, or other type of double trailer combination).
- Conduct a comprehensive analysis of collisions taking place on Alberta's LCV network for the years 1999 to 2005, inclusive.
- Analyze LCV collisions taking place in urban areas from 1999 to 2005, inclusive.
- Develop exposure estimates on Alberta's LCV network by vehicle type, recognizing changes in the network during the study period.
- Develop collision rates by vehicle type for the LCV network.

Important considerations for this study are as follows:

- Safety performance is defined in terms of collision frequency and rate. Rate is a function of traffic exposure.
- The following cities are identified as "urban areas" for the collision analysis: Calgary, Edmonton, Lethbridge, Red Deer, Medicine Hat, Fort McMurray, and Grande Prairie.
- The collision analysis relies on data provided by AIT for the period between 1999 and 2005, inclusive.
- The exposure analysis relies on a mixture of raw, semi-processed and fully processed databases provided by AIT and Saskatchewan Highways and Transportation, and industry intelligence. Discussions with data providers are necessary to clarify database-related issues, understand the databases, and normalize differences between them.
- The LCV network is as defined by AIT, taking into consideration changes over the study period.
- The environmental scan is limited to material published in 1995 and later.

1.3. LCV NETWORK IN ALBERTA

The Alberta LCV network is defined pursuant to Section 62 of the Traffic Safety Act in “Attached Conditions for the Operation of Long Combination Vehicles”. This document defines LCV network routes in terms of two vehicle groups: (1) TPDs and triples; and (2) RMDs and other extended length doubles. Turnpike doubles and triples are only permitted on multi-lane highways with four or more driving lanes, except for a few short two-lane highway sections. Rocky Mountain doubles and other extended length doubles are permitted on the TPD and Triple network in addition to a specified network of two-lane undivided highways.

The LCV network has expanded several times between 1999 and 2005, with the most significant change occurring in late 2003. To accommodate these changes, two LCV networks are defined in this project. The first is for the period from January 1, 1999 to December 31, 2003 and the second is for the period from January 1, 2004 to December 31, 2005. The 1999 to 2003 network (excluding urban areas) consisted of approximately 4,500 centerline-kilometers, 1,800 of which permitted TPDs and triples. The 2004 to 2005 network consisted of 5,300 centerline-kilometers, 2,000 of which permitted TPDs and triples (the network has not changed since 2005). Figure 2 shows the LCV networks used in this study and Table A-1 in Appendix A lists the LCV network routes for the two periods between 1999 and 2005.

1.4. DATA SOURCES

1.4.1. Collision Analysis

The collision analysis is based on data extracted by AIT from the Alberta Collision Information System (ACIS). The database used in the analysis contains all collisions taking place on Alberta’s LCV network by year between 1999 and 2005, as well as all collisions taking place in urban areas for the same time period.

1.4.2. Exposure Analysis

No single data source is available to develop exposure estimates by vehicle type on Alberta’s LCV network for the study period. As such, a methodology was developed that utilizes a variety of data sources and integrates them using a hierarchical scheme.

The following data sources were used in the exposure analysis:

- Average daily traffic volumes provided by AIT by traffic control section for five vehicle classes on the LCV network for each year in the study period.
- Raw data from five weigh-in-motion (WIM) stations on the Alberta LCV network for 2005.
- A specialized vehicle length survey conducted on Highway 63 in 2005.
- Raw data from three WIM stations in Saskatchewan for 2005 and 2006.

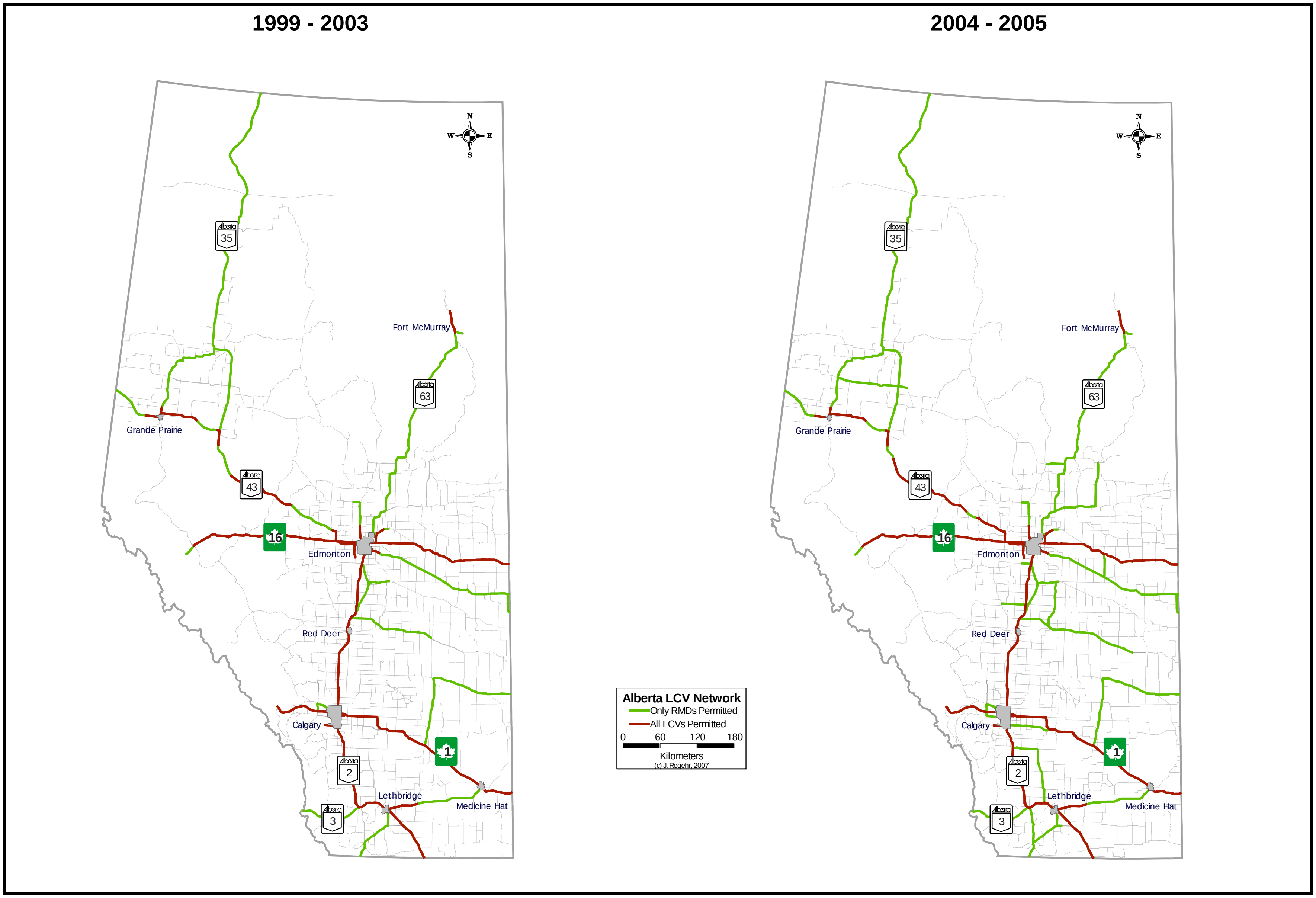


Figure 2: Alberta LCV network

Source: J. Regehr, Ph.D. thesis research, 2007

- Interviews conducted with several AIT Commercial Vehicle Enforcement Branch officers.

- Specialized 12-hour vehicle classification counts conducted by AIT at selected locations on the Alberta LCV network in 2007.

- Short-term vehicle classification counts conducted by Montufar & Associates at selected locations on the Alberta LCV network in 2007.

- Fleet mix data (provided by AIT) derived from the 1999 Canadian Council of Motor Transport Administrators (CCMTA) National Roadside Survey (NRS).

Details regarding each of these data sources are provided in Chapter 3 and Appendix D.

1.4.3. Geographic Analysis

Alberta Infrastructure and Transportation provided the geospatial data used to produce the geographic information system (GIS) basemap used in this study. The base map incorporates provincial and municipal boundary datasets as well as the highway control sections dataset (current as of March 31, 2006). Additional datasets were produced for the purposes of this study. These include the development of special LCV segments, LCV volumes, and a geo-referenced collision dataset.

1.5. VEHICLE TYPE DEFINITIONS

The vehicle type definitions used in this study are the same for the collision analysis and the exposure analysis. This was done to be consistent with AIT's traffic monitoring program and for estimating meaningful collision rates.

From the Alberta Collision Information System, two fields are used to identify a vehicle: object identification and attachment. Object identification refers, for the most part, to the type of power unit involved in a collision (e.g., mini-van, motorhome, passenger car, truck tractor), although it is also used to identify collisions involving animals or fixed objects. Attachment refers to the type of trailer a given object identification was towing at the time of the collision (e.g., large single trailer, farm equipment, recreational trailers, small utility trailer).

The combination of these two fields forms the different vehicle types used in this study, which are consistent with those identified in the traffic monitoring program. Table 2 shows the different types of vehicles as derived from ACIS. Figure 3 illustrates some of the different types of trucks that fall under each of the categories identified in Table 2.

The vehicles of interest to this study are:

- Passenger vehicles
- Straight truck and bobtails
- Tractor semitrailers
- Legal-length tractor double trailers
- Rocky Mountain doubles

- Turnpike doubles
- Triple trailer combinations

1.6. FACTORS INFLUENCING COMPARISON TO 2001 STUDY

Several factors hinder the ability to compare the results of this study with those from the 2001 Study by Woodrooffe and Associates. The most significant of these are the expansion of the LCV network, and the methodology used in the determination of traffic exposure estimates. The 2001 Study developed traffic exposure estimates relying substantially on 1999 CCMTA NRS data for a smaller LCV network than the one used in the current study. In addition, since the 2001 Study, improved traffic monitoring technologies, analysis techniques, and traffic data sources (e.g., WIM devices and special vehicle classification algorithms) have become available. For this reason, the project team, in consultation with AIT, implemented an alternative methodology for developing more refined traffic exposure estimates on Alberta's LCV network. This results in higher quality exposure estimates, and hence, stronger collision rate estimates.

Therefore, while it was important to maintain compatibility with the 2001 Study, it is not possible to draw direct comparisons between the two because of these critical changes.

1.7. REPORT ORGANIZATION

This report is divided into four chapters. Chapter 2 presents a summary of findings from an environmental scan (the literature review and jurisdictional survey) about the latest developments (1995 and later) regarding the safety of LCVs in North America. The chapter describes the literature search, and the approach used to conduct the jurisdictional review.

Chapter 3 presents the findings from a comprehensive analysis of the safety performance of LCVs relative to other vehicle types operating on the LCV network and urban areas. The chapter starts with an overview of the methodologies used to analyze collisions, determine traffic exposure, and calculate rates by vehicle type. This is followed by a comprehensive analysis of collision frequency and rate for vehicles operating on the LCV network. Next, the chapter presents the results of a comprehensive collision analysis for urban areas. In this case, there are no rate calculations as traffic volume information by vehicle type is not available for these areas. Finally, the results of a sensitivity analysis of vehicles-in-collisions rates to changes in traffic exposure are presented.

Chapter 4 presents conclusions based on this study.

Table 2: Vehicle types derived from ACIS

Vehicle Type	Object ID	Attachment type	
Passenger vehicle	Passenger car (01)	All types	
	Pick-up/van < 4500 kg (02)	All types	
	Mini-van/MPV/SUV (03)	All types	
	Motorcycle/scooter (06)	All types	
	Moped (22)	All types	
Straight truck and bobtail	Truck > 4500 kg (04)*	All types (except large triple trailer – 03)	
		No attachment	
	Truck tractor (05)	No attachment	
	Emergency vehicle (18)	All types	
Tractor semitrailer	Truck tractor (05)	Large single trailer (01)	Articulated or tractor trailer combinations
		Recreation trailer (04)	
		Small utility trailer (05)	
		Farm equipment (06)	
		Towed motor vehicle (07)	
		Oversize with pilot (08)	
		Oversize without pilot (09)	
		Other (98)	
Legal-length tractor double trailer	Truck tractor (05) *	Large double trailer (02)*	
Rocky Mountain double	Truck tractor (05)^	Large double trailer (02)	
	Truck > 4500 kg (04)^	Large double trailer (02)	
Turnpike double	Truck tractor (05)^	Large double trailer (02)	
	Truck > 4500 kg (04)^	Large double trailer (02)	
Triple trailer combination	Truck tractor (05)^	Large triple trailer (03)	
	Truck > 4500 kg (04)^	Large triple trailer (03)	
Other vehicle	Truck tractor (05)	Unknown (97 or 99)	
	Pedestrian (07)	All types	
	Bicycle (08)	All types	
	School bus (09)	All types	
	Transit bus (10)	All types	
	Intercity bus (11)	All types	
	Other bus (12)	All types	
	Fixed object (13)	All types	
	Train (14)	All types	
	Animal (15)	All types	
	Motorhome (16)	All types	
	Construction equipment (17)	All types	
	Farm equipment (19)	All types	
	Off-highway vehicle (20)	All types	
	Motorized snow vehicle (21)	All types	
	Other (98)	All types	
Unknown	Unknown (99 or 97)	All types	

* Does not include double trailers identified by trucking companies as being either RMDs or TPDs.

^ These are as confirmed by trucking companies based on telephone interviews.

Straight trucks and bobtails

Tractor semitrailers

Legal-length tractor double trailer combinations

Long combination vehicles (clockwise from top left: RMD, Triple trailer, TPD)

Figure 3: Commercial vehicle types used in this study

2. ENVIRONMENTAL SCAN

This chapter presents a summary of findings from an environmental scan (literature review and jurisdictional survey) about the latest developments (1995 and later) regarding the safety of LCVs in North America. The chapter describes the literature search, and the approach used to conduct the jurisdictional review. Details about the environmental scan are included in Appendix B.

2.1. LITERATURE REVIEW

A comprehensive search of recent literature (1995 and later) was conducted by the project team. This search included: (1) engineering periodicals and journals; (2) readily-available research papers and texts; (3) conference proceedings; and (4) documents on the World Wide Web. The search included the sources shown in Appendix B, and the documents selected for the literature review are listed in the Bibliography.

Much of the material contained in this chapter for available literature between 1995 and 2003 was extracted from "Extended Length Vehicle Safety Study: Phase 1 – Preliminary Research" by Clayton, Montufar and Regehr (2003). This chapter combines the findings from the Clayton et al. study with other findings from the literature search for this project. Units of measurement used in the original documents are retained in the literature review.

The literature review addressed the following topics as they pertain to LCVs:

- Safety of long combination vehicles
- Vehicle stability and control
- Road engineering and weather conditions
- Driver standards and training
- Enforcement
- Emerging technologies

Table 3 shows a synthesis of the literature review. Detailed material used to generate this table is included in Appendix B.

2.2. JURISDICTIONAL SURVEY

This section provides a synthesis of findings from a jurisdictional survey of LCV operations and experiences regarding their safety performance. Details regarding this survey are found in Appendix B.

Table 3: Synthesis of the literature review

- Studies about LCV safety performance (as measured by collision frequency and collision rates) show disparate results. Some studies indicate that LCVs are safer than other truck configurations, and some studies conclude that LCVs pose a detriment to road safety. One study found that LCVs are no "more or less safe" than other combination trucks. Several studies conclude that direct comparison of collision rates between LCVs and other truck classes is hindered by a lack of reliable and relevant data regarding the number of collisions involving LCVs and LCV exposure.

- Vehicle performance measures commonly used to evaluate LCV stability and control are: off-tracking (low-speed and high-speed), rearward amplification, trailer sway, static roll stability, load transfer ratio, and lateral stability. In general, LCVs (particularly triple trailer combinations) have poorer stability and control performance than shorter trucks, but this does not necessarily translate into reduced on-road safety performance. The on-road safety performance of LCVs is also a function of other factors such as driver training and road geometry.

- According to the literature, critical road engineering issues related to LCV operations are: lane and shoulder width at horizontal curves, intersections and access/egress points, shoulder and pavement integrity, stopping and intersection sight distance, and vertical grade. Poor weather conditions such as rain, snow, or ice can also result in potential safety problems for LCVs. However, this is no different than the situation with other large commercial vehicles.

- Passing maneuvers involving LCVs require more time and distance to complete than those in which there is not an LCV involved. The literature cites concerns regarding overtaking of LCVs on two-lane highways without adequate passing opportunities. However, there is nothing in the literature that provides statistics about collision rates involving passing of LCVs on these types of highways.

- LCV driver standards and training requirements contribute positively to the safety performance of LCVs. Some studies indicate that LCVs are involved in fewer collisions because of the strict operating restrictions placed on their use, and the special driver training requirements.

- There is a variety of emerging technologies within the commercial vehicle realm that may help improve the safety of LCV operations: (1) driver-related technologies such as vision enhancement and fatigue warning systems; (2) vehicle-related technologies such as roll stability control systems, collision avoidance technologies, and lane departure warning systems; (3) automated inspection systems utilizing technologies such as radio frequency vehicle identification, WIM devices, and non-intrusive inspection systems; and (4) road weather information systems.

- In general, the literature identifies the following special permitting requirements to help improve LCV safety: information reporting, route restrictions, temporal restrictions, equipment specifications, driver qualifications and safety record, clear demonstration of safety compliance, and use of advanced technologies.

The jurisdictions contacted by the project team are Saskatchewan, Manitoba, and the five CANAMEX Corridor states (Montana, Idaho, Utah, Nevada, and Arizona). Government officials from each jurisdiction were contacted by telephone, and interviews took place on different days over a period of three weeks in January and February 2007. The information from the interviews was supplemented with information contained in the U.S. Code of Federal Regulations (CFR) for highways. The Code presents operational conditions, routes, legal citations, and size and weight provisions that were in effect on or before the Intermodal Surface Transportation Efficiency Act (ISTEA) freeze of 1991, and which still remain in effect.

Once the interviews were conducted, each government official interviewed was asked to review and provide comments on the accuracy of the information recorded by the project team pertaining to their own jurisdiction.

When conducting the jurisdictional survey, the project team recognized that there are differences with regards to how an LCV is defined in the Canadian Prairie Region and the U.S. These differences were addressed as much as possible in the interviews for consistency with the Canadian definition.

In the U.S., the CFR defines LCVs as prescribed by the ISTEA of 1991. The ISTEA defines LCVs as any combination of a truck tractor and two or more trailers or semitrailers which operates on the Interstate Highway System at a GVW greater than 80,000 pounds. This could, in effect, include B-trains operating on I-15 between Montana and Alberta. The CFR uses the term Commercial Motor Vehicle (CMV) when referring to a vehicle combination with two or more cargo-carrying units operating on the U.S. National Network (NN). The U.S. NN is a specially designated set of highways on which the truck size and weight provisions of the Surface Transportation Assistance Act (STAA) of 1982 apply (102-inch maximum vehicle width, 48-foot minimum semitrailer length, 28-foot minimum trailer length, and 80,000 pounds maximum GVW). This system includes all Interstate highways and designated Federal-aid primary highways.

The jurisdictional survey addresses the following factors affecting the safety performance of LCVs:

- Weather and road conditions
- Temporal restrictions
- Driver training and qualifications
- Speed control
- Monitoring and evaluation programs
- Vehicle-related requirements
- Enforcement of LCV regulations.

Table 4 shows a synthesis of the jurisdictional survey. Detailed material used to generate this table is included in Appendix B. The CFR contains complete details of regulations for LCVs in the U.S., and provincial governments have complete details of regulations for LCVs in each province.

Table 4: Synthesis of the jurisdictional review

- Alberta is the only jurisdiction that has specifically evaluated the safety performance of LCVs by determining collision rates for LCVs compared to other vehicle types. Some jurisdictions have not perceived a need to do this based on statistics relating to multi-trailer collision frequency. Other jurisdictions have undertaken studies that investigate the safety of LCVs based on findings from the literature.

- There are wide-ranging approaches in the application of weather and road condition restrictions for LCV operations. One jurisdiction specifies restrictions due to visibility, ice/snow on the road, and wind, while other jurisdictions do not specify any of these restrictions. Most jurisdictions indicate that they have not experienced any noticeable difference in LCV collisions as a result of weather or road conditions.

- There are wide-ranging approaches in the application of temporal restrictions for LCV operations. Restrictions for statutory holidays, weekends, specific times of the day, or seasons are in effect in various combinations in the Canadian Prairie Region. None of the U.S. jurisdictions surveyed restrict LCV operations temporally. Most jurisdictions indicate that they have not experienced high concentrations of collisions during specific times of the day or days of the week.

- With the exception of two jurisdictions, all jurisdictions require special training or qualifications for LCV drivers. The jurisdictional survey reveals that more stringent driver training and qualifications standards for LCV drivers compared to other commercial drivers contributes positively to LCV safety performance. Alberta is one of the most stringent jurisdictions when it comes to driver training and qualifications for LCV operations.

- There are wide-ranging approaches to speed control for LCVs. These approaches vary due to the tradeoff between the perceived safety improvement of lowering LCV speeds, and the perceived safety reduction of the resulting speed differentials between LCVs and other vehicles in the traffic stream.

- Each jurisdiction surveyed specifies vehicle-related requirements for LCV operations differently. Requirements are based on the following considerations: minimum speed on grade, minimum power-to-weight ratio, operation at speeds compatible with other traffic, maximum trailer sway, minimum following distance, heavy trailers preceding lighter trailers, and off-tracking limitations.

- All jurisdictions surveyed report high compliance rates with LCV regulations. This high compliance rate is attributed to severe penalties issued to non-compliant carriers, such as suspension or removal of LCV permits, fines, and/or legal action. This level of compliance is perceived to improve the safety of LCV operations.

- Most jurisdictions do not specifically record LCVs as a distinct vehicle class in their collision reporting system. This poses a barrier to analyzing the extent and nature of LCV collisions in these jurisdictions. It is partly for this reason that the only information most jurisdictions have on LCV safety is either based on the performance of other multi-trailer combinations, or on experiences from other jurisdictions.

3. SAFETY PERFORMANCE OF VEHICLES OPERATING ON ALBERTA'S LCV NETWORK

Chapter 3 presents the findings from a comprehensive analysis of the safety performance of LCVs relative to other vehicle types operating on the LCV network and urban areas. As indicated in Chapter 1, safety performance is defined in terms of collision frequency and rate. Rate is a function of traffic exposure.

The chapter starts with an overview of the methodologies used to analyze collisions, determine traffic exposure, and calculate rates by vehicle type. This is followed by a comprehensive analysis of collision frequency and rate for vehicles operating on the LCV network. Next, the chapter presents the results of a comprehensive collision analysis for urban areas. In this case, there are no rate calculations as traffic volume information by vehicle type is not available for these areas. Finally, the results of a sensitivity analysis of vehicles-in-collisions rates to changes in traffic exposure are presented.

3.1. METHODOLOGY

To determine the safety performance of LCVs operating on Alberta's LCV network, it is necessary to: (1) conduct a comprehensive collision analysis of vehicles operating on the network, (2) develop traffic exposure estimates by vehicle type, and (3) calculate collision rates and vehicles-in-collisions rates by vehicle type. The methodology used for each of these components of the study is presented in this section. The exposure methodology is based on doctoral thesis research by Regehr (2007).

3.1.1. Collision Analysis

This collision analysis is based on data extracted by Alberta Infrastructure and Transportation from the Alberta Collision Information System (ACIS).

While information on the types of vehicles involved in collisions is available in the database, ACIS does not differentiate between the specific types of double trailer configurations that are involved in collisions (i.e., Turnpike doubles, Rocky Mountain doubles, or other types of doubles). To address this data gap, the project team contacted all trucking companies identified as operating LCVs to verify the actual vehicle configuration involved in the collision. There were 2,038 double trailer combinations involved in collisions over the study period in urban areas and the LCV network. The collision report for each case was provided to the project team by AIT for use while contacting each carrier.

Through a series of telephone calls, electronic mail exchange, and other available sources, the project team determined the number of RMDs and TPDs involved in collisions in urban areas and the LCV network between 1999 and 2005.

Alberta Infrastructure and Transportation also conducted their own investigation for collisions involving triple trailer combinations on the LCV network. This information was provided to the project team for use in the analysis.

For the purposes of this study, the following are identified as urban areas: Calgary, Edmonton, Lethbridge, Red Deer, Medicine Hat, Fort McMurray, and Grande Prairie. LCV network routes through other towns in the study area (e.g., Hinton, Fort McLeod, Peace River, Valleyview, Athabasca, and others) are included in the comprehensive collision analysis pertaining to vehicles operating on the LCV network. The collision analysis for urban areas is discussed in Section 3.4.

As stated in Section 1.5, the vehicles of interest to this study are: passenger vehicles, straight trucks and bobtails, tractor semitrailers, legal-length tractor double trailers, Rocky Mountain doubles, Turnpike doubles, and triple trailer combinations. Therefore, the collision analysis only refers to these vehicles.

3.1.2. Exposure Analysis

The objective of the exposure analysis is to develop volume estimates by vehicle type on the Alberta LCV network. The exposure analysis involves five steps.

Step 1 divides the LCV network into segments, which are assumed to have homogeneous LCV volume characteristics. The LCV segments consist of one or more traffic control sections. The segmentation process applies three criteria (Figure 4):

- LCV segments must intersect other LCV segments at segment nodes.
- LCV segment nodes occur at locations where the divided/undivided nature of the highway changes.
- Urban area boundaries intersect at LCV segment nodes.

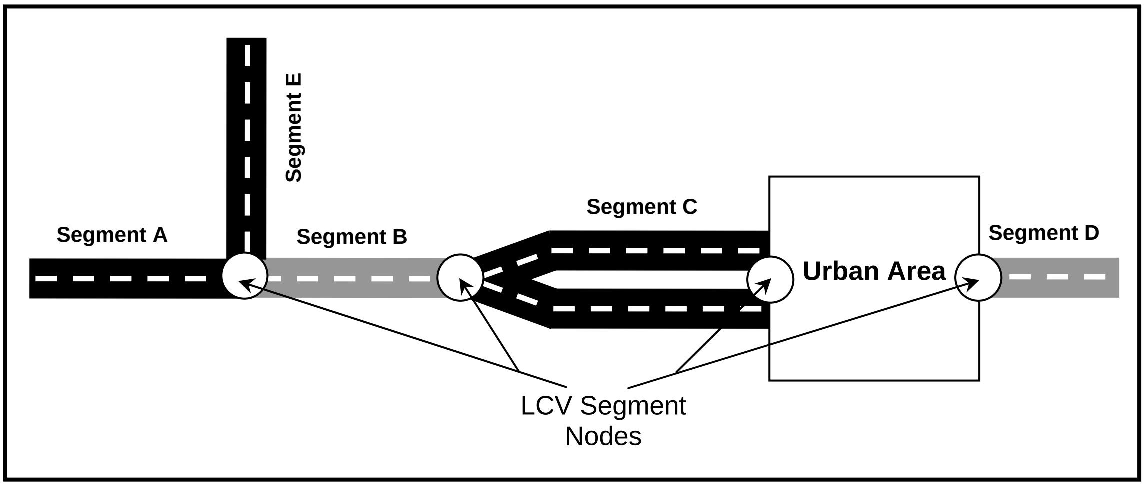


Figure 4: LCV segmentation

Step 2 uses existing volume data provided by AIT to determine the volumes of passenger vehicles, straight trucks and bobtails, and all tractor trailers (i.e., tractor semitrailers, legal-length tractor double trailers, and LCVs) on the LCV network for each year in the study period. Total volumes for each traffic control section are expressed as weighted annual average daily traffic (WAADT), with the fleet mix distributions provided as a percent of this total. As illustrated in

Figure 5, the total distance traveled (i.e., the vehicle kilometers of travel or VKT) by passenger vehicles, straight trucks and bobtails, and all tractor trailer combinations is determined directly from this step. The total distance traveled by each vehicle type within the tractor trailer combinations category is determined in subsequent steps. The sum of the distance traveled by each of these vehicle types equals the total distance traveled by tractor trailer combinations for each LCV segment.

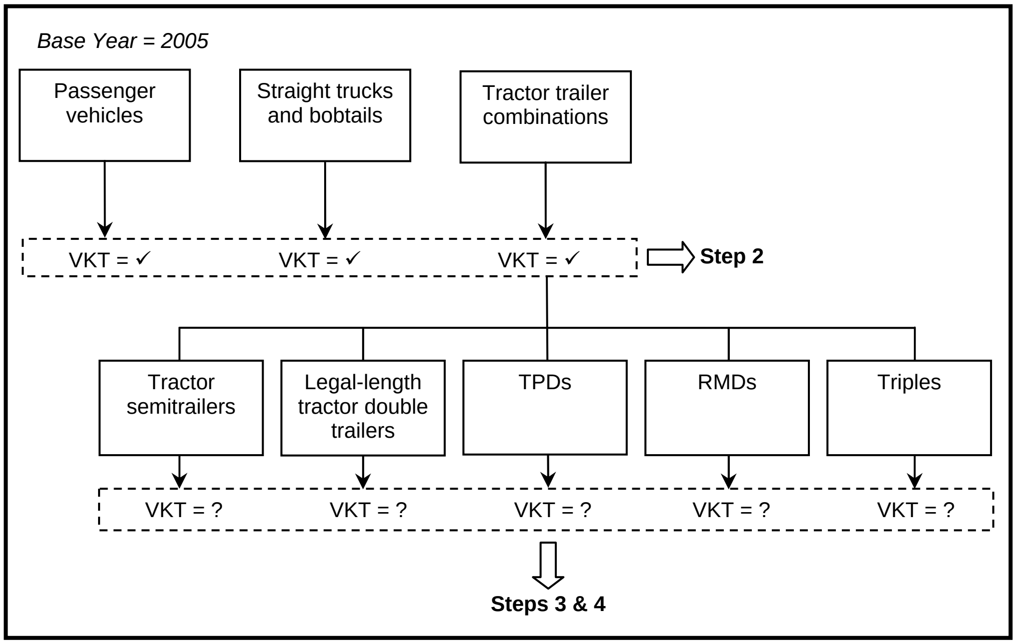


Figure 5: Schematic of VKT determination for different vehicle types

Step 3 determines LCV exposure for each LCV segment in the base exposure estimation year. In this analysis, 2005 was considered the base exposure estimation year since LCV volume data from a variety of sources was available for this year. LCV exposure estimates are assumed to remain constant along the length of the LCV segment irrespective of annual average daily traffic (AADT) or annual average daily truck traffic (AADTT) changes along the segment. The project team used a tiered approach to accomplish this step. This approach, originally developed and applied for Manitoba truck traffic volumes by Tang (2003), overcomes existing gaps in LCV volume data and enables a variety of data sources to be utilized and incorporated into one information system. The tiers work as follows:

1. Tier 1 applies LCV volumes measured by a WIM device or automatic vehicle classifier (AVC) directly to the LCV segment on which it is located. A complete set of WIM data is available for five sites on the Alberta LCV network in 2005. These sites are located on Highway 2 near Red Deer and Leduc, on Highway 3 near Fort McLeod, on Highway 16 near Edson, and on Highway 2A near Leduc. Regehr and Montufar (2007) developed an algorithm to classify LCVs from standard WIM datasets using inter-axle spacing measurements. This algorithm was calibrated in Alberta to determine volumes for RMDs, TPDs, and triple trailer combinations from these datasets. In addition, a special two-week AVC survey conducted in 2005 on Highway 63 provided vehicle length data. The principles developed in the algorithm for WIM datasets were adapted and applied to the AVC dataset. The volumes of tractor semitrailers and legal-length tractor double trailers were also determined from the WIM and AVC datasets.

2. Tier 2 transfers known LCV volumes to adjacent LCV segments on which direct measurements are not available. Transfers are made only if no material changes in LCV volumes are expected on the adjacent segments. Data from three Saskatchewan WIMs were processed using the classification algorithm to estimate LCV volumes on Highways 1, 9, and 16 in Alberta.

3. Tier 3 applies LCV volume estimates to remaining links according to the following hierarchy of data sources: AIT Commercial Vehicle Enforcement Branch officers, 12-hour classification counts conducted by AIT, short-term classification counts conducted by the project team, and the 1999 National Roadside Survey. The project team applied LCV intersection flow balancing techniques at intersections where a major origin-destination pattern was identified due to the presence of an urban area or an important regional trucking route. Intersection flow balancing was not applied in cases where the intersection node was an urban area or where one of the intersecting routes experienced fewer than five LCVs per day (as identified by the Commercial Vehicle Enforcement Branch officers). Flow balancing was applied to LCV traffic at six intersections: Highway 16 and Highway 43; Highway 43 and Highway 49; Highway 2 and Highway 35; Highway 28 and Highway 63; Highway 16 and Highway 16A; and Highway 1 and Highway 1A. The LCV intersection flow balancing technique is illustrated in the schematic diagram shown in Figure 6.

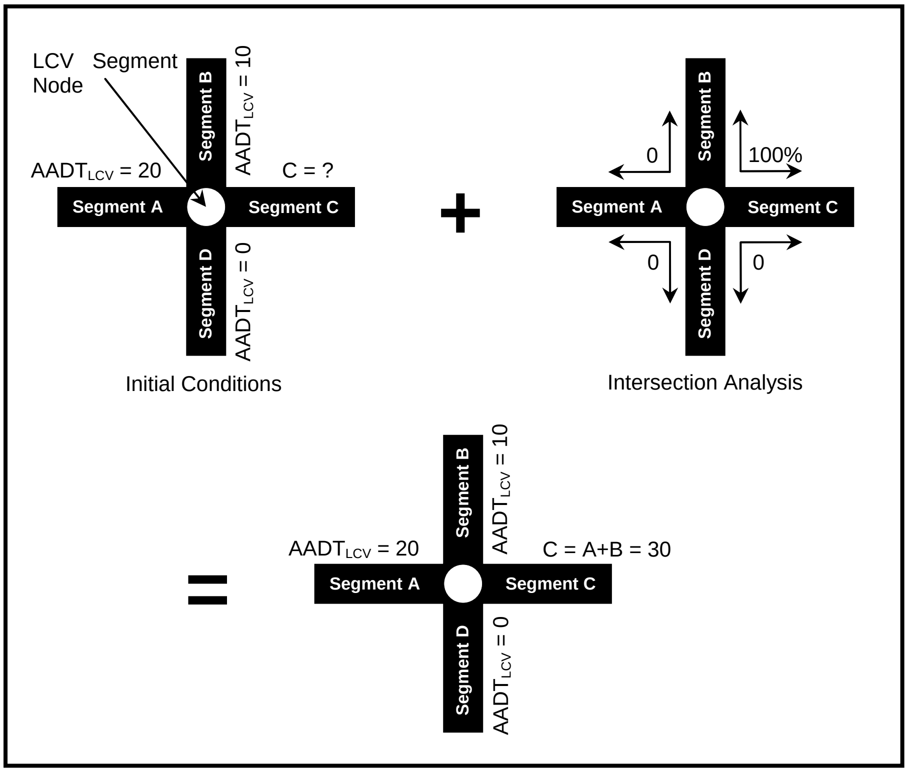


Figure 6: LCV intersection flow balancing technique

Step 4 in the exposure analysis assigns a permanent classification control station (WIM or AVC) to each segment for which there is no LCV, tractor semitrailer, or legal-length tractor double trailer classification data available for the base year. The assignment is based on "similar highway" judgments made by the project team and confirmed with industry experts. The tractor trailer combination fleet mix distribution measured at the permanent classification control station was applied to the tractor trailer combination estimate on the target segment. For example, in cases where the LCV volume estimates were provided by AIT Commercial Vehicle Enforcement Branch officers, the total daily LCV volume was subtracted from the total daily volume of tractor trailer combinations. The remaining tractor trailer combination traffic was divided into tractor semitrailers and legal-length tractor double trailers according to the relative proportions of these vehicles observed at the control station. Similarly, the LCV fleet mix at the control station was applied to the known LCV volumes on the target segment to determine specific LCV types.

Step 5 applies the tractor trailer combination fleet mix distribution determined for each LCV segment in the base year to the corresponding LCV segment in each of the other years in the study period. The proportion of travel by each vehicle type was calculated by dividing the total distance traveled by each vehicle type by the total distance traveled by all tractor trailer combinations along each LCV segment in the base year. This distribution was assumed to remain constant over the study period. The distribution was then multiplied by the total distance traveled by tractor trailers in each year in the study period.

Once these five steps were completed, exposure estimates for the LCV network became available for use in the rate calculations.

3.1.3. Rate Calculations

Two types of rate calculations can assist in determining safety performance based on traffic exposure. Collision rate by vehicle type, and vehicles-in-collisions rate by vehicle type. The study team determined which collision rate analysis method to use based on the type of analysis performed, as well as on the 2001 Study.

The two equations used in these rate calculations are:

$$\textit{Collision rate} = \frac{\textit{Number of collisions by vehicle type}}{\textit{Total exposure by the same vehicle type}}$$

$$\textit{Vehicles-in-collisions rate} = \frac{\textit{Number of vehicles of a given type involved in collisions}}{\textit{Total exposure by the same vehicle type}}$$

The collision rate is always less than or equal to the vehicles-in-collisions rate because the former deals with the number of collisions while the latter deals with vehicles in collisions for the same exposure levels.

3.2. EXPOSURE ESTIMATES FOR LCV NETWORK

Table 5 shows the total distance traveled by vehicle type on the LCV network over the study period. Between 1999 and 2005, there were nearly 67 billion vehicle-kilometers of travel (VKT) on Alberta's LCV network by the study vehicles, resulting on an average of about 10 billion VKT per year. Passenger vehicles accounted for 83 percent (56 billion) and trucks (straight trucks and bobtails, tractor semitrailers, legal-length tractor double trailers, and LCVs) accounted for 17 percent (11 billion).

Table 5: Exposure estimates by vehicle type for the LCV network (1999-2005)

Vehicle type	**Total distance traveled (100 million kilometers)**	**Average distance traveled per year (100 million kilometers)**
Passenger vehicle	558.70	79.81
Straight truck and bobtail	29.82	4.26
Tractor semitrailer	56.50	8.07
Legal-length tractor double trailer	21.59	3.08
Rocky Mountain double	1.12	0.16
Turnpike double	1.31	0.19
Triple trailer	0.13	0.02
Total	**669.17**	**95.60**

Of the truck VKT, tractor semitrailers accounted for one-half, straight trucks and bobtails accounted for 27 percent, legal-length double trailer combinations accounted for 20 percent, and LCVs accounted for two percent. Figure 7 shows a flow map of LCV traffic on Alberta's LCV network for 2005. This traffic exhibits the following characteristics:

- Nearly one-half of all LCV VKT occurs on Highway 2 between Calgary and Edmonton. This highway section represents less than five percent of the LCV network centerline-kilometers.

- Two highways comprised two-thirds of all LCV VKT; 52 percent on Highway 2 and 13 percent on Highway 63. These highways represent 22 percent of the LCV network centerline-kilometers.

- Five highways, which represent one-half of the LCV network centerline-kilometers, comprised over 80 percent of all LCV VKT:

    - 52 percent on Highway 2
    - 13 percent on Highway 63
    - 7 percent on Highway 43
    - 6 percent on each of Highways 1 and 16

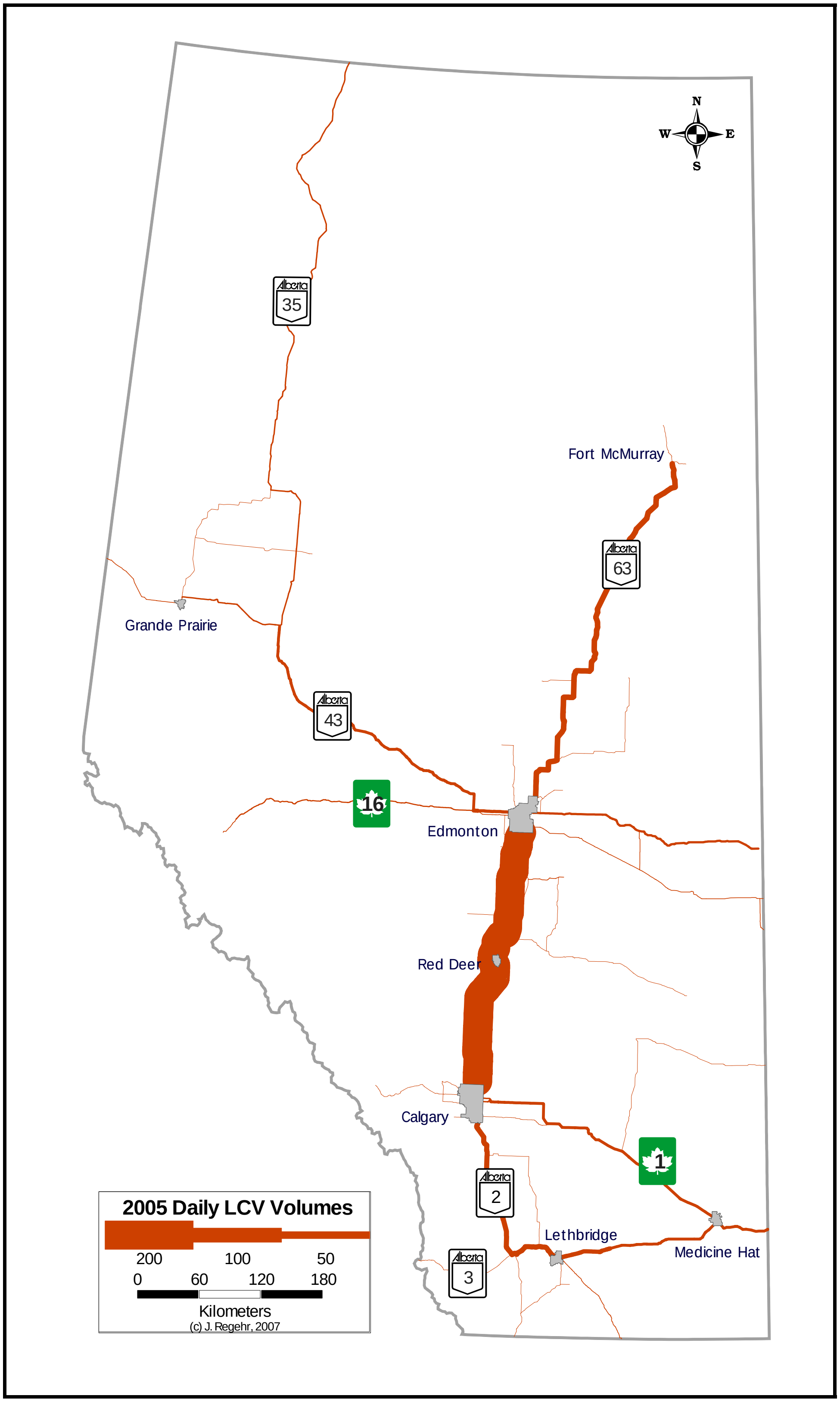


Figure 7: 2005 daily LCV volumes on the LCV network
Source: J. Regehr, Ph.D. thesis research, 2007

3.3. COLLISION FREQUENCY AND RATE ANALYSIS FOR LCV NETWORK

This analysis refers to collisions taking place on the LCV network, and does not consider collisions in urban areas. The analysis pertaining to urban areas is contained in Section 3.4.

3.3.1. Collisions by Vehicle Type

Between 1999 and 2005 there were 49,963 reported collisions on Alberta's LCV network involving 94,624 vehicles (or "objects"). Table 6 shows the number of vehicles by type. This analysis is only concerned with the seven vehicle types of interest to the study, and subsequent analysis in this section only deals with these vehicles.

Table 6: Number of vehicles involved in collisions on the LCV network by type

Vehicle type	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Total**	**Avg per yr**
Passenger vehicle	7477	7531	7931	8440	9036	9700	9790	59905	8558
Straight truck and bobtail	308	405	488	516	627	673	808	3825	546
Tractor semitrailer	302	326	331	322	388	420	402	2491	356
Legal-length tractor double trailer	132	138	125	149	160	144	135	983	140
Rocky Mountain double	3	1	5	2	6	9	10	36	5
Turnpike double	1	4	4	1	4	3	4	21	3
Triple trailer	1	1	1	0	1	2	2	8	1
Total study vehicles	**8224**	**8406**	**8885**	**9430**	**10222**	**10951**	**11151**	**67269**	**9610**
Other	2955	3212	3643	3726	4055	4395	4740	26726	
Unknown	46	79	98	101	82	101	122	629	
GRAND TOTAL	11225	11697	12626	13257	14359	15447	16013	94624	

Over the study period, there were 49,738 reported collisions involving the 67,269 ***study vehicles*** on the LCV network. This represents an average of 7,106 reported collisions involving 9,610 vehicles per year. Two-thirds of these collisions were single-vehicle and one-third was multiple-vehicle. These collisions resulted in 1,275 people killed and 28,142 people injured.

Figure 8 illustrates the historical distribution of vehicles involved in reported collisions for the seven-year period. The primary graph shows all vehicle types considered in this study, and the imbedded graph shows trucks only.

On average, over the study period, passenger vehicles accounted for about 90 percent of all vehicles involved in collisions, and trucks accounted for about 10 percent. Of the trucks involved in collisions, over one-half were straight trucks and bobtails. Tractor semitrailers accounted for about one-third of all trucks involved in collisions, and legal-length tractor double trailers accounted for nearly 15 percent. Long combination vehicles accounted for about one percent of all trucks involved in collisions.

Figure 8 also shows that between 1999 and 2005 there was a decreasing trend in the percentage of vehicles involved in collisions for all vehicle types, except for straight trucks and bobtails. This vehicle type showed an increasing trend over the study period.

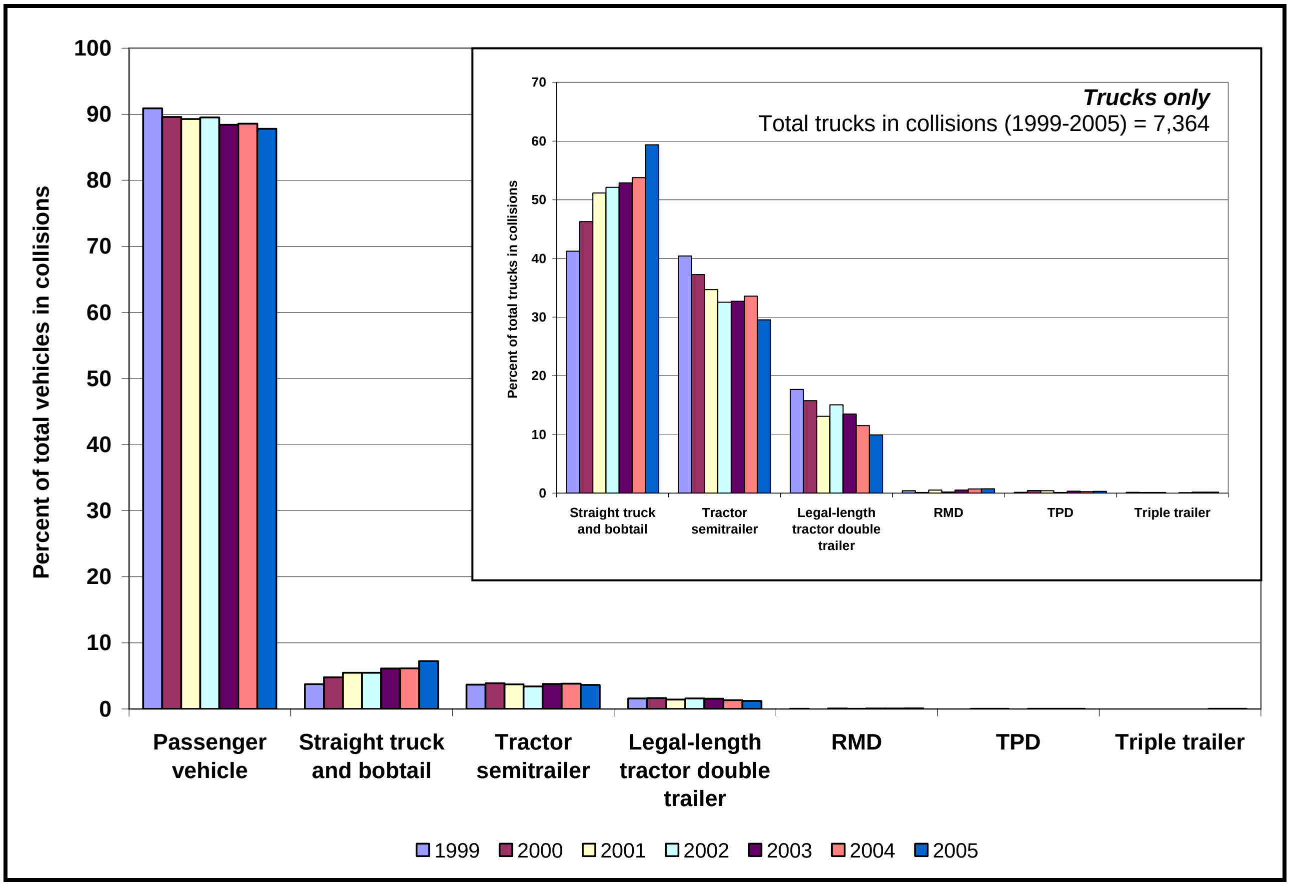


Figure 8: Historical distribution of vehicles involved in collisions by type

The collision rates for each of the study vehicle types over the seven-year period are shown in Table 7. This rate is different than the vehicles-in-collisions rate which is calculated using the total number of vehicles in collisions, instead of the number of collisions, as discussed in Section 3.1.3.

The table shows that straight trucks and bobtails had the highest collision rate at 123 collisions per 100 million VKT. Turnpike doubles showed the lowest collision rate of all vehicle types at 16 collisions per 100 million VKT. Long combination vehicles as a group had an overall collision rate of 25 collisions per 100 million VKT (65 collisions / 256 million VKT). Articulated combinations in general (tractor semitrailers, legal-length tractor doubles, and LCVs) had a collision rate of 42 collisions per 100 million VKT (3,389 collisions / 8,065 million VKT). This collision rate is similar to that found by Montufar (2002) for the same vehicle types operating on Alberta’s Primary highway network from 1993 to 1998.

Table 7: Collision rate by vehicle type on the LCV network (1999-2005)

Vehicle type	Number of collisions	Distance traveled (100 million km)	Collision rate (Collisions per 100 million VKT)
Passenger vehicle	46375	558.70	83
Straight truck and bobtail	3670	29.82	123
Tractor semitrailer	2369	56.50	42
Legal-length tractor double trailer	955	21.59	44
Rocky Mountain double	36	1.12	32
Turnpike double	21	1.31	16
Triple trailer	8	0.13	62
Total	**49738**	**669.17**	**74**

Note that the total number of collisions is not the sum of all collisions because there are cases where two different vehicle types are involved in the same collision. If one were to take the sum of the individual vehicle types, there would be double-counting.

3.3.2. Collision Severity

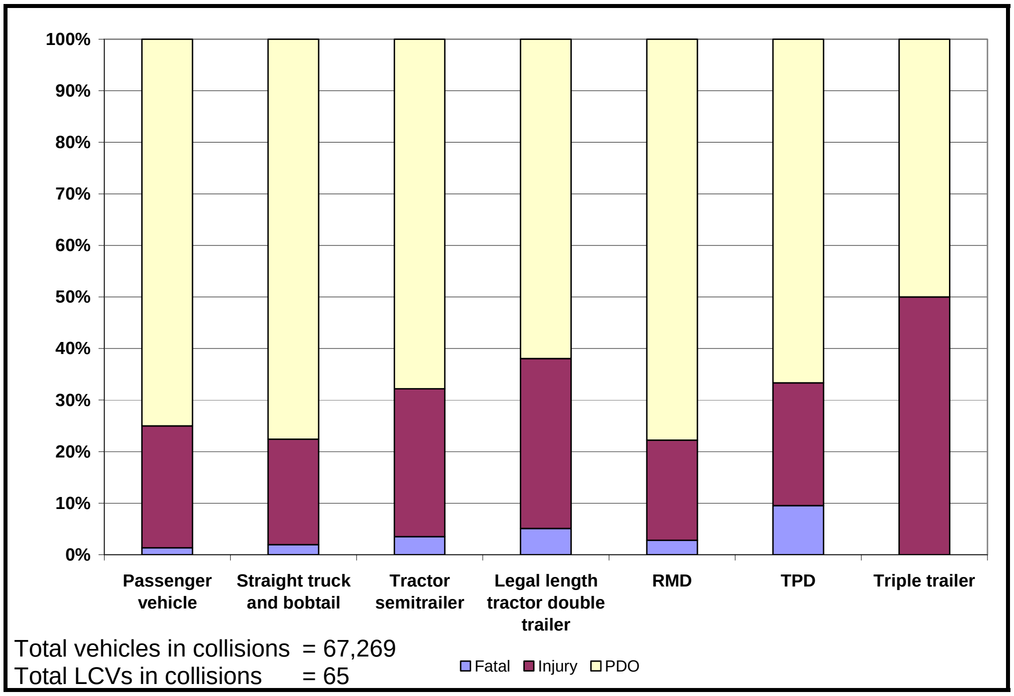
Table 8 illustrates the number of vehicles in reported collisions on the LCV network by collision severity. Figure 9 shows the percent distribution by vehicle type within each severity category.

Passenger vehicles accounted for about 80 percent of all vehicles involved in fatal collisions and nearly 90 percent of all vehicles in injury or property damage only (PDO) collisions. Comparatively, trucks accounted for about 20 percent of all vehicles involved in fatal collisions, and 10 percent of all vehicles in injury or PDO collisions.

Considering only trucks involved in collisions, LCVs accounted for one percent of all trucks in each fatal, injury, and PDO collisions. This compares to other articulated units (tractor semitrailers and legal-length tractor double trailers), which accounted for nearly two-thirds of trucks involved in fatal collisions, 57 percent of trucks in injury collisions, and 43 percent of trucks in PDO collisions.

Table 8: Vehicles involved in collisions by severity on the LCV network

Vehicle type	Fatal	Injury	PDO	Total vehicles
Passenger vehicle	791	14155	44959	**59905**
Straight truck and bobtail	75	782	2968	**3825**
Tractor semitrailer	87	715	1689	**2491**
Legal-length tractor double trailer	50	324	609	**983**
Rocky Mountain double	1	7	28	**36**
Turnpike double	2	5	14	**21**
Triple trailer	0	4	4	**8**
Total vehicles	**1006**	**15992**	**50271**	**67269**



Total vehicles in collisions = 67,269
Total LCVs in collisions = 65

Figure 9: Vehicles in collisions by severity on the LCV network

Long combination vehicles were involved in 36 single-vehicle collisions and 29 multiple-vehicle collisions.

Rocky Mountain doubles were involved in 24 single-vehicle collisions and 12 multiple-vehicle collisions. Nearly all single-vehicle collisions resulted in PDO (21 of 24), and three resulted in injury. The severity outcome of multiple-vehicle collisions resulted in one fatal, four injury, and seven PDO collisions.

Turnpike doubles were involved in 11 single-vehicle and 10 multiple-vehicle collisions. Eight of the 11 single-vehicle collisions resulted in PDO and three in injury. Six of the 10 multiple-vehicle collisions resulted in PDO, two in injury, and two in fatality.

Triple trailer combinations were involved in one single-vehicle and seven multiple-vehicle collisions. The single-vehicle collision resulted in PDO. Four of the seven multiple-vehicle collisions resulted in injury and the remaining three resulted in PDO.

The involvement of LCVs in single-vehicle collisions was investigated further. The analysis found that nearly all of the single-vehicle LCV collisions (22 of 36) took place during hours of darkness, and mostly between midnight and 05:00. One-quarter of these (9 of 36) involved animal strikes, and the remaining three-quarters involved trucks running off the road. Over one-third of the LCV single-vehicle collisions (13 of 36) took place in the fall, one-quarter in each winter and spring (9 of 36), and 14 percent (5 of 36) in summer. Adverse road surface condition (snow, ice, slush or wet) played a role in about 40 percent of these collisions.

Table 9 shows the vehicles-in-collisions rates by severity and vehicle type on the LCV network for the study period.

Table 9: Vehicles-in-collisions rate by severity for LCV network (vehicles in collisions per 100 million VKT)

Vehicle type	Fatal	Injury	PDO	Total vehicles
Passenger vehicle	1	25	80	**107**
Straight truck and bobtail	3	26	100	**128**
Tractor semitrailer	2	13	30	**44**
Legal-length tractor double trailer	2	15	28	**46**
Rocky Mountain double	1	6	25	**32**
Turnpike double	2	4	11	**16**
Triple trailer	0	31	31	**62**
Total	**2**	**24**	**75**	**101**

Note that the rates for the "total vehicles" column are calculated by taking the total vehicles in collisions by type divided by the total exposure by vehicle type, and not by adding the fatal, injury, and PDO columns. As with any calculation of this nature, there are rounding errors associated with it.

3.3.3. Temporal Characteristics of Collisions

The temporal distribution of collisions refers to month of year, day of week, and time of day. Months were grouped into seasons as follows:

- Spring ➔ March, April and May
- Summer ➔ June, July and August
- Fall ➔ September, October and November
- Winter ➔ December, January and February

The season with the largest proportion of total vehicles involved in collisions was winter (29 percent), followed by fall (28 percent). Spring accounted for the lowest proportion of total vehicles involved in collisions (19 percent), followed by summer (24 percent).

Figure 10 illustrates the temporal distribution of vehicles in collisions by season. As the figure shows, for each vehicle type, winter and fall are the seasons which show the largest percent of vehicles involved in collisions. This trend is also evident in collisions involving trucks only (grouping all truck categories), articulated combinations (grouping tractor semitrailers, legal-length doubles, and LCVs), and LCVs only. The winter effect is more evident, however, for tractor semitrailers, legal-length tractor doubles, and triple trailer combinations (although the case for triples is exaggerated due to the small frequency of involvement).

Of the eight triple trailer combinations involved in collisions, winter accounted for three, fall and spring accounted for two each, and summer accounted for one.

Nearly one-third (11 of 36) of RMDs were involved in collisions in winter, and another 30 percent (11 of 36) were involved in collisions in fall. Spring accounted for 28 percent (10 of 36) of RMDs in collisions, and summer accounted for 11 percent (4 of 36).

Turnpike doubles were involved in six collisions in winter and seven in fall. Spring and summer accounted for the smallest proportion of collisions involving TPDs (4 of 21) each season.

Regarding the severity of collisions involving LCVs by season, there are no obvious seasonal effects on collision severity based on collision frequency. This is because LCVs are mainly involved in PDO collisions. Of the three fatal collisions involving LCVs, one took place in spring and two in fall. Similarly, of the 16 injury collisions involving LCVs, five took place in each winter and spring, two took place in summer, and four took place in fall.

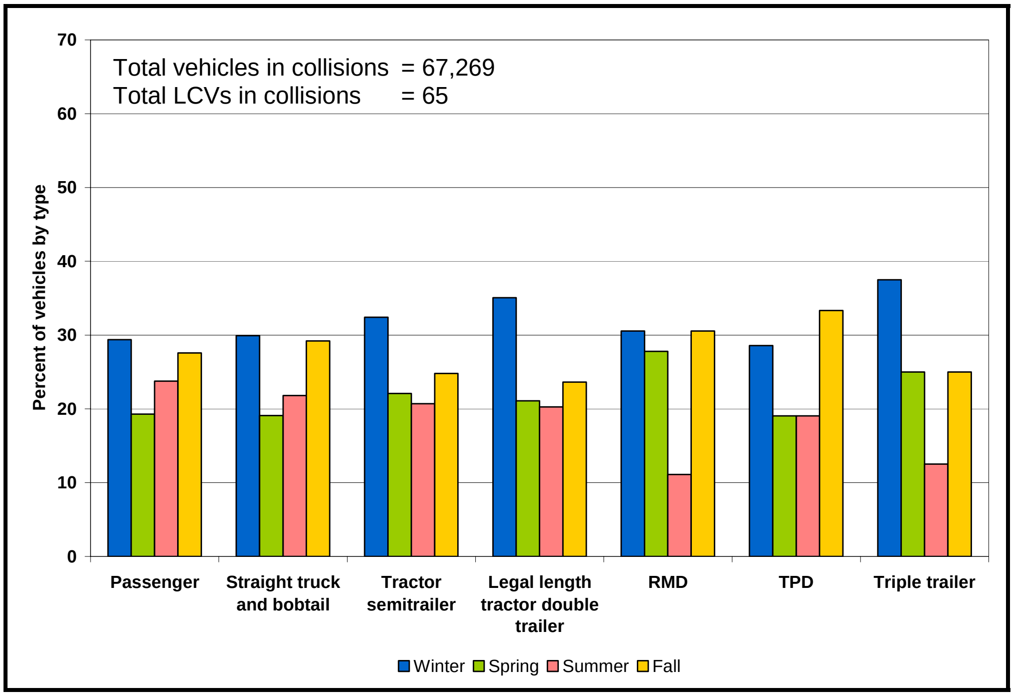
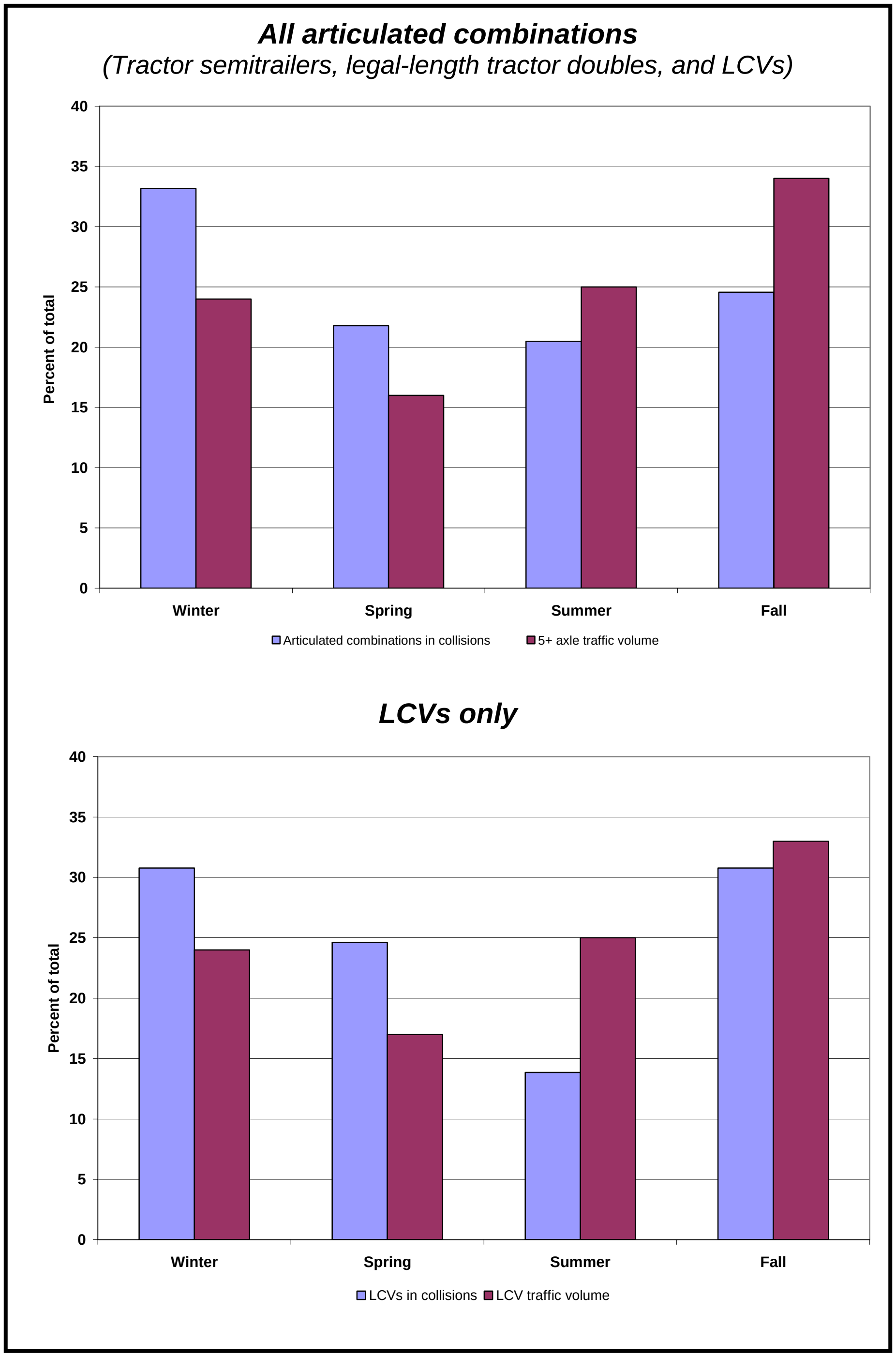


Figure 10: Vehicles in collisions on the LCV network by type and season

Figure 11 shows the seasonal effect on traffic and vehicles in collisions for articulated combinations (tractor semitrailers, legal-length tractor doubles, and LCVs) on the LCV network. This figure was created using traffic data from the five WIM stations on the LCV network, and assuming that the 5+ axle vehicle category is a good representation of all articulated combinations. The figure shows that winter and spring are over-represented in terms of the number of articulated combinations involved in collisions relative to their corresponding traffic volume operating on the network during these seasons. The opposite is true for summer and fall. In these seasons, the percent of articulated combinations involved in collisions is less than the corresponding percent of traffic operating on the network.

In the case of LCVs only, the gap between the number of LCVs involved in collisions and the corresponding percent of LCV traffic in the fall is not large, and for all practical purposes, the two values are the same. However, the gaps in all other situations for both LCVs only and all articulated combinations are material.



All articulated combinations

(Tractor semitrailers, legal-length tractor doubles, and LCVs)

LCVs only

Figure 11: Seasonal effect on traffic and vehicles in collisions for articulated combinations on the LCV network

Regarding day of week distribution of collisions, there were no obvious differences by vehicle type. Weekends showed the smallest proportion of vehicles involved in collisions, and weekdays showed the largest proportion. This is indicative of traffic operating patterns.

Time of day plays a significant role in the number of vehicles involved in collisions by vehicle type. Time of day was grouped into the following periods for analysis purposes:

- Morning ➔ 06:00 to 11:59
- Afternoon ➔ 12:00 to 17:59
- Evening ➔ 18:00 to 23:59
- Night ➔ 00:00 to 05:59

Figure 12 illustrates the temporal distribution of vehicles in collisions by time of day. In general, day time (morning and afternoon) accounted for 60 percent of all vehicles involved in collisions, and night time (evening and night) accounted for 40 percent. This distribution applied to most vehicle types, except LCVs, which may be explained by their operating characteristics.

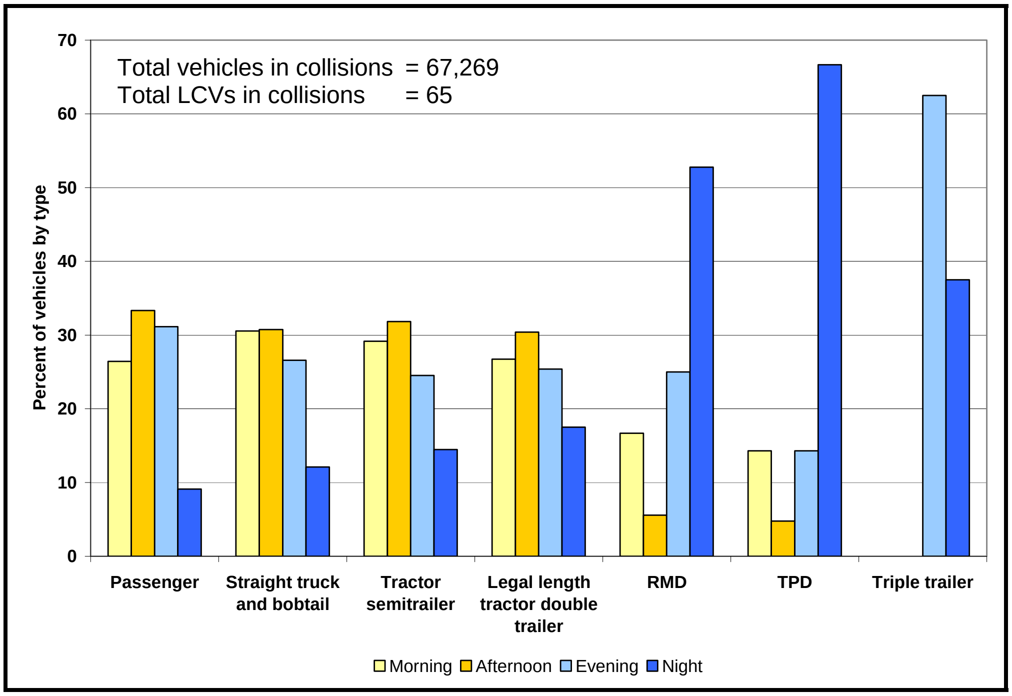


Figure 12: Vehicles in collisions on the LCV network by type and time of day

Of the eight triple trailer combinations involved in collisions, late evening hours accounted for five and night hours accounted for three.

Over one-half (19 of 36) of RMDs were involved in collisions at night and one-quarter (9 of 36) were involved in collisions during the evening hours. Morning hours accounted for 6 of 36 RMDs in collisions, and afternoon hours accounted for the remaining two.

Turnpike doubles were involved in two-thirds (14 of 21) of collisions during night hours. Evening and morning hours accounted for three TPDs involved in collisions each. The remaining collision took place in the afternoon hours.

3.3.4. Collision Location and Highway Type

Table 10 shows the number of vehicles involved in collisions by location. Nearly three-quarters of all vehicles were involved in non-intersection related collisions. Fifteen percent were involved in intersection-related collisions.

Regarding LCVs, 80 percent of these vehicles were involved in non-intersection related collisions and two of the 65 were involved in intersection-related collisions. The location type for the remaining 11 LCVs was cited as either "other" or "unknown".

Table 10: Vehicles in collisions by location on the LCV network

Vehicle type	**Non-intersection**	**Intersection**	**Other**	**Unknown**	**Total vehicles**
Passenger vehicle	43340	9445	852	6268	**59905**
Straight truck and bobtail	2825	411	73	516	**3825**
Tractor semitrailer	1880	227	85	299	**2491**
Legal-length tractor double trailer	753	97	29	104	**983**
Rocky Mountain double	27	2	1	6	**36**
Turnpike double	18	0	0	3	**21**
Triple trailer	7	0	0	1	**8**
Total vehicles	**48850**	**10182**	**1040**	**7197**	**67269**

The analysis is based on the "Traffic Control Device" field from ACIS.
"Other" refers to pedestrian crosswalks, school bus, lane control signal, and railway crossing.

Table 11 illustrates the highway type associated with vehicle involvement in collisions on the LCV network. Two-lane undivided highways accounted for one-third (22,135 of 67,269), and multi-lane highways accounted for one-half of total vehicles involved in collisions. This is a reflection of the level of traffic exposure on each highway type.

Of all vehicles involved in collisions on two-lane undivided highways, trucks accounted for 12 percent and passenger vehicles accounted for 88 percent. This distribution was the same for vehicles involved in collisions on multi-lane highways.

Table 11: Vehicles in collisions by highway type on the LCV network

Vehicle type	**Gravel**	**2-lane undivided**	**Multi-lane**	**Unknown**	**Total vehicles**
Passenger vehicle	17	19452	31040	9396	**59905**
Straight truck and bobtail	2	1431	2058	334	**3825**
Tractor semitrailer	0	811	1496	184	**2491**
Legal-length tractor double trailer	0	419	497	67	**983**
Rocky Mountain double	0	20	16	0	**36**
Turnpike double	0	2	19	0	**21**
Triple trailer	0	0	8	0	**8**
Total vehicles	**19**	**22135**	**35134**	**9981**	**67269**

Vehicles-in-collisions rates per 100 million VKT by highway type are shown in Table 12. This rate was calculated using only exposure information for 2005 as some sections of the network were divided over the study period and the project team considered it more practical to use only the latest exposure information for this analysis. The collision frequency used was the average by vehicle type over the study period.

Table 12: Vehicles in collisions per 100 million VKT by highway type

Vehicle type	2-Lane undivided		Multi-lane	
	2005 Exposure (100 million VKT)	Rate (vehicles/100 million VKT)	2005 Exposure (100 million VKT)	Rate (vehicles/100 million VKT)
Passenger vehicle	26.24	106	63.70	70
Straight truck and bobtail	1.67	122	3.09	95
Tractor semitrailer	2.53	46	6.56	33
Legal-length tractor double trailer	1.17	51	2.37	30
Rocky Mountain double	0.11	25	0.07	31
Turnpike double	NA	NA	0.20	14
Triple trailer	NA	NA	0.02	60
Total	**31.72**	**100**	**76.01**	**66**

NA –These vehicles are not allowed to operate on undivided highways.
Note that rate calculations are based on non-rounded VKT estimates, therefore the rates shown in this table are not strictly the result of the number of vehicles in collisions shown in Table 11 divided by the exposure shown in Table 12.

In 2005, two-lane undivided highways accounted for about 30 percent of total VKT on the LCV network by all vehicle types, and multi-lane highways accounted for 70 percent. Multi-lane highways showed an overall lower vehicles-in-collisions rate than undivided highways. The overall rate for multi-lane highways was 66 vehicles in collisions per 100 million VKT, compared to 100 for undivided highways. This is expected as it is well documented that divided (or in this case, multi-lane) highways result in lower collision frequency per vehicle-distance traveled than undivided highways.

Rocky Mountain doubles are the only vehicles that showed a larger rate for multi-lane highways than for undivided highways. There is no obvious explanation for this.

The project team plotted the location of collisions involving LCVs on a geographic platform. Figure 13 shows the location of all 65 LCV collisions over the study period, and Figures C-1, C-2, and C-3 in Appendix C show the collision location by LCV type. Four highways accounted for three-quarters of all collisions involving LCVs. These were:

- Highway 2 between Edmonton and Calgary (20 of 65 collisions),
- Highway 35 north of Peace River (10 of 65 collisions),
- Highway 1 east of Calgary (9 of 65 collisions), and
- Highway 43 between Edmonton and Grande Prairie (9 of 65).

Other highways accounted for the remaining 17 collisions involving LCVs as follows:

- Highway 16 (7 of 65),
- Highway 2 south of Calgary (4 of 65),
- Highway 63 (2 of 65),
- Highway 9 (2 of 65),
- Highway 49 (1 of 65), and
- Highway 3 (1 of 65).

Figure 13 also shows that nearly one-half of RMDs were involved in collisions along Highway 35 and 43 northwest of Edmonton, compared to only 22 percent (8 of 36) along Highway 2 between Edmonton and Calgary. This is indicative of the operating patterns of RMDs and the type of LCV activity between these two major centers, where most of the LCVs are TPDs.

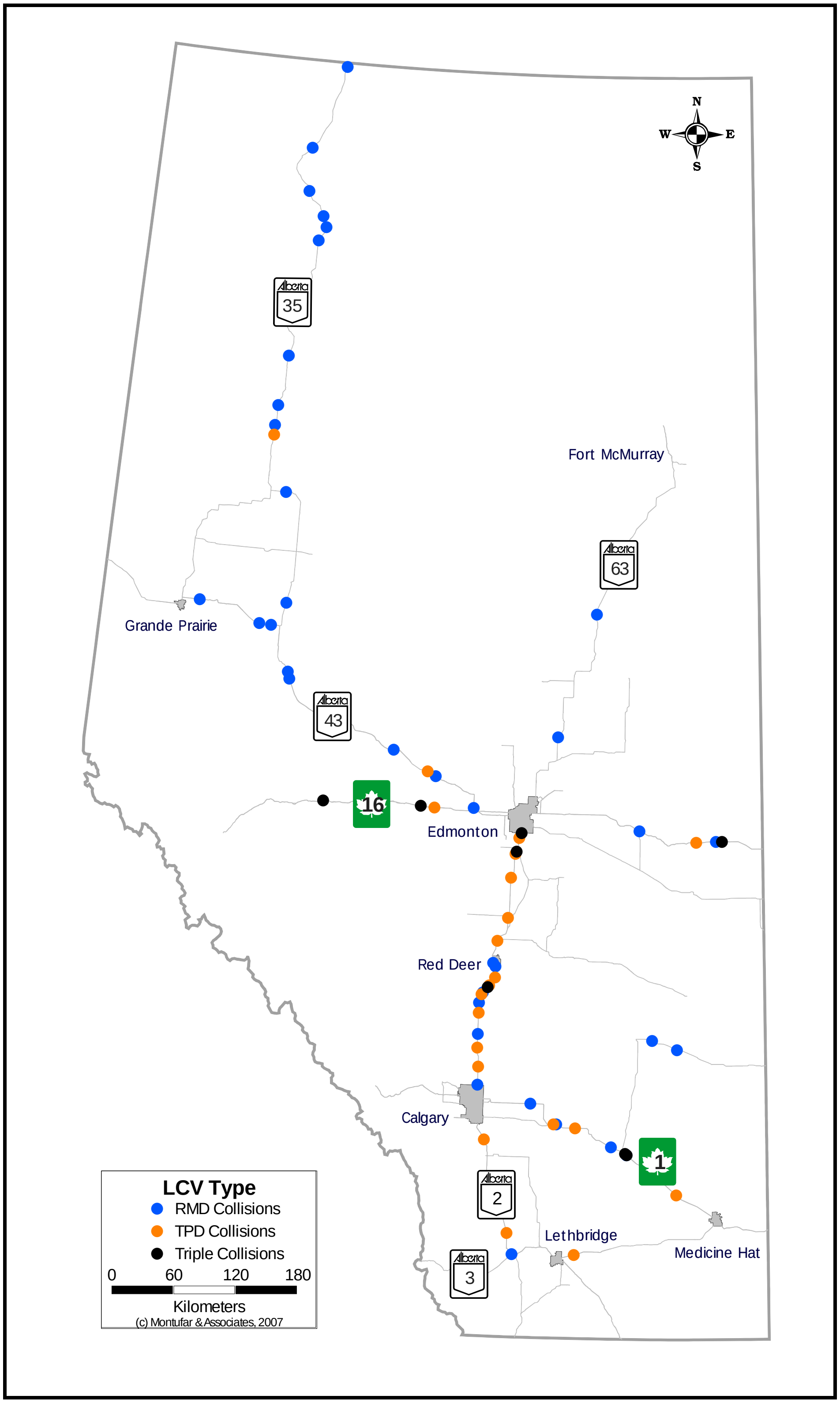


Figure 13: Geographic location of collisions involving LCVs

3.3.5. Collisions Involving Passing Maneuvers

Over the study period there were only two collisions involving LCVs and passing maneuvers. Comparatively, there were 243 other articulated combinations (tractor semitrailers and legal-length doubles) involved in passing-related collisions. There were also 1,584 passenger vehicles and 244 straight trucks and bobtails involved in passing-related collisions. These all took place on both divided and undivided highways.

The two passing-related collisions involving LCVs were associated with an RMD and a TPD. In the first case, the RMD was passing another vehicle on Highway 63. In the second case, the TPD was being passed by another vehicle on a divided section of Highway 2.

3.3.6. Collisions by Driver Age

The minimum age required to obtain a commercial driver's license in Alberta is 18. Special training specifically for LCV operations is required to drive an RMD, TPD, or triple trailer combination. Figure 14 shows the age distribution of drivers involved in collisions by truck type.

The largest proportion of drivers involved in collisions while operating a truck was between the ages of 35 and 44. This age group accounted for one-third of all drivers in collisions. The age group which accounted for the smallest proportion of drivers involved in truck collisions was 65 years or older, accounting for only three percent.

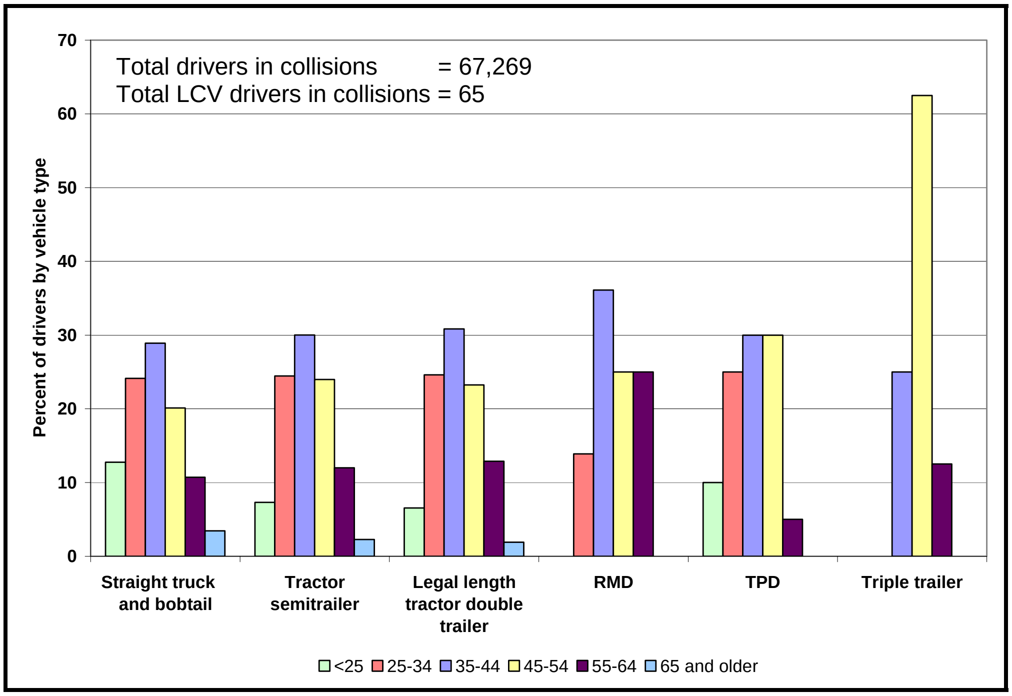


Figure 14: Age distribution of drivers involved in collisions by truck type

When comparing LCVs to other articulated combinations (tractor semitrailers and legal-length tractor doubles), there were no significant differences in terms of the age distribution of drivers involved in collisions while operating these vehicles.

Regarding LCV collisions only, two of the drivers involved in collisions were under age 25 and 10 were between the ages of 25 and 34. These two age categories accounted for nearly 20 percent of all LCVs involved in collisions. Drivers between ages 35 and 44 accounted for nearly one-third of LCVs in collisions (21 of 65). Most of these involved RMDs (13 of 65), six involved TPDs and two involved triple trailers. There were 20 drivers between the ages of 45 and 54 involved in LCV collisions. Five of these were operating triples, nine were operating RMDs and six were operating TPDs. Drivers between the ages of 55 and 64, accounted for 11 of the 65 LCVs in collisions.

3.3.7. Contributing Factors to Collisions

There are at least four types of contributing factors to collisions based on ACIS: *driver condition*, *driver action*, *vehicle condition*, and *environmental condition*. Each of these factors consists of a number of variables. For example, driver condition includes the following variables as shown in the collision report form: driver had been drinking, impaired by alcohol, impaired by drugs, fatigued, and driver had medical defect. Driver action includes: driver committed a stop sign violation, yield sign violation, improper lane change, followed too closely, backed unsafely, and others. Vehicle condition includes: defective brakes, tires failed, improper load, lighting defect, and load shifted. Environmental condition includes: rain, hail, snow, high wind, fog, and others. Table C-1 of Appendix C contains a copy of Alberta's collision report form code definitions.

In this analysis, contributing factor variables that were listed as "normal" were not considered as contributors to a collision. For example, under vehicle condition, one of the variables is "no apparent defect", or under driver action, one of the variables is "driving properly". The analysis excluded these variables as they cannot be interpreted as having contributed to a collision. Similarly, the analysis also excluded variables that were recorded as "unknown" or "other."

There were 67,269 study vehicles involved in reported collisions over the seven-year period. Driver condition was reported as a contributing factor for four percent (2,883 of 67,269) of these vehicles. Driver action was reported for one-quarter (16,791 of 67,269), vehicle condition was reported for one percent (634 of 67,269), and environmental condition was reported for 22 percent (14,928 of 67,269) of these vehicles.

The distribution of contributing factors for passenger vehicles was different from that for articulated combinations (tractor semitrailers, legal-length tractor doubles, and LCVs). In the case of articulated combinations, driver action and environmental condition were each reported for 30 percent of these vehicles. These two contributing factors were reported for 25 percent and 21 percent of passenger vehicles, respectively.

Table 13 shows details about the contributing factors involving LCVs in collisions. This table also includes the "normal" conditions, "unknown", and "other" for reference purposes only. However, the discussion is as previously stated. Driver action and environmental condition were the two contributing factors that were most frequently reported in collisions involving LCVs. Snow and rain were cited as contributing factors in one-quarter of the collisions (16 of 65) involving LCVs. Driver running off the road was cited as a contributing factor in 17 percent of LCV collisions (11 of 65). There is no easy way to find out, however, whether these two contributors to collisions are inter-related. In other words, did the driver run off the road because of the snow or rain, or because of other factors independent of the weather conditions?

Table 13: Contributing factors involving LCV collisions

		RMD	**TPD**	**Triples**	**Total LCV**
Driver condition	Apparently normal	29	17	7	53
	Had been drinking	0	0	0	0
	Impaired by alcohol	1	0	0	1
	Impaired by drugs	0	0	0	0
	Fatigue/asleep	2	1	0	3
	Medical defect	0	0	0	0
	Other	0	0	0	0
	Unknown	4	3	1	8
	Total Drivers	**36**	**21**	**8**	**65**
Driver action	Driving properly	17	13	6	36
	Yield sign violation	0	1	0	1
	Failed to yield right-of-way at Uncontrolled Intersection	0	0	0	0
	Failed to yield right-of-way to Pedestrian	0	0	0	0
	Followed too closely	1	0	0	1
	Parked vehicle	0	1	0	1
	Backed unsafely	0	0	0	0
	Left turn across path	0	0	0	0
	Improper lane change	0	1	0	1
	Disobeyed traffic signal	0	0	0	0
	Run off road	9	2	0	11
	Improper turn	0	0	0	0
	Left of center	1	1	0	2
	Improper passing	1	0	0	1
	Other	0	0	0	0
	Unknown	7	2	2	11
	Total Drivers	**36**	**21**	**8**	**65**
Vehicle condition	No apparent defect	32	18	8	58
	Defective brakes	0	0	0	0
	Tires failed	0	1	0	1
	Improper load/shift	0	0	0	0
	Lighting defect	0	0	0	0
	Other	1	0	0	1
	Unknown	3	2	0	5
	Total Vehicles	**36**	**21**	**8**	**65**
Environmental condition	Clear	23	16	5	44
	Raining	4	1	0	5
	Hail/sleet	1	0	0	1
	Snow	6	3	2	11
	Fog/smog/smoke/dust	1	0	0	1
	High wind	0	1	0	1
	Other	1	0	0	1
	Unknown	0	0	1	1
	Total Vehicles	**36**	**21**	**8**	**65**

An additional indicator of collision causation is the road surface condition at the time of the collision. Figure 15 shows the percent of vehicles involved in collisions by road surface condition. In general, adverse road surface conditions (wet, slush, snow, or ice) were a contributing factors for one-third of total vehicles involved in collisions. This proportion is true for passenger vehicles and all trucks. However, considering articulated combinations only, adverse road surface conditions were a contributing factor in nearly 40 percent of all articulated trucks involved in collisions. This is also true for LCVs only. These findings are consistent with those by Montufar (2002).

Over one-half of LCV collisions (37 of 65) took place during dry road surface conditions as follows: 18 involved RMDs, 15 involved TPDs, and four involved triples. Adverse road surface conditions were a contributing factor in 40 percent of LCV collisions (26 of 65) as follows: 18 involved RMDs, six involved TPDs, and two involved triples.

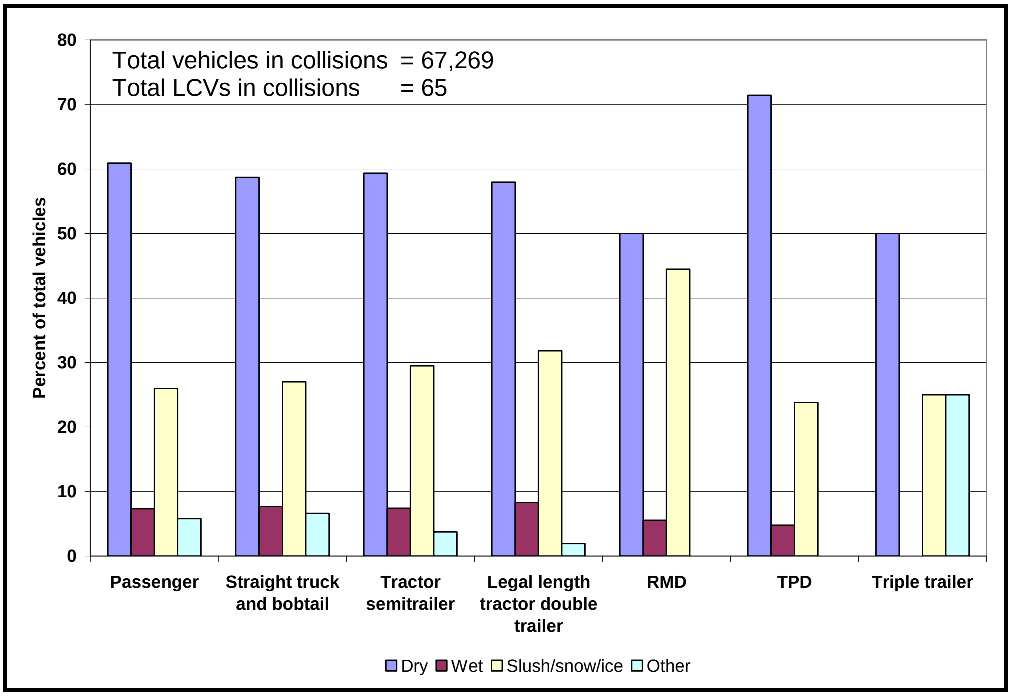


Figure 15: Vehicles involved in collisions by road surface condition
"Other" includes: Loose surface, muddy, other, and unknown

The last issue of discussion in this analysis is the involvement of wildlife in vehicle collisions. Over the study period, there were 337 articulated combinations involved in collisions where an animal was struck. Nine of these vehicles were LCVs, accounting for nearly 15 percent of all LCV collisions. The remaining 328 vehicles were tractor semitrailers (228 of 328) and legal-length tractor doubles (100 of 328). Five of the nine LCVs involved in animal-striking collisions were RMDs, three were TPDs, and one was a triple trailer combination. All nine LCVs involved in these collisions resulted in single-vehicle run-off-the-road collisions.

3.4. COLLISION FREQUENCY ANALYSIS FOR URBAN AREAS

This analysis deals with collisions taking place in urban areas only. For the purposes of this study, the following are identified as urban areas: Calgary, Edmonton, Lethbridge, Red Deer, Medicine Hat, Fort McMurray, and Grande Prairie. LCV network routes through other towns in the study area (e.g., Hinton, Fort McLeod, Peace River, Valleyview, Athabasca, and others) are included in the comprehensive collision analysis pertaining to vehicles operating on the LCV network.

Between 1999 and 2005 there were 443,814 reported collisions in urban areas in Alberta, involving 923,657 vehicles (or objects). Table 14 shows the number of vehicles by type. Similar to the analysis for the LCV network, this analysis is only concerned with the seven study vehicle types previously identified.

Table 14: Number of vehicles by type in reported collisions in urban areas

Vehicle type	1999	2000	2001	2002	2003	2004	2005	Total	Avg per yr
Passenger vehicle	98366	107124	108395	118357	111937	108388	119080	771647	110235
Straight truck and bobtail	3169	3373	3365	3964	3800	3712	4426	25809	3687
Tractor semitrailer	468	573	550	508	542	559	513	3713	530
Legal-length tractor double trailer	83	77	86	83	60	67	91	547	78
Rocky Mountain double	0	0	1	0	0	0	1	2	<1
Turnpike double	1	3	3	5	3	4	6	25	4
Triple trailer	2	3	2	1	4	0	2	14	2
Total study vehicles	**102089**	**111153**	**112402**	**122918**	**116346**	**112730**	**124119**	**801757**	**114536**

Note: The urban collision database listed 66 vehicles as triple trailer combinations involved in collisions. However, based on the experience from AIT's telephone calls involving triples on the LCV network, it was determined that the same kind of discrepancy was present in urban areas. Therefore, the project team decided to consider only the 14 triples with a van/box trailer body type, and remove from the triple trailer analysis the 52 vehicles identified as having the following trailer body types: lowboy, highboy, tanker, dump, car carrier, livestock carrier, log carriers, and unknown. These vehicles were assigned to the "other" vehicle category, which is not part of the study vehicles.

Over the study period, there were 441,218 reported collisions involving the 801,757 ***study vehicles*** in urban areas. This represents an average of 63,031 collisions involving 114,537 vehicles per year. These collisions accounted for 712 people killed and 216,261 people injured.

Over the study period, passenger vehicles accounted for 96 percent of all vehicles involved in collisions in urban areas, and trucks accounted for the remaining four percent. This is unlike the situation observed on the LCV network, where trucks accounted for 10 percent of vehicles in collisions.

Of the trucks involved in collisions, 86 percent were straight trucks and bobtails. Tractor semitrailers accounted for 12 percent, and legal-length tractor double trailer combinations accounted for about two percent. Long combination vehicles accounted for 0.1 percent of all trucks involved in collisions.

Also unlike the situation observed on the LCV network, between 1999 and 2005 there was no decreasing trend in the percentage of vehicles involved in collisions in urban areas but rather, an approximately constant distribution from year to year for most vehicle types. However, similar to the situation on the LCV network, straight trucks and bobtails also showed an increasing trend in the percentage of vehicles involved in collisions over the study period.

3.4.1. Collision Severity

Table 15 illustrates the number of vehicles in reported collisions in urban areas by collision severity.

Table 15: Vehicles involved in collisions by severity in urban areas

Vehicle type	**Fatal**	**Injury**	**PDO**	**Total vehicles**
Passenger vehicle	587	145986	625074	**771647**
Straight truck and bobtail	33	3525	22251	**25809**
Tractor semitrailer	17	615	3081	**3713**
Legal-length tractor double trailer	6	99	442	**547**
Rocky Mountain double	0	0	2	**2**
Turnpike double	0	5	20	**25**
Triple trailer	1	3	10	**14**
Total vehicles	**644**	**150233**	**650880**	**801757**

Passenger vehicles accounted for about 90 percent of all vehicles involved in fatal collisions, 97 percent of all vehicles in injury collisions, and 96 percent of vehicles in PDO collisions. Comparatively, trucks accounted for nearly nine percent of all vehicles involved in fatal collisions, three percent of all vehicles in injury collisions, and four percent of all vehicles in PDO collisions. This is different than the situation on the LCV network, where the severity outcome of collisions involving trucks is more serious.

Twenty-two percent (9 of 41) of the LCV collisions were single-vehicle and 78 percent (32 of 41) were multiple-vehicle. This is different than on the LCV network, where 55 percent of the LCV collisions were single-vehicle and 45 percent were multiple-vehicle. There were only two collisions involving RMDs. One was single-vehicle and the other was multiple-vehicle.

Turnpike doubles were involved in four single-vehicle and 21 multiple-vehicle collisions. Three of the four single-vehicle collisions resulted in PDO and one resulted in injury. Four of the 21 multiple-vehicle collisions resulted in injury and 17 resulted in PDO.

Triple trailer combinations were involved in four single-vehicle and 10 multiple-vehicle collisions. All single-vehicle collisions resulted in PDO. Six of the 10 multiple-vehicle collisions resulted in PDO, three resulted in injury, and one resulted in fatality.

3.4.2. Temporal Characteristics

The temporal distribution of vehicles in collisions in urban areas is shown in Figure 16. The same grouping of months as for collisions on the LCV network was used.

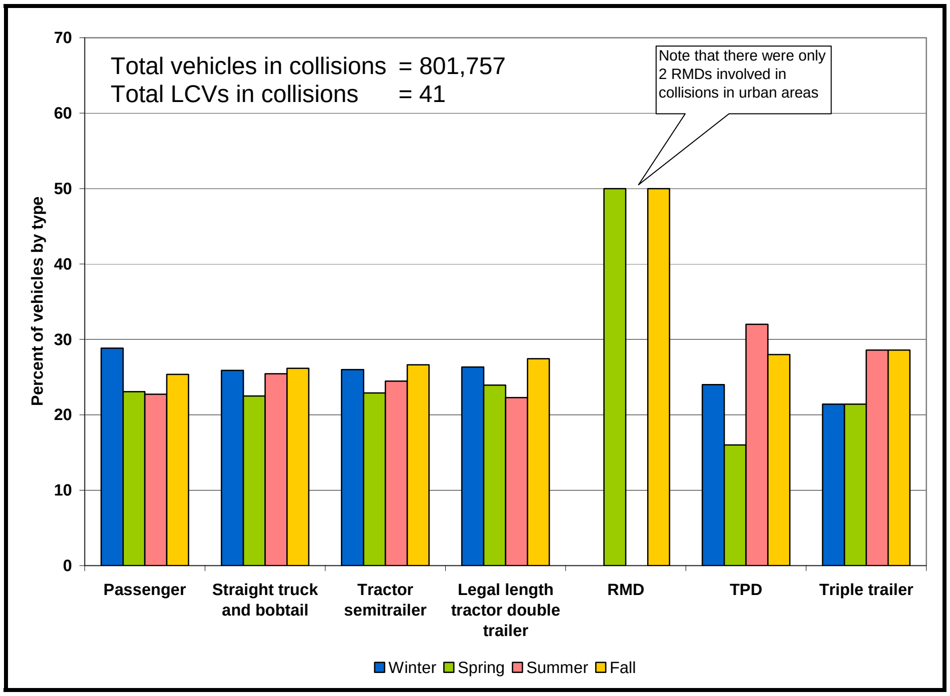


Figure 16: Vehicles in collisions in urban areas by type and season

Similar to the situation involving collisions on the LCV network, the season with the largest proportion of total vehicles involved in collisions in urban areas was winter (29 percent), followed by fall (25 percent). Spring and summer accounted for the lowest proportion of total vehicles involved in collisions with 23 percent each.

As Figure 16 shows, for most vehicle types, winter and fall showed the largest percent of vehicles involved in collisions. Similar to collisions on the LCV network, this distribution was also evident in collisions involving trucks only and articulated combinations as a group. Furthermore, there was no apparent seasonal effect involving LCV collisions, mainly because of the randomness associated with small collision frequencies.

Regarding the severity of collisions involving LCVs by season, there were no obvious seasonal effects on collision severity based on collision frequency. This is similar to the findings regarding collisions on the LCV network.

The day of week distribution of collisions showed no obvious differences by vehicle type, except that most vehicles involved in collisions on weekends were passenger vehicles.

Figure 17 illustrates the temporal distribution of vehicles in collisions by time of day. The same time groupings as for the LCV network analysis were used. Similar to collisions on the LCV network, day time (morning and afternoon) accounted for most of the vehicles involved in collisions in urban areas (nearly three-quarters), and night time (evening and night) accounted for the remaining quarter. This distribution applies to all vehicle types, except TPDs. There were 11 Turnpike doubles involved in collisions in the evening hours, and five in the night hours. Nine of the 25 TPDs collided in the daytime.

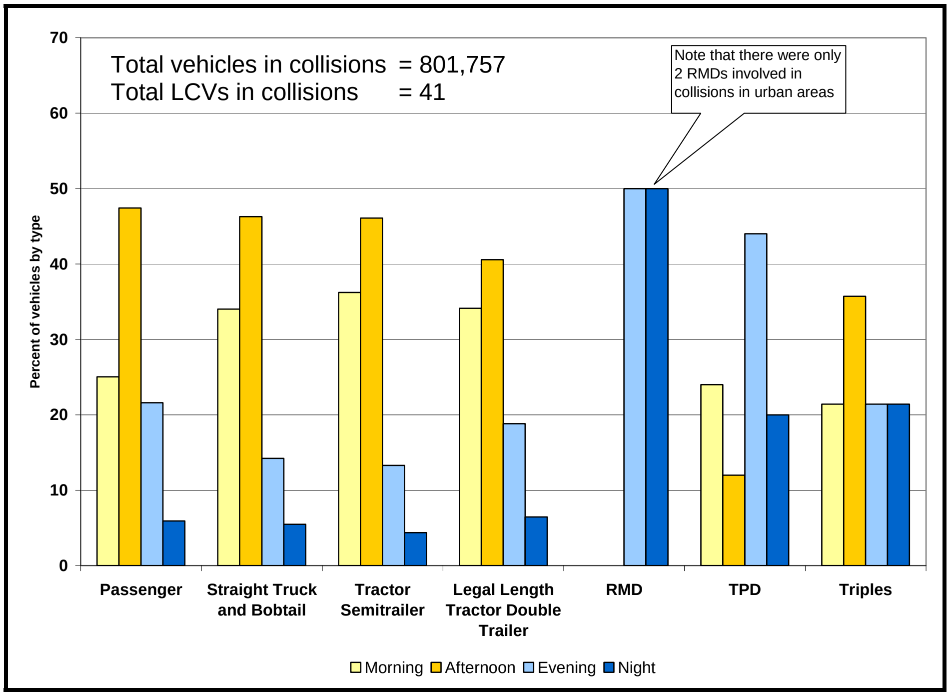


Figure 17: Vehicles in collisions in urban areas by type and time of day

3.4.3. Contributing Factors to Collisions

There is a difference between urban areas and the LCV network regarding the distribution of contributing factors to collisions. Unlike the situation on the LCV network, environmental condition was reported for only 11 percent of vehicles involved in collisions in urban areas. Driver action was reported as a contributing factor for 45 percent of all vehicles involved in collisions in urban areas, but for 56 percent of LCVs. Improper turning and improper lane change alone accounted for one-half of all the LCV collisions citing driver action as a contributing factor. Nearly all of these involved TPDs.

The last issue of discussion in this analysis is the impact of road surface conditions on urban area collisions. Adverse road surface conditions (wet, slush, snow, or ice) were identified as a contributing factor for one-quarter of total vehicles involved in collisions. This proportion is true for passenger vehicles, all trucks, and articulated combinations. This is different from the results involving collisions on the LCV network, where adverse road surface conditions were a contributing factor for nearly 40 percent of all articulated trucks involved in collisions.

Over two-thirds of LCV collisions (28 of 41) took place during dry road surface conditions. Adverse road surface conditions accounted for nearly one-third of LCV collisions (13 of 41).

3.5. SENSITIVITY ANALYSIS

This sensitivity analysis tests the effect of variations in the exposure estimates by vehicle type or vehicle group on the vehicles-in-collisions rate. Table 16 shows the calculated vehicles-in-collisions rates, and the rates resulting from a 10 percent increase and decrease in the VKT for each vehicle type.

Table 16: Sensitivity of vehicles-in-collisions rates to changes in VKT by vehicle type

Vehicle type	**Vehicles-in-collisions rate (per 100 million VKT)**		
	10% decrease in VKT	**Calculated rate**	**10% increase in VKT**
Passenger vehicle	119	107	97
Straight trucks and bobtail	143	128	117
Tractor semitrailer	49	44	40
Legal-length tractor double trailer	51	46	41
Rocky Mountain double	**36**	**32**	**29**
Turnpike double	**18**	**16**	**15**
Triple trailer combination	**70**	**62**	**57**
All LCV	**28**	**25**	**23**
All non-LCV articulated truck	49	44	40
All articulated truck	49	44	40
All truck	74	67	61
All vehicles	112	101	91

Table 16 reveals the following:

- The vehicles-in-collisions rate for all trucks with a 10 percent decrease in VKT is lower than the vehicles-in-collisions rate for passenger vehicles with a 10 percent increase in VKT. Assuming that there is no change in the number of collisions, one of the following events would need to occur for these rates to be equal: (1) the VKT for passenger vehicles increases by 61 percent and the vehicles-in-collisions rate for all trucks remains constant; or (2) the VKT for all trucks decreases by 38 percent and the vehicles-in-collisions rate for passenger vehicles remains constant.

- The vehicles-in-collisions rate for all LCVs with a 10 percent decrease in VKT is lower than the vehicles-in-collisions rate for all non-LCV articulated trucks with a 10 percent increase in VKT. Assuming that there is no change in the number of collisions, one of the following events would need to occur for these rates to be equal: (1) the VKT for all non-LCV articulated trucks increases by 75 percent and the vehicles-in-collisions rate for all LCVs remains constant; or (2) the VKT for all LCVs decreases by 42 percent and the vehicles-in-collisions rate for all non-LCV articulated trucks remains constant.

- The vehicles-in-collisions rate for TPDs with a 10 percent decrease in VKT is lower than the vehicles-in-collisions rate for all non-LCV articulated trucks with a 10 percent increase in VKT. Assuming that there is no change in the number of collisions, one of the following events would need to occur for these rates to be equal: (1) the VKT for all non-LCV articulated trucks increases by 170 percent and the vehicles-in-collisions rate for TPDs remains constant; or (2) the VKT for TPDs decreases by 63 percent and the vehicles-in-collisions rate for all non-LCV articulated trucks remains constant.

4. CONCLUSIONS

The purpose of this study is to help improve the understanding about the safety performance of LCVs relative to the safety performance of passenger vehicles, straight trucks and bobtails, tractor semitrailers, and legal-length tractor double trailers operating on the LCV network and urban areas. This improved understanding will help define future truck size and weight policy for Alberta highways, and provide information to policy makers in Alberta and its trading partners concerning LCV safety.

This chapter presents the conclusions of the study regarding the environmental scan (literature review and jurisdictional survey), and the analysis of the safety performance of LCVs in Alberta.

Important definitional considerations are:

- Safety performance is defined in terms of collision frequency and collision rate. Rate is a function of traffic exposure.

- The following are identified as urban areas: Calgary, Edmonton, Lethbridge, Red Deer, Medicine Hat, Fort McMurray, and Grande Prairie. LCV network routes through other towns in the study area (e.g., Hinton, Fort McLeod, Peace River, Valleyview, Athabasca, and others) are included in the comprehensive safety analysis pertaining to vehicles operating on the LCV network.

- The vehicle types of interest to this study are: passenger vehicles, straight trucks and bobtails, tractor semitrailers, legal-length tractor double trailers, Rocky Mountain doubles, Turnpike doubles, and triple trailer combinations.

4.1. ENVIRONMENTAL SCAN

A comprehensive environmental scan (literature review and jurisdictional survey) about the latest developments (1995 and later) regarding the safety of LCVs in North America was conducted. Chapter 2 presents results of the scan and Appendix B contains detailed information about it.

- Of all CANAMEX corridor states and Canadian Prairie Region jurisdictions, Alberta is the only jurisdiction that has specifically evaluated the safety performance of LCVs by determining collision rates for LCVs compared to other vehicle types. In 2001, Woodrooffe and Associates found collision rates and vehicles-in-collisions rates for different vehicle types operating on Alberta's LCV network as shown in Table 17 and Table 18.

- Studies about LCV safety performance (as measured by collision frequency and collision rates) show disparate results. Some studies indicate that LCVs are safer than other truck configurations, and some studies conclude that LCVs pose a detriment to road safety.

Table 17: Collision rate by vehicle type on the LCV network (1995-1998)

Vehicle type	Number of collisions	Distance traveled (100 million VKT)	Collision rate (collisions per 100 million VKT)
Personal vehicle	11800	217.87	54.16
Unit truck	688	3.82	180.11
Tractor semitrailer	879	11.54	75.88
Multi trailer	406	4.03	100.70
Rocky Mountain double	11	1.07	10.31
Turnpike double	20	1.19	16.87
Triple	6	0.09	67.04
All LCVs	37	2.34	15.80

Source: Table A and Table B, Appendix A, Woodrooffe (2001)

Table 18: Vehicles-in-collisions rate by vehicle type on the LCV network (1995-1998) (vehicles in collisions per 100 million VKT)

Vehicle type	Number of vehicles in collisions	Distance traveled (100 million VKT)	Vehicles-in-collisions rate
Personal vehicle	19206	217.87	88.15
Unit truck	715	3.82	187.19
Tractor semitrailer	918	11.54	79.52
Multi trailer	418	4.03	103.70
Rocky Mountain double	11	1.07	10.31
Turnpike double	20	1.19	16.87
Triple	6	0.09	67.04
All LCVs	37	2.34	15.80

Source: Table 4 and Table 5, Woodrooffe (2001)

- LCV driver standards and training requirements contribute positively to the safety performance of LCVs. Some studies indicate that LCVs are involved in fewer collisions because of the strict operating restrictions placed on their use, and the special driver training requirements. Alberta is one of the most stringent jurisdictions along the CANAMEX corridor and the Canadian Prairie Region regarding driver training and qualifications requirements for LCV operations.

- Most jurisdictions along the CANAMEX corridor and the Canadian Prairie Region do not specifically record LCVs as a distinct vehicle class in their collision reporting system. This poses a barrier to analyzing the extent and nature of LCV collisions in these jurisdictions.

4.2. THE SAFETY PERFORMANCE OF LCVS IN ALBERTA

A comprehensive analysis of the safety performance of LCVs relative to other vehicle types operating on the LCV network and urban areas was conducted.

- There were 106 LCVs involved in 106 reported collisions on the Alberta LCV network and in urban areas over the study period. These accounted for 0.02 percent of all collisions in the study area (106 of 490,956). Sixty percent of these (65 of 106) took place on the LCV network and 40 percent (41 of 106) in urban areas.

- Over the study period (1999 to 2005), LCVs kept a steady trend in the percentage of vehicles involved in collisions from year to year. Other vehicle types, except for straight trucks and bobtails, showed a decreasing trend in the percentage of vehicles involved in collisions.

- The severity outcome of LCV collisions on the LCV network was lower than that of other vehicle types. LCVs accounted for one percent of all trucks (articulated and non-articulated) in fatal collisions, one percent of all trucks in injury collisions, and one percent of all trucks in PDO collisions. Other articulated units (tractor semitrailers and legal-length tractor double trailers) accounted for nearly two-thirds of trucks in fatal collisions, 57 percent of trucks in injury collisions, and 43 percent of trucks in PDO collisions. Taking traffic exposure into consideration, LCVs have a lower fatality, injury, and PDO rate per 100 million VKT than other vehicle types.

- Nearly three-quarters of all LCV collisions (urban and on the LCV network) resulted in PDO. The severity outcome of LCV collisions on the LCV network was more serious than in urban areas. This urban versus LCV network severity outcome was similar for all other vehicle types.

- Over one-half of LCV collisions on the LCV network were single-vehicle collisions. Most of these were attributed to night-time driving and wildlife intervention. Single-vehicle collisions accounted for 37 percent of collisions involving other articulated combinations.

- LCVs were over-represented in collisions on the LCV network in winter (December, January and February) and spring (March, April and May), relative to the corresponding seasonal traffic volume distribution. Winter accounted for 30 percent of LCV collisions and for 24 percent of LCV traffic. Spring accounted for 25 percent of LCV collisions and for 17 percent of LCV traffic. Other articulated combinations also showed similar collisions-to-traffic proportions in winter and spring.

- Driver action and environmental condition were the main contributing factors listed for LCVs involved in collisions on the LCV network and in urban areas. Driver action was particularly associated with Turnpike doubles operating in urban areas. Improper turning and improper lane change were cited as contributing factors in 40 percent of TPD collisions in urban areas.

- Adverse road surface conditions (wet, slush, snow, or ice) were cited as contributing factors for about 40 percent of all LCVs involved in collisions on the LCV network. This proportion was similar for other truck types but smaller for passenger vehicles. Comparatively, adverse road surface conditions were cited as contributing factors for one-quarter of all LCVs involved in collisions in urban areas. The same proportion was experienced by all other vehicle types.

- There was one collision involving an LCV passing another vehicle on an undivided highway in the LCV network.

- Four highways accounted for 75 percent of collisions involving LCVs: Highway 2 between Edmonton and Calgary (20 of the 65 collisions), Highway 35 north of Peace

River (10 of 65 collisions), Highway 1 east of Calgary (9 of 65 collisions) and Highway 43 between Edmonton and Grande Prairie (9 of 65). Most Rocky Mountain doubles were involved in collisions along Highways 35 and 43 northwest of Edmonton.

- From a collision rate perspective, LCVs as a group had the best safety performance of all vehicle types with 25 collisions per 100 million vehicle-kilometers traveled (VKT) on the LCV network. The collision rates for other vehicle types in descending order of performance were: tractor semitrailers—42 collisions per 100 million VKT, legal-length tractor doubles—44 collisions per 100 million VKT, passenger vehicles—83 collisions per 100 million VKT, and straight trucks and bobtails—123 collisions per 100 million VKT.

- Turnpike doubles had the lowest collision rate of all individual vehicle types (16 collisions per 100 million VKT), followed by Rocky Mountain doubles (32 collisions per 100 million VKT). The collision rate for triple trailer combinations was 62 collisions per 100 million VKT.

- LCVs were under-represented in terms of collision frequency with respect to traffic exposure. They accounted for 0.1 percent of all collisions on the LCV network, and for 0.4 percent of all traffic exposure. Other vehicle types that were also under-represented were tractor-semitrailers and legal-length tractor doubles. Single unit trucks and bobtails, as well as passenger vehicles, were over-represented in terms of collision frequency with respect to traffic exposure.

- A sensitivity analysis revealed that a 10 percent decrease in LCV VKT, combined with a 10 percent increase in non-LCV articulated truck VKT, still results in a lower rate (in terms of vehicles in collisions per 100 million VKT) for all LCVs than for all non-LCV articulated trucks. Assuming that there is no change in the number of collisions, one of the following events would need to occur for these rates to be equal: (1) the VKT for all non-LCV articulated trucks increases by 75 percent and there is no change in LCV exposure; or (2) the VKT for all LCVs decreases by 42 percent and there is no change in non-LCV articulated truck exposure.

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APPENDIX A: LCV NETWORK

Table A-1: LCV network routes

1999 - 2003		2004 - 2005	
All LCVs Permitted			
All multi-lane highways with 4 or more driving lanes		All multi-lane highways with 4 or more driving lanes	
1A	Calgary to east to Jct. 1	1A	Calgary to east to Jct. 1
11A	Jct. 2 to Gaetz Ave., Red Deer	11A	Jct. 2 to Gaetz Ave., Red Deer
4	At Milk River	4	At Milk River
Only RMDs Permitted			
1A	Calgary to Jct. 22	1A	Calgary to Jct. 22
2	USA boundary to Jct. 5	2	USA boundary to Jct. 3
	Jct. 642 to Jct. 18		Jct. 642 to Jct. 18
	Jct. 43 to Jct. 49 (Donnelly)		Jct. 43 to McLennan
2A	Jct. 2 (Leduc) to Jct. 2 (Morningside)	2A	Jct. 2 (Leduc) to Jct. 2 (Morningside)
3	BC boundary to Jct. 2	3	BC boundary to Jct. 2
	Jct. 36 to Medicine Hat		Jct. 36 to Medicine Hat
5	Jct. 2 to Lethbridge	5	Jct. 2 to Lethbridge
		8	Calgary to Jct. 22
9	Jct. 36 to SK boundary	9	Jct. 36 to SK boundary
12	Jct. 2 to Jct. 36	12	Jct. 2 to Veteran
13	Jct. 2A to Camrose	13	Jct. 2A to Camrose
14	Edmonton to SK boundary	14	Edmonton to SK boundary
15	Edmonton to Jct. 45	15	Edmonton to Jct. 45
16	Jct. 40 to East Jasper Park Gates	16	Jct. 40 to East Jasper Park Gates
17	Jct. 14 to SK boundary	17	Jct. 14 to SK boundary
18	Jct. 2 to Westlock	18	Jct. 2 to Westlock
		21	Jct. 12 to Jct. 13
22	Jct. 1 to Jct. 1A	22	Jct. 8 to Jct. 1A
		22X	Calgary to Jct. 24
		23	Jct. 2 to Jct. 3
28	Jct. 28A to Jct. 63	28	Jct. 28A to Jct. 36
28A	Edmonton to Jct. 28	28A	Edmonton to Jct. 28
35	Jct. 2 to NWT boundary	35	Jct. 2 to NWT boundary
36	Jct. 1 to Jct. 9	36	Jct. 1 to Jct. 9
			Jct. 14 to Jct. 16
			Jct. 28 to Lac La Biche
		39	Jct. 2 to Calmar
43	Jct. 16 to BC boundary	43	Jct. 16 to BC boundary
49	Jct. 43 (Valleyview) to Jct. 2 (Donnelly)	49	Jct. 43 (Valleyview) to Jct. 2 (Rycroft)
		52	Jct. 5 to Raymond
		53	Jct. 2 to Rimbey
		55	Jct. 63 to Athabasca
63	Jct. 28 to Ft. McMurray	63	Jct. 28 to Ft. McMurray
69	Jct. 63 to S. Industrial Park (Ft. McMurray)	69	Jct. 63 to S. Industrial Park (Ft. McMurray)
		901	Jct. 22X to Jct. 1

Note: Shaded cells indicate changes in the 2004-2005 network from the 1999-2003 network.

APPENDIX B: ENVIRONMENTAL SCAN

B.1 LITERATURE REVIEW

The comprehensive literature search conducted by the team as part of this project included the following sources:

Special Library Catalogues
- University of Michigan Transport Research Institute (UMTRI)
- The Transportation Research Information System (TRIS)
- U.S. National Transportation Library
- Texas A&M University Library
- U.S. DOT Library
- University of California PATH Database
- University of Manitoba Bison Catalogue

Research Centers
- Battelle Memorial Institute
- The Volpe National Transportation Systems Center
- University of North Carolina Transport Research Institute
- Turner Fairbank Highway Research Center

Trade Magazines
- Today's Trucking
- Transport Topics
- Motortruck

Government Agencies
- Transportation Association of Canada
- Transport Canada
- Alberta Infrastructure and Transportation
- Saskatchewan Highways and Transportation
- Manitoba Infrastructure and Transportation
- Alaska Department of Transportation
- Montana Department of Transportation
- Idaho Department of Transportation
- Utah Department of Transportation
- Nevada Department of Transportation
- Arizona Department of Transportation
- Federal Motor Carrier Safety Administration

Professional Associations/Affiliations
- U.S. Transportation Research Board, including conference proceedings
- Canadian Association of Road Safety Professionals conference proceedings
- Canadian Transportation Research Forum conference proceedings
- Canadian Society for Civil Engineering conference proceedings

Scientific/Engineering Journals
- Public Roads
- ITE Journal
- Volpe Journal
- Road Management and Engineering Journal
- Canadian Journal of Civil Engineering
- ASCE Transportation Journal

Trucking Associations
- Canadian Trucking Alliance
- Alberta Trucking Association
- Alberta Trucking Industry Safety Association
- Manitoba Trucking Association
- Saskatchewan Trucking Association
- American Trucking Associations

Special Interest Groups
- Citizens for Reliable and Safe Highways (CRASH) web site

The literature review found the following:

B.1.1 THE SAFETY OF LONG COMBINATION VEHICLES

In most cases, safety is defined in the literature by (or understood to be) collision frequency and collision rates. The following summarizes what recent literature (1995 and later) says about the safety of long combination vehicles.

- The U.S. Department of Transportation's Western Uniformity Scenario Analysis (2004), requested by the Western Governors' Association, reviewed several studies conducted to identify the crash propensity of LCVs. The findings of these studies are disparate, owing to the "difficulty in analyzing a relatively small population of vehicles and obtaining reliable accurate vehicle miles traveled [VMT] and crash data for each vehicle type." The U.S. Department of Transportation (DOT) noted that previous attempts to isolate the safety performance of LCVs from regular doubles have "fallen under criticism" due to: (1) "difficulty matching the survey respondents to the VMT estimates;" (2) sampling sets that are "not large enough"; or (3) "self-selection bias" in the sampled population.

  The U.S. DOT cited a study by the Federal Highway Administration in 1996 in which 75 commercial motor carriers (operating both LCVs and non-LCVs) were surveyed regarding crash and exposure data for the period 1989 to 1994. The study calculated mean crash rates for LCVs and non-LCVs as 887 crashes per 100 million VMT (551 per 100 million vehicle kilometers traveled (VKT)) and 1786 crashes per 100 million VMT (1110 per 100 million VKT), respectively. Fatal crash rates for LCVs and non-LCVs were calculated as 24 per 100 million VMT (15 per 100 million VKT) and 21 per 100 million VMT (13 per 100 million VKT), respectively. Additional findings from the study were: (1) LCV crashes were "more severe" than non-LCV crashes; and (2) LCV operators "predominantly operated in rural areas on higher quality roads, possessed far better safety fitness records than the carrier population at-large, and tended to assign exceptionally experienced drivers to their vehicles, both LCVs and non-LCVs."

- Forkenbrock and Hanley (2003) analyzed conditions present in fatal collisions involving single-trailer trucks compared to those with two or three trailers. Using multiple classification analysis and automatic interaction detector techniques, the authors concluded that multiple trailer trucks "are more likely to be involved in fatal crashes in the following conditions: darkness; snow, slush or ice on the road surface; involvement of three or more vehicles, indicating at least moderate traffic volume; and higher-speed facilities with 65 to 75 mph limits." It is not known which of the multiple-trailer trucks involved in the fatal collisions were regular doubles, and which were LCVs. The authors indicate that "it is unlikely…that LCVs are safer than other multiple-trailer trucks under the conditions in which multiple-trailer trucks are shown to be more likely to be involved in fatal crashes than are single-trailer trucks."

- Thompson (2002) made a presentation on truck productivity at the Commercial Vehicle Operations Seminar organized by the Center for Transportation Engineering and Planning (C-TEP) in Calgary. In this presentation, he addressed safety concerns associated with LCV operations by reviewing the safety experience of LCVs in Alberta. He indicated that between 1995 and 1998, LCVs were involved in 37 collisions, two of which were fatal. Of these collisions, none of the fatal or major injury incidents were found to be the fault of the LCV driver. The presentation outlined three reasons for LCV safety: (1) permit requirements (including driver qualifications, truck equipment upgrades, and operational restrictions); (2) on-board computers/monitoring equipment; and (3) better on-road safety performance.

- Woodrooffe (2001) conducted a study for Alberta Infrastructure and Transportation to undertake an in-depth review of LCVs in Alberta between 1995 and 1998. The purpose of the study was to determine the safety performance of commercial trucks, including LCVs, and to determine the contributing factors to collisions involving LCVs. The study found that LCVs have the lowest collision rates of all vehicle classes in the province, including personal vehicles. Furthermore, Rocky Mountain doubles were found to have the best safety performance of all LCV configurations. Regarding contributing factors to collisions involving LCVs, the study found that adverse weather and road surface conditions were present in 42 percent of all LCV collisions.

- Woodrooffe and Ash (2001) prepared a report on the economic efficiency of LCVs in Alberta. The report discussed the "safety efficiency" of LCVs. They found that, assuming a constant transport demand, the elimination of LCVs would result in 105,400,000 km (an 80 percent increase in the number of movements) of additional tractor semitrailer exposure per year. At a rate of 76.15 collisions per 100 million vehicle-kilometers traveled, approximately 80.25 additional tractor semitrailer collisions, or a net increase of 67 truck collisions per year could be expected.

- Craft (2000) reports that of the 17,191 combination trucks involved in fatal accidents in the United States from 1991-1996, 221 (1.3 percent) were LCVs. Fatal accident rates for LCVs were compared with non-LCV double trailers and tractor-semitrailers by vehicle length, weight, body type, and trip type. Craft concludes that LCVs are not significantly "more or less safe than other combination trucks."

- Kenny et al. (2000b) state that in more than 30 years of LCV operations in Alberta, LCVs have been involved in fewer collisions than average commercial vehicles due to the strict operating restrictions placed on their use. They indicate that one percent of truck tractor collisions in Alberta involved an LCV.

- Scopatz (2000) conducted a review of the AAA Foundation for Traffic Safety research program, which identified barriers to the analysis of collisions involving LCVs in five states (Florida, Idaho, Nevada, Oregon, and Utah). The review found that there was a lack of reliable data on truck configurations involved in collisions, and specific measures of LCV exposure did not exist. Because of this, there was no empirical method of assessing the relative safety of LCVs.

- Trialpha Consulting Limited (2000) assessed the safety of Saskatchewan's Special Haul Programs in 1999, which includes the permitting of LCVs. In 1999, there were seven reported collisions of vehicles operating in Special Haul Programs. None of these collisions involved an LCV. LCVs had an annual exposure of 14,677,727 km.

- The U.S. Department of Transportation's Comprehensive Truck Size and Weight Study (2000) addressed the issue of the relative safety of LCVs. The Federal Highway Administration "was not able" to determine crash rates for LCVs because of the "lack of sufficient data." They made several estimates of multitrailer combination vehicle safety (a vehicle category dominated by standard doubles, but which includes a small proportion of LCVs). They assumed that LCVs were "likely to have similar crash propensities" to multi-trailer units. The study found that when using aggregated crash data, multi-trailer vehicles exhibit a three percent lower fatal crash rate than single trailer trucks. When fatal crash rates were stratified by highway class, it was found that multi-trailer vehicles exhibit higher fatal crash rates than any other vehicle type on rural interstates, rural arterials, and other rural roads. The report predicted future fatal crash rates for multi-trailer units by applying travel distribution characteristics of single-trailer combinations to the crash rate histories of multi-trailer combinations. In this way, the study estimated that multi-trailer combinations could be "expected to experience an 11 percent higher overall crash rate than single-trailer combinations."

- Nix (1995) states that there is no evidence that long trucks (referring to LCVs) pose a "particular safety hazard." Based on a literature review, Nix highlights the three difficulties associated with determining the relative safety of LCVs: (1) lack of accident data for both long trucks and other vehicles; (2) lack of exposure data; and (3) inability to compare accident rates of LCVs to other configurations due to significant operational differences. Nix concludes that since LCVs can move more freight with fewer kilometers of travel, they have lower exposure to accidents, and if LCVs have the same accident rate as other trucks, then it follows that they would be involved in fewer total accidents.

- In a study sponsored by the Association of American Railroads, Barnett (1995) outlined the system safety effects of LCV use. Barnett defines the system safety effects as road accidents that do not physically involve an LCV, but would not have occurred in their absence. The "greatest" of these effects was the psychological impact that LCVs have on other motorists. Barnett indicates that the presence of an LCV in a traffic stream may cause an increase in the number of lane changes by other drivers, a greater number of acceleration changes, and may distract drivers from recognizing and responding to hazardous conditions.

B.1.2 VEHICLE STABILITY AND CONTROL

Key terms used in this section are defined below.

Off-tracking: The measure of the distance between the path of the front inside wheel and the path of the rear inside wheel as a vehicle traverses a curve or turn. Two types of off-tracking may occur. In *low-speed off-tracking*, the rear wheels track inside the path of the front wheels. It is a problem when turning at intersections or into loading areas. *High-speed off-tracking* occurs when the rear wheels track outside the front wheels. This is closely related to the road width requirements for the travel of combination vehicles. The maximum *swept path* is equal to the width of the vehicle plus the off-tracking (either low-speed or high-speed) distance (Harkey et al. 1996).

Rearward amplification: The increased side force or lateral acceleration acting on the rear trailer as a result of rapid steering in articulated vehicles (a result of rapid lane changes or evasive maneuvers). Rearward amplification increases the probability of trailer rollover (Woodrooffe et al., 1997).

Trailer sway: The side-to-side movement of multiple trailers. This does not involve rapid steering but regular travel (Woodrooffe et al., 1997).

Static roll stability: The lateral acceleration needed to produce vehicle rollover. Lateral acceleration on a curve is highly sensitive to speed. The speed required to produce rollover reduces as curve radius decreases (Blow et al., 1998).

Load transfer ratio: The proportion of load on one side of a vehicle unit transferred to the other side of the vehicle in a transient maneuver. When the load transfer ratio reaches a value of one, rollover is about to occur (Woodrooffe et al., 1997).

Lateral stability: The ability of the rearmost trailer to travel inside its lane, or in the case of evasive maneuvers, the ability to not roll over (March, 2001).
The following summarizes the information obtained in recent literature regarding stability and control of LCVs, and other performance measures.

- The U.S. Department of Transportation's Western Uniformity Scenario Analysis (2004), requested by the Western Governors' Association, determined the static rollover threshold, rearward amplification, and load transfer ratio of several truck configurations including LCVs. In terms of static rollover threshold, all the configurations analyzed have a "good to excellent rating" for static rollover threshold, but the van trailer LCVs generally "perform worse" than the Surface Transportation Assistance Act (STAA) van double (These are the shorter double trailer combinations). LCVs are "more prone than typical tractor-semitrailers to rearward amplification." The load transfer ratio was found to be dependent on the type of dolly connection, with B and C-train configurations having "superior characteristics."

- Harwood et al. (2003) reviewed truck characteristics that are factors in roadway design. Table B-1 shows the details regarding the maximum low-speed off-tracking and maximum swept path of three LCV configurations.

Table B-1: Off-tracking and swept path values for LCVs at a 90-degree intersection

Truck Combination (trailer lengths in meters)	**Maximum off-tracking for specified turn radius (m)**		**Maximum swept path for specified turn radius (m)**	
	30.48 m (100 ft)	45.72 m (150 ft)	30.48 m (100 ft)	45.72 m (150 ft)
Tractor Semitrailer (14.6)	4.2	2.9	6.7	5.5
RMD (14.6/8.7)	3.9	2.7	6.4	5.2
TPD (14.6/14.6)	5.2	3.7	7.7	5.9
TPD (16.2/16.2)	5.5	3.8	8.0	6.3

Source: Harwood et al. (2003)

- March (2001) reviewed potential trucking scenarios evaluated within the Comprehensive Truck Size and Weight Study. One was the proposal for a nationwide LCV network in the United States. Although March did not specifically address safety impacts associated with this scenario, he did state that LCVs have inherently "poorer stability and control" because of their length and number of trailers. March indicated that short multi-trailer combinations have "poor lateral stability" but reduced off-tracking difficulties compared to LCVs with longer trailers.

- Bruce and Morrall (2000) investigated the operating characteristics of LCVs in urban areas. Specifically, they examined low speed turning movements and acceleration characteristics. Citing Harkey et al. (1996), they concluded that “at-grade intersections pose the most serious problems for LCV off-tracking and LCV combinations may encroach into adjacent lanes on the exiting or receiving leg of the intersection.” The results from a series of timed acceleration tests indicated that a Rocky Mountain double (430 hp, 15-speed transmission, and 46,090 kg GVW) would require 19.6 seconds to negotiate a left turn with a 25 m travel distance, and 19.0 seconds to negotiate a right turn with a 12 m travel distance.

- The U.S. Department of Transportation’s Comprehensive Truck Size and Weight Study (2000) determined stability and control measures for 13 truck types relative to five-axle tractor semitrailers. The study showed that: (1) a seven-axle, 120,000 lb (54,545 kg) RMD has approximately six percent poorer static roll stability, 72 percent poorer rearward amplification, and 87 percent poorer load transfer ratio than a five-axle tractor semitrailer; (2) a nine-axle, 148,000 lb (67,272 kg) TPD has approximately the same static roll stability, 36 percent poorer rearward amplification, and 49 percent poorer load transfer ratio than a five-axle tractor semitrailer; (3) a seven-axle, 132,000 lb (60,000 kg) C-train triple has approximately eight percent poorer static roll stability, 100 percent poorer rearward amplification, and 27 percent better load transfer ratio than a five-axle tractor semitrailer; and (4) a seven-axle, 132,000 lb (60,000 kg) A-train triple has approximately seven percent poorer static roll stability, 212 percent poorer rearward amplification, and 87 percent poorer load transfer ratio than a five-axle tractor semitrailer.

- Fancher and Gillespie (1997) developed a relationship between the swept path of common LCVs and the ramp radius. For RMDs, this relationship estimated swept path values of 14.6 ft, 13.8 ft, and 13.1 ft for ramp radii of 175 ft, 200 ft, and 230 ft, respectively. For TPDs, the relationship estimated swept path values of 17.6 ft, 16.4 ft, and 15.4 ft for ramp radii of 175 ft, 200 ft, and 230 ft, respectively. The authors also stated that the off-tracking performance of any vehicle was subject to a number of other vehicle and road factors, including wheelbase, axle spreads and positions, hitch dimensions, tractor width, curb path, and intersection layout.

- Harkey et al. (1996) cited a study by Ervin et al. (1984) which determined the operational characteristics of LCVs as shown in Table B-2, Table B-3, and Table B-4. The authors conclude that high-speed off-tracking of LCVs “may not create a significant safety problem” if the travel lanes are wider than 3.4 m and the driver positions the vehicle properly upon entering the curve. With low-speed off-tracking, the authors indicate that the behavior of RMDs and TPDs could be problematic on rural roads with “severe horizontal and vertical curvature.” Off-tracking of all LCVs at rural and urban intersections “significantly affect operations” at these locations. Regarding vehicle stability, RMDs exhibit some lateral sway, but “not enough to pose a safety problem”, TPDs have been found to exhibit “little or no sway”, and triples exhibit a “significant amount of trailer sway.” RMDs and TPDs were also found to be more stable in terms of rearward amplification than triples and shorter regular doubles.

Table B-2: High-speed off-tracking and maximum swept path values for combinations negotiating a curve of radius 183 m (600 ft)

Truck Combination (trailer lengths in meters)	Off-tracking (m)	Maximum Swept Path (m)
Tractor Semitrailer (14.6)	0.16	2.75
TPD (14.6/14.6)	0.34	2.93
TPD (13.7/13.7)	0.38	2.97
RMD (14.6/8.5)	0.41	3.00
STAA Double (8.5/8.5)	0.44	3.00
RMD (13.7/8.5)	0.44	3.03
Triple (8.5/8.5/8.5)	0.65	3.24

Source: Ervin et al., 1984 cited in Harkey et al. (1996)

Table B-3: Low-speed off-tracking and maximum swept path values for combinations negotiating a curve of radius 92 m (300 ft)

Truck Combination (trailer lengths in meters)	Off-tracking (m)	Maximum Swept Path (m)
STAA Double (8.5/8.5)	0.61	3.20
Triple (8.5/8.5/8.5)	0.88	3.48
Tractor Semitrailer (14.6)	0.98	3.57
RMD (13.7/8.5)	1.04	3.63
RMD (14.6/8.5)	1.16	3.75
TPD (13.7/13.7)	1.49	4.09
TPD (14.6/14.6)	1.71	4.30

Source: Ervin et al., 1984 cited in Harkey et al. (1996)

Table B-4: Off-tracking and maximum swept path values for combinations negotiating a 90-degree intersection with a curb of radius 13.7 m (45 ft)

Truck Combination (trailer lengths in meters)	Off-tracking (m)	Maximum Swept Path (m)
STAA Double (8.5/8.5)	3.81	6.41
Triple (8.5/8.5/8.5)	5.15	7.75
Tractor Semitrailer (14.6)	5.34	7.93
RMD (13.7/8.5)	5.64	8.24
RMD (14.6/8.5)	6.13	8.72
TPD (13.7/13.7)	7.44	10.03
TPD (14.6/14.6)	8.27	10.86

Source: Ervin et al., 1984 cited in Harkey et al. (1996)

- Barton et al. (1995) conducted a field-based study on the operation of LCVs in Alberta. The study concluded that "Rocky Mountain doubles fail to meet [Transportation Association of Canada - TAC] standards marginally with respect to each of the three performance measures" (low-speed off-tracking, high speed off-tracking, and rearward amplification). The authors indicate that the deficiency in low-speed off-tracking could be addressed by appropriate lane widening at intersections. With respect to high-speed off-tracking, the provision of adequate shoulders would reduce the severity of this problem. Finally, with respect to rearward amplification, the authors indicate that "these vehicles still perform better than the 8-axle A/C double combinations".

  TPDs "fail to meet TAC standards for low-speed off-tracking"; however, their performance is "superior" to RMDs and triples with respect to high-speed off-tracking and rearward amplification. The authors concluded that the operation of TPDs on two-lane highways is “acceptable” from a performance perspective, “provided that road geometrics are adequate to accommodate” low-speed off-tracking.

Triples do not meet any of the three performance measures investigated. “Until it can be demonstrated that measures such as improving the dolly converter on a triple assures satisfactory performance qualities, it is not wise to operate triples on two-lane highways.”

B.1.3 ROAD ENGINEERING AND WEATHER CONDITIONS

This section discusses road engineering and weather conditions and their impact on the safety of long combination vehicle operations. The section addresses road surface condition, road design, traffic signing, pavement markings, traffic signalization, traffic control, and passing opportunities.

This is the only section in this chapter which includes literature predating 1995 because it was determined by the project team that: (1) road engineering issues do not change much over time; and (2) weather conditions directly interact with road engineering. Both issues can have a significant impact on the safety of LCV operations.

- McCutchon et al. (2006) based on a safety assessment of a particular two-lane, undivided rural road in Manitoba, identified four infrastructure-related priorities for accommodating RMDs: (1) “pavement repairs in the vicinity of hazards located adjacent to the roadway edge;” (2) “resurvey of passing sight lines and a remarking of passing restrictions to match the passing sight distance requirements of LCVs;” (3) “remediation of severe pavement rutting;” and (4) “provision of edge line painting through all horizontal curves.” In addition to infrastructure-related measures, LCV permit conditions requiring transparent demonstration of safety compliance and the utilization of advanced technologies may enhance the on-road safety performance of LCVs.

- Hanley and Forkenbrock (2005) developed a passing model to analyze the safety of passing LCVs operating on two-lane highways. The model incorporates: different performance levels of the passing vehicles, varying levels of driver agressiveness, oncoming traffic volume, and the length of the impeding vehicle. The authors conclude that “with moderate oncoming traffic, the odds of failure to pass a 120-ft LCV versus a 65-ft standard truck are about 2-6 times greater.”

- Kosior and Summerfield (2001) analyzed crash rates of LCVs under inclement weather conditions. The analysis showed that LCVs “did not appear over represented” in crash statistics. The authors explain this finding by noting that carriers use more experienced drivers for LCVs than for other trucks.

- Sparks et al. (2000) evaluated the implications of allowing LCVs (specifically Turnpike doubles) on a two-way two-lane rural highway in Saskatchewan. Of specific interest were the number of vehicles and the time spent in queues behind LCVs, the total number of vehicles passing LCVs, and the safety margin of these passing maneuvers. They concluded that LCVs could operate during off-peak nighttime hours “without adversely affecting traffic operations or overall safety.”

- In a study by Alberta Infrastructure and Transportation, Janz (2000) investigated traveling speed and following time by vehicle type on a four-lane divided highway (Highway 2 between Calgary and Edmonton, near Leduc, Alberta). At this location, LCVs comprised 1.2 percent of the traffic volume, with RMDs accounting for about one-third of this total. The study found that, in general, as vehicle size increases, vehicle speeds decrease, and following times increase. In particular, Janz made the following conclusions about LCV operating characteristics:

    - LCVs consistently travel at an average speed of 103 km/h. This is below the posted speed limit (110 km/h), but in excess of the LCV speed limit of 100 km/h. Specifically: (1) 59.7 percent of RMDs exceeded the LCV speed limit, and 14.5 percent exceeded the posted speed limit; and (2) 54.9 percent of TPDs and triples exceeded the LCV speed limit, and 4.7 percent exceeded the posted speed limit. By comparison, 17.9 percent of tractor semitrailers exceeded the posted speed limit.

    - LCVs are operated during times that minimize their interaction with the motoring public (even though this is not required by the permit). The highest volumes of LCVs on Highway 2 occur between the hours of 10:00 pm and 6:00 am (ranging between 3.9 and 14.2 percent of total traffic volume during these hours).

    - LCV drivers exhibit the best following behavior of all commercial vehicles. Alberta Infrastructure and Transportation Driver Safety and Research recommends a following time of at least four seconds for commercial vehicles. RMDs and TPDs/triples failed to maintain a four second following time in 18.6 percent and 14.6 percent of the observations, respectively, compared to 23.4 percent for tractor semitrailers.

- Kenny et al. (2000a) reviewed design and operational considerations used by Alberta to accommodate LCVs. The report included minimum turning templates and acceleration characteristics for selected LCV configurations. It stated that a sight distance of 500 m was “acceptable and safe” for LCVs entering an undivided highway via a left turn at an at-grade intersection.

- Kenny et al. (2000b) indicate that there are strict restrictions in place regarding the operation of LCVs during peak traffic periods and in “adverse road conditions” in Alberta. For example, LCVs are not permitted between Calgary and Edmonton during peak traffic periods such as Friday afternoons or Mondays of holiday weekends. On this route (Highway 2), LCVs are only allowed to enter and exit at interchanges, roadside facilities, and intersections which have acceleration and deceleration lanes. LCVs are restricted from operating “during or immediately after snowstorms or in high winds.”

- Barton and Morrall (1998) conducted a study for Alberta Infrastructure and Transportation to develop recommendations relating to the use of LCVs on two-lane highways in Alberta. In the study, they indicate that it is important to ensure that motorists are provided with a “reasonable passing opportunity to overtake LCVs.” In Alberta, this reasonable opportunity is defined by a concept called the “net passing opportunity” (NPO), which is a function of the percentage of passing zones on the highway and the number and frequency of gaps in the opposing traffic stream. According to the authors, Alberta’s Highway Geometric Design Guide calls for a minimum of 30 percent NPO on two-lane highways. They indicate that “as long as the road and traffic conditions ensure this 30 percent NPO to a motorist trying to pass an

LCV, the LCV operation is feasible from a passing operations point of view." The study concluded that no LCVs could be permitted on a two-lane highway with less than 30 percent passing zones.

The authors also reviewed the literature on the overtaking requirements for non-passenger vehicles using actual field experiments. They found that most research does not examine the traffic volumes under which longer vehicles could operate without negatively affecting traffic flow. While they report that the lengths of vehicles tested in these studies were less than LCVs, they extrapolated to LCV lengths using research by Troutbeck (1981). They found the overtaking times and distances for different vehicle types traveling at 100 km/h. Table B-5 shows the results of the analysis.

Table B-5: Overtaking when impeding vehicle travels at 100 km/h

Vehicle Overtaken	Length (m)	Overtaking Time (sec)	Overtaking Distance (m)
Passenger car	5	13.3	446
Standard double	25	17.6	593
Rocky Mountain double	30	18.5	623
Turnpike double	38	20.0	674
Triple trailer	35	19.7	667

Source: Barton and Morrall (1998)

- In a study sponsored by the Association of American Railroads, Barnett (1995) suggests that passing an LCV on a two-lane road could be "considerably more hazardous" than passing another type of vehicle. The reason for this is that the passing maneuver would require more distance to complete. It would take more time to overtake the LCV and would increase the required passing speed. The same study also indicates that LCVs could pose a "formidable visual obstacle to nearby drivers." The large size of the LCV could delay recognition and response to posted warning signs or adverse road conditions.

- The General Accounting Office (GAO) (1992) states that rutted highways can affect the operational characteristics of long combination vehicles. Rutting is of particular concern if axle widths of the converter dollies are narrower than those on the rear trailer. This can cause additional trailer sway because the narrower wheels of the converter dollies may fall into the ruts, while the wider wheels on the rear trailer try to climb out of the ruts.

  The GAO (1992) also indicates that weather conditions and environmental factors such as gusting winds can affect trailer sway and the overall stability of LCVs. Poor weather conditions such as rain, snow, or ice can decrease a LCVs ability to accelerate, resulting in potential safety problems, mainly due to speed differentials between themselves and other vehicles. A study quoted in this report pointed out that a speed differential of 15 miles per hour (24 km/h) between vehicles can increase the accident rate by nine times, and a differential of 20 miles per hour (32 km/h) can increase it by 15 times.

- A study by the Alberta Transportation Safety Branch (1991) determined that the passing time required for a car traveling 15 km/h faster than a 23 m long truck traveling at 100 km/h on a two-lane highway was 15 seconds. By proportionality, the report stated that this time would increase by 10 percent if the car passed an RMD, by 13 percent if the car passed a triple, and by 20 percent if the car passed a TPD.

The study also included results from demonstration tests designed to determine the aerodynamic effects of LCVs. The tests revealed that greater air turbulence surrounding LCVs was "not disruptive" and anti-sail mud flaps sufficiently controlled water spray. It was also predicted that LCVs would not cause any more snow swirl than ordinary trucks.

- In a study sponsored by the AAA Foundation for Traffic Safety, Transportation Research and Marketing (1990) found that the operation of long doubles in wet or snowy weather "could create a substantially increased automobile accident rate" because of the splash and spray effects. The study states that automobile drivers can be "totally blinded" by "precipitation thrown onto the auto windshield."

- Harkey and Robertson (1989) indicate that slower moving LCVs on two-lane routes "may result in queues of vehicles which cannot pass due to the lack of adequate size gaps." Rear trailer amplification may cause drivers to be "hesitant in their passing maneuvers." They also state that passing an LCV may "present serious safety problems" if pavement markings are not based on LCV dimensions.

  The authors also investigated options for providing local access for LCVs operating on rural Interstate highways. In this analysis, they identified "safety implications" of roadway geometry characteristics. The off-tracking characteristics of LCVs "may cause the vehicle to run off the pavement onto the shoulder and may possibly result in a rollover accident." Horizontal curves with "small radii" were identified because high-speed operation may result in a wheel leaving the pavement or a sudden shift in cargo. Vertical grades "must be small enough" to ensure that they do not "impose a safety problem."

- Robertson et al. (1987) identify highway grade as a safety concern for LCV operations. The study determines that the observed speeds of LCVs on upgrades of three, four, and six percent are as shown in Table B-6. Two-lane passing operations require increased sight distances and passing times, both of which are magnified if operating on a grade.

Table B-6: Observed speed of LCVs on upgrades

Grade	RMD		TPD		Triples	
	mph	km/h	mph	km/h	mph	km/h
3	31	50	27	44	28	45
4	27	44	24	39	20	32
6	19	31	21	34	15	24

The authors also state that the loss of control of an LCV because of slippery roadway conditions is the primary concern associated with inclement weather. Another concern is the splash, spray and snow swirl problems associated with LCVs that cause difficulties for nearby drivers. It was found that LCVs do not cause more intense exposure to these factors, but they do increase the exposure time for nearby motorists. Crosswinds acting on the larger surface area of an LCV could increase the possibility of trailer sway and rollover.

- Stobbs (1986) studied the impact of operating RMDs on Highway 11 (a two-lane, undivided highway with 3.7 m lanes and 2.0 m shoulders) between Saskatoon and Prince Albert, Saskatchewan. He analyzed the number of passing conflicts that would occur between RMDs and the motoring public during the restricted hours of operation (generally between 11:30 PM and 6:30 AM). A passing conflict was defined as an event when one vehicle overtakes another and cannot immediately pass because of an approaching vehicle. Because of the reduced volumes on the highway at this time of day, RMDs were segregated from 92 percent of the motoring public, and passing conflicts were reduced by 94 percent per trip.

B.1.4 DRIVER STANDARDS AND TRAINING

The following summarizes the information obtained in recent literature (1995 and later) regarding LCV driver standards and training issues.

- Staplin et al. (2004) cited an article by Schulz in 2003 which noted that the Federal Motor Carrier Safety Administration had recently issued minimum training standards for operators of double and triple trailer LCVs, and requirements for instructors who train LCV drivers.

- Kenny et al. (2000b) discuss operating restrictions for LCVs on Alberta's highways. They state that operating restrictions include "strict criteria" for driver experience and safety records. Drivers must have "2 years or 150,000 km of articulated vehicle operation experience and be free from driving-related Criminal Code convictions for the previous 3 years."

- In a study by Alberta Infrastructure, Janz (2000) cites two major contributing factors for the "higher safety performance" of LCV drivers in Alberta: (1) permit requirements; and (2) voluntary corporate and driver operating practices. Janz states that the LCV permit is "probably the largest contributor to the safe operation" of LCVs in Alberta. The following conditions included in the permit "are designed to improve the safe operation" of LCVs:

  - Information reporting requirements
  - Route restrictions for LCV operations
  - Restricted times and days for LCV operations
  - Minimum equipment specifications
  - Maximum equipment sizes and weights for each LCV type
  - Driver instructor qualifications
  - Minimum driver qualifications, training and experience
  - Requirement of "no driving-related Criminal Code convictions in the prior 36 months; no more than two moving violations in the prior 12 months; and no more than three moving violations in the prior 36 months."

  Of the foregoing conditions, Janz indicates that the last one "is probably the highest contributor" to LCV safety. Because the LCV driver is ultimately responsible for operational safety, the absence of recent convictions and violations improves overall LCV driver behavior.

- In response to FHWA Docket No. 95-5, Washington (1995), on behalf of United Parcel Service (UPS), indicates that the UPS LCV (primarily triples) drivers are required to undertake rigorous classroom and on-road training courses. In addition, they must have a minimum of five years driving experience, and three years of safe driving experience (no accident involvement). UPS feels that these precautions contribute to the good safety record of their LCV fleet.

B.1.5 ENFORCEMENT

There was no recent literature found regarding this issue. However, the U.S. General Accounting Office conducted a study which was published in 1994 (GAO, 1994). The study found that states had not performed special inspections of LCVs, and there was some evidence suggesting that longer combinations were under-represented in roadside inspection programs.

B.1.6 EMERGING TECHNOLOGIES

This section presents findings from the literature about emerging technologies to improve the safety of commercial vehicle operations in general. Although there are hundreds of such technologies, the purpose of this section is to present a few selected ones which may also be applied to LCV operations for improved safety.

B.1.6.1 Driver-related Technologies

There are different types of driver-related technologies available. Two are discussed here based on recent literature.

- FMCSA (2005a) states that fatigue warning systems are used to assess the fatigue level of a driver and initiate a warning. The SleepWatch system consists of a wrist-worn device that monitors rest-activity patterns and predicts the driver’s personal sleep needs. Copilot uses an infrared retinal monitoring system to measure slow eyelid closures, a sign of driver drowsiness. The SafeTRAC system analyzes a driver’s lane tracking performance and assesses the level of alertness of the driver. These systems provide warnings to drivers if their behaviour indicates an unsafe level of fatigue.

- Sturgess and Whistler (2003) provide a description of vision enhancing technologies. These are radar or thermal-based systems that assist driver’s vision in conditions such as rain, snow, or darkness. Radar systems detect objects within a predefined distance from the vehicle, and warn the driver to take evasive actions. Thermal systems assist drivers in identifying pedestrians, cyclists, wildlife, and other various roadside objects. Images are projected onto the vehicle’s windshield so drivers do not need to divert their attention from the roadway.

B.1.6.2 Vehicle-related Technologies

Five applications of interest, based on recent literature are discussed.

- Roll stability control systems monitor lateral forces exerted on a vehicle and automatically apply brakes to counteract these forces (FMCSA, 2005b). In-vehicle rollover warning systems integrate vehicle sensors, in-cab displays, and GIS-based roadway geometry mapping to prevent vehicle rollover and collisions. These systems are not limited to specific curves that have the appropriate infrastructure in place since the technologies are only associated with the vehicle.

- Forward collision avoidance technologies use radar sensors mounted on a vehicle to detect slower moving vehicles in the same lane (Figure B-1). The system provides a warning in time for the driver to take action to avoid a collision (FMCSA, 2005c).

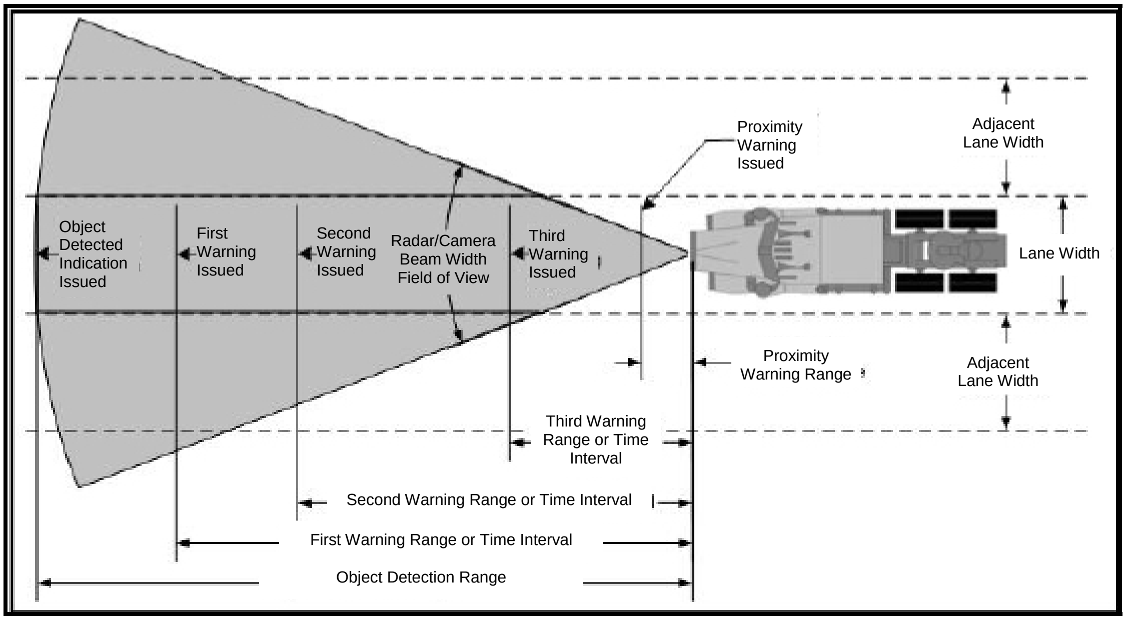


Figure B-1: Forward collision avoidance systems
Source: FMCSA, 2005c

- Adaptive cruise control technologies utilize radar sensors similar to those used in collision avoidance sensors to detect the presence of leading vehicles (Figure B-2). If the cruising vehicle intrudes within a predefined safe following distance, the brakes are automatically applied (FMCSA, 2005c).

- FMCSA (2005d) states that lane departure warning systems (LDWS) monitor the position of a vehicle within a roadway lane and warn a driver if the vehicle deviates outside the lane width (Figure B-3). LDWS are vision-based systems that use algorithms to interpret video images of the roadway ahead of the vehicle. The driver is warned if the traveling speed exceeds predefined thresholds or if the lane markings are not adequate for detection. No automatic action is taken.

- Baker et al. (2000) discuss runaway truck signal control systems, which integrate weigh-in-motion (WIM) technologies, axle sensors, height detectors, and inductive loops to measure the speed, weight, and dimension of a vehicle. In-road tracking sensors installed downstream of the WIM and dimension sensors are used to determine the vehicle's deceleration. An algorithm incorporates these data and predicts whether the truck is traveling at a safe speed for an upcoming curve, downgrade, or traffic signal given the physical characteristics of the roadway. If the truck is traveling too fast, an advance warning is displayed via a dynamic message sign.

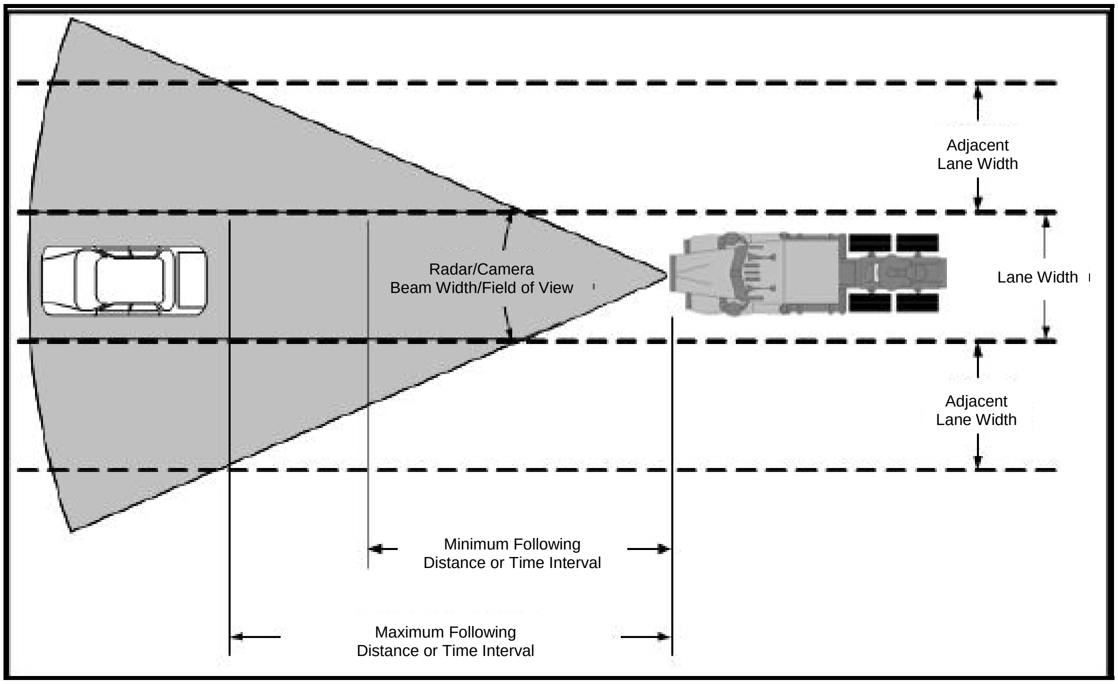


Figure B-2: Adaptive cruise control systems
Source: FMCSA, 2005c

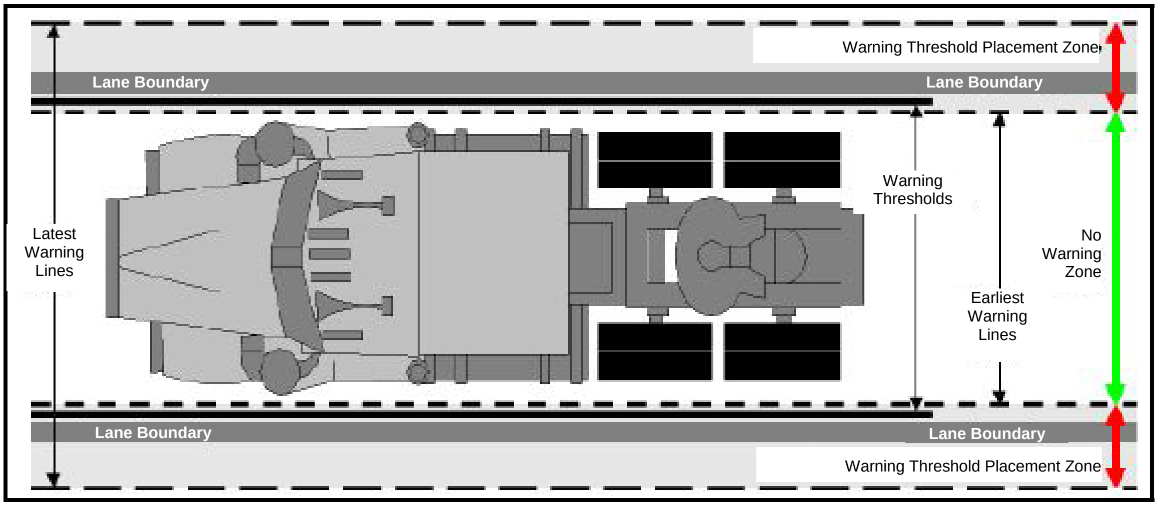


Figure B-3: Lane departure warning systems
Source: FMCSA, 2005d

B.1.6.3 Automated Enforcement Systems

These are different types of advanced technologies to assist in enforcement. Two are discussed here:

- The U.S. Department of Transportation (2005) states that automated inspection systems improve commercial vehicle operations at ports, trucking terminals, inspection stations, and border crossings. Component technologies include Automatic Vehicle Identification (AVI) such as Radio Frequency Identification (RFID) technologies and smart cards, WIM, and automatic vehicle classification (AVC) devices. Non-intrusive inspection technologies use X-ray and gamma ray scanners to assist enforcement personnel in identifying cargo inside the vehicle. Biometric identification tools incorporate fingerprint or iris recognition into smart card systems which can be integrated with vehicle and driver databases.

- The U.S. Federal Motor Carrier Safety Administration (FMCSA, 2002) conducted a study to determine the effectiveness of the Infrared Inspection System (IRISystem). This system uses a portable infrared camera to detect defective brakes at an inspection facility. Thermal images of the wheels of trucks entering the inspection facility provide a real-time indication of defective brakes. Wheels with functional (warm) brakes appear bright white in the infrared image, while the wheels with inoperative (cold) brakes appear darker. The images are used to screen trucks for more detailed brake inspections. The study found that the percentage of vehicles placed out-of-service due to brake problems increased from 34 percent to 84 percent with the IRISystem screening.

B.1.6.4 Road Weather Information Systems

Fayish and Jovanis (2004) define a road weather information system (RWIS) as an amalgamation of technologies that collect, transmit, model, and distribute weather and road condition information. Montufar and McGregor (2003) state that because these systems are used for monitoring and forecasting weather and road surface conditions, they can help with the implementation of an intelligent road maintenance strategy to reduce truck collisions. Web-based information dissemination and integration with web-mapping technologies and traveler information systems broadens the effectiveness of an RWIS by providing easy access to real-time information.

B.2 JURISDICTIONAL SURVEY

B.2.1 JURISDICTIONAL SURVEY OVERVIEW

B.2.1.1 Extent of Network

The Canadian Prairie Region LCV network serves a population base of over six million people and consists primarily of low volume roads (i.e., between 100 and 5,000 trucks per day). Alberta, Saskatchewan, and Manitoba routinely permit LCVs on all major highways. Turnpike doubles are used on divided highways and some undivided sections. As of May 1, 2006, the TPD network totaled 3,800 centerline-kilometers (Regehr and Montufar, 2007). Rocky Mountain doubles are permitted on all divided highways plus certain two-lane highways that meet specific geometric criteria (e.g., paved shoulder width), provide essential connectivity to key freight generators or attractors, or represent a critical linkage for northern or remote regions. As of May 1, 2006, the two-lane RMD network totals 8,900 centerline-kilometers (Regehr and Montufar, 2007). Triples are operated to a limited extent on divided highways.

Similar to Alberta, all jurisdictions surveyed have allowed at least one type of LCV operation since the 1970s. In some cases, all types of LCVs (RMDs, TPDs, and triples) started being permitted on selected highway networks around the same time. In other cases, such as the situation in Montana, certain LCVs were not permitted to operate in the state until later (e.g., triples were not permitted until the early 1990s). However, no jurisdiction other than Alberta has explicitly evaluated the safety performance of LCV operations in their state or province.

B.2.1.2 Weather and Road Conditions

Similar to Alberta, most jurisdictions require LCV operators to exercise caution and reduce speeds when hazardous conditions due to snow, ice, or other type of precipitation arise. Nevada is the only jurisdiction which does not restrict travel during any weather or road conditions. Saskatchewan, Idaho, and Utah identify restrictions over and above those identified by Alberta, particularly relating to visibility. Most jurisdictions indicate that they have not experienced any noticeable difference in LCV collisions as a result of weather or road conditions. Similar to findings from the jurisdictional survey, the literature does not provide conclusive evidence that collision rates involving LCVs increase or decrease with operations during inclement weather. Some literature indicates that the following weather-related factors may affect the safety performance of LCVs: high speed winds; icy roads; and splash, spray, and snow swirl effects.

B.2.1.3 Temporal Restrictions

Similar to Alberta, temporal restrictions (e.g., time of day, day of week, or seasonal) to the operation of LCVs apply in Saskatchewan and Manitoba. These restrictions do not apply in the CANAMEX states. However, Arizona may restrict or prohibit the operation of LCVs when traffic or other safety considerations make such operations unsafe, but the State has not yet exercised this authority. Most jurisdictions indicate that they have not experienced high concentrations of LCV collisions during specific times of day or days of week.

B.2.1.4 Driver Training and Qualifications

In addition to a commercial driver's license, all jurisdictions, except for Manitoba and Idaho, require LCV drivers to have special training and education specifically concerning their operation. This practice is consistent with Alberta regulations. Evidence in the literature and through interviews with government officials suggests that increased driver training and qualifications decreases LCV collision rates since only highly skilled and experienced drivers are allowed to operate these vehicles. In addition, LCV carriers are encouraged to maintain high safety standards to ensure that they keep their LCV permits.

B.2.1.5 Speed Control

Speed control restrictions are present in Alberta LCV permit regulations and vary between jurisdictions. Manitoba, Utah, Nevada, and Arizona do not have special speed control restrictions for LCVs or other commercial vehicles. Montana and Idaho have special speed control requirements for triple trailer combinations only, and Saskatchewan has specific speed requirements for LCV operations in general. One jurisdiction indicates that speed differentials between LCVs and other vehicles may contribute to increased collision frequency involving these vehicles. Alberta restricts LCV speed to the lesser of 100 kph or the posted speed limit, however other jurisdictions do not unanimously concur that reducing LCV speed decreases collision rates. Some literature argues that lower speeds reduce stopping distances of LCVs and provide longer reaction time, while other literature argues that speed differentials increase the risk of collisions, particularly on two-lane highways where long queues can build up behind an LCV and promote aggressive driving behaviour during passing maneuvers.

B.2.1.6 Monitoring and Evaluation

Similar to Alberta, dedicated LCV collision monitoring and evaluation provisions do not exist in Manitoba, Saskatchewan or the CANAMEX Corridor states. Utah is the only jurisdiction where collision reports contain specific fields for reporting information such as trailer length. Most jurisdictions indicate that LCV collisions do not warrant special analysis since there are so few to consider. This leads to a lack of consensus amongst jurisdictions and the literature regarding the effectiveness of dedicated LCV monitoring and evaluation programs in decreasing LCV collision rates.

B.2.1.7 Vehicle-related Requirements

Each jurisdiction has different vehicle-related requirements stated specifically in their LCV regulations. No two jurisdictions have an identical set of vehicle-related requirements for LCVs. U.S. jurisdictions specify a minimum speed that an LCV must maintain on any grade where operated, while Saskatchewan and Alberta specify minimum LCV weight-to-power ratios. Arizona, Nevada, and Utah uniquely identify that LCVs must be capable of operating at speeds compatible with other traffic. Some jurisdictions have maximum allowable sway regulations and most U.S. jurisdictions interviewed have minimum distances that LCVs must maintain between other vehicles operating on the highway. Four jurisdictions instruct LCV operators to ensure that heavier trailers always precede lighter trailers while another four have off-tracking limits for highway operation.

B.2.1.8 Enforcement Issues

Similar to Alberta, enforcement of LCV regulations is conducted in each jurisdiction as part of the general commercial vehicle enforcement program. All jurisdictions report having experienced high compliance rates with LCV regulations. This high compliance rate has been attributed to severe penalties issued to non-compliant carriers such as suspension or removal of LCV permit, fines, and/or legal action.

The following sections present detailed summaries regarding LCV operations in each of the jurisdictions contacted for this survey.

B.2.2 SASKATCHEWAN

Saskatchewan has allowed LCVs since the 1970's. Rocky Mountain doubles were first introduced, followed by Turnpike doubles and triple trailer combinations. Table B-7 shows maximum allowable size and weight limits of LCVs operating in Saskatchewan.

Table B-7: Size and weight limits of LCVs operating in Saskatchewan

Configuration	Length (m)	Gross Vehicle Weight (kg)
Rocky Mountain double	31.0	62,500
Turnpike double	38.0	62,500
Triple Trailer	38.0	53,500

Note: Maximum allowable GVWs are a function of the type of converter dolly, axle arrangement, and other factors. Details of size and weight limits are contained in the Saskatchewan regulations.

Unlike Alberta, Saskatchewan has not explicitly evaluated the safety performance of LCV operations in the province. However, Saskatchewan officials state that LCV operators have experienced very few collisions relative to the amount of travel they undertake. This makes provincial officials feel that these vehicles are very safe.

The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Saskatchewan.

B.2.2.1 Extent of Network

Similar to Alberta, Saskatchewan allows LCVs to operate on a limited two-lane and four-lane network. Turnpike doubles, Rocky Mountain doubles, and triple trailers are allowed to operate on four-lane highways. Select two-lane highways allow RMDs only. Saskatchewan officials use discretionary judgment when selecting routes to include in the LCV network. Considerations in this process include sight lines, traffic volumes, passing opportunity, passing distance and road and surface width. Currently there is no shoulder width or paving requirements on highways to allow LCVs.

B.2.2.2 Weather and Road Conditions

Unlike the situation in Alberta, where the province does not explicitly set visibility distance criteria that instructs carriers when to avoid operating LCVs, Saskatchewan prohibits LCV operation when visibility is reduced to 1,000 m or less, the highway is icy or heavily snow covered, or when the operation may otherwise pose a particular hazard.
However, the carrier is responsible to judge when these conditions exist and take appropriate action. Because Saskatchewan officials find this regulation to be too subjective, they are considering changes to it. However, details regarding these changes are still in development and could not be released publicly at the time of this report.

B.2.2.3 Temporal Restrictions

Saskatchewan's temporal restrictions for LCVs are defined on a route-by-route basis. Hourly restrictions apply to two-lane roads in the following four categories:

- Commuter zones
  - LCVs are not permitted to operate in a 50 km commuter zone around Saskatoon and Regina on weekday mornings and evening peak hours.
  - These zones take precedence over all other restriction schedules.

- Routes with minor restrictions
  - LCVs are not permitted to operate on statutory holiday weekends and on statutory holidays that fall on weekdays, between the hours of 11:00 AM and 9:00 PM.

- Routes with seasonal restrictions
  - LCV operations are restricted during Friday daytime and Sunday daytime in the winter (between the September long weekend and May long weekend).
  - LCV operations are not permitted during the daytime in summer.
  - The same restrictions apply to these routes as for the routes with minor restrictions.

- Routes with year-round restrictions
  - LCV operations are not permitted during the daytime.

Some four-lane highways do not permit LCV operations on statutory holidays between 12:00 PM and 9:00 PM.

B.2.2.4 Driver Training and Qualifications

Similar to Alberta, in addition to a Class 1-A commercial vehicle driver's license, Saskatchewan requires LCV drivers to have an Energy Efficient Motor Vehicle (or Long Combination Vehicle) driver certificate. To obtain this certificate, drivers must:

- Have submitted a driver's abstract dated not more than one month prior to the issue date of the certificate. Abstracts shall have no driver-related Criminal Code violations in the prior 36 months, no more than two moving violations in the prior 12 months, and no more than three moving violations in the prior 36 months.

- Have completed a Professional Driver Improvement Course within 48 months.

- Have passed the Canadian Trucking Alliance Long Combination Vehicles Driver Training Course or equivalent and a recognized refresher course every 48 months.

Unlike Alberta, Saskatchewan does not have any requirements involving the length of driving experience (in terms of time or kilometers driven) with articulated vehicles.

B.2.2.5 Speed Control

Unlike Alberta where LCVs are restricted to traveling the lesser of 100 km/h or the posted speed limit, the speed limit for LCVs in Saskatchewan is 90 km/h (or less if posted) on all roads. This LCV limit applies even on roads where the speed limit for other vehicles is 100 km/h or more. The speed limit for LCVs was chosen based on the speed that best accommodates safety in terms of vehicle dynamics such as stability, aggressive evasive maneuverability, and stopping distances. Recent changes in vehicles, infrastructure, and increased speed limits to 110 km/h on four-lane highways in the province, have encouraged Saskatchewan to review LCV speed limits.

B.2.2.6 Monitoring and Evaluation

Carriers must report all accidents of a significant nature (vehicle upset, personal injury, death) or caused by mechanical failure as soon as possible. Saskatchewan officials can also perform random safety compliance audits on trucking companies to determine operating characteristics such as hours of operation and collisions. Through bills of lading, collision reports, and discussions with specific trucking companies, Saskatchewan officials can determine the number of collisions in which each vehicle configuration was involved.

B.2.2.7 Vehicle-related Requirements

Similar to Alberta, Saskatchewan requires that LCVs have a power-to-weight ratio of one horsepower per 160 kg of GVW. LCVs must meet TAC performance criteria for off-tracking and must have speed recording devices installed.

B.2.2.8 Enforcement Issues

Saskatchewan conducts regular enforcement and safety performance audits specifically targeted to LCV operations. The province has found that carriers are typically compliant with permit/agreement requirements and regulations. The violations that have occurred are equally distributed between local independent companies and long-haul operators. Violators may have their permits terminated or suspended for a length of time as determined by Saskatchewan officials.

B.2.3 MANITOBA

Manitoba has allowed LCVs since the late 1970's. Rocky Mountain doubles were first introduced, followed by Turnpike doubles and triple trailer combinations. The allowable size and weight limits of LCVs operating in Manitoba are shown in Table B-8.

Table B-8: Size and weight limits of LCVs operating in Manitoba

Configuration	Length (m)	Gross Vehicle Weight (kg)
Rocky Mountain double	31.5	62,500
Turnpike double	38.5	62,500
Triple Trailer	35.0	53,500

Note: Maximum allowable GVWs are a function of the type of converter dolly, number of axles, and other factors. Details of size and weight limits are contained in the Manitoba regulations.

Unlike Alberta, Manitoba has not explicitly evaluated the safety performance of LCV operations in the province.

In 2003, Manitoba Transportation and Government Services (now Manitoba Infrastructure and Transportation—MIT), commissioned a study to conduct a comprehensive literature review of LCV operations in North America and other countries. This was done to address a request for the operation of RMDs on Provincial Trunk Highway (PTH) 6 between Winnipeg and Thompson, Manitoba. PTH 6 is a two-lane undivided highway with gravel and partially-paved shoulders and is the only road connection between Winnipeg and designated northern communities. Following that study, the province conducted a detailed safety assessment of the highway in question and as a result implemented edge line painting and improved shoulders to eliminate drop-offs. The assessment also found that passing opportunities were a major concern.

Once the safety issues with the highway were addressed, the province authorized a pilot project to allow the operation of RMDs on this highway. Strict conditions are in place to address passing opportunities and other road engineering issues. These conditions include mandating RMDs to have signs on the back of the last trailer warning other drivers that it is a long vehicle. A maximum of two trips per day leaving Winnipeg are allowed but only after 8:00 PM every day. RMDs participating in this pilot project are also required to have monitoring devices installed that allow MIT to keep a record of vehicle operating characteristics such as speed and kilometers traveled.

If this pilot project is successful, Manitoba will examine additional undivided highways to investigate the potential for allowing LCVs on those highways.

Provincial officials indicate that the province is interested in allowing LCVs on other highways to increase productivity and reduce greenhouse gas emissions but not at the expense of safety. In the absence of substantial data about the safety performance of LCVs, Manitoba is cautious about formulating an opinion regarding their safety performance. Initial experiences with RMDs on PTH 6 have been favorable, but a final analysis at the end of the pilot project will accurately determine the safety performance of RMDs on this road.
The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Manitoba.

B.2.3.1 Extent of Network

In Manitoba, LCVs are allowed to operate on all divided highways and most two-lane highways with paved shoulders. Rocky Mountain doubles are also allowed on selected two-lane highways where the cross-section provides an "extended lane width" paved surface. This means two 12-foot (3.66 m) lanes and two 3-foot (0.91 m) shoulders. These roads normally also include additional shoulder width (paved or gravel). Alberta has similar network characteristics as Manitoba, however TPDs in Alberta are also allowed to operate on select two-lane highways.

B.2.3.2 Weather and Road Conditions

Original regulations stated that LCVs should not operate when visibility was less than 500 meters or when the road surface was slippery. This regulation was changed to indicate that LCV drivers must operate in a reasonable and prudent manner, having regard for road and weather conditions. The permit specifically refers permittees to the Manitoba Road Weather Information System for detailed information about roads and weather (phone number 204-945-3704). The appropriateness of this condition is currently being reviewed to make it easier to enforce.

B.2.3.3 Temporal Restrictions

Manitoba's temporal restrictions for LCVs are defined by statutory holidays and season (winter/summer). Similar to Alberta, LCV movements in Manitoba are not allowed on statutory holidays (except for Boxing Day), and after 4:00 PM on days preceding these holidays. Other than on statutory holidays, there are no temporal restrictions for LCV operations during winter months (between the September long weekend and May long weekend) in Manitoba. In summer, LCV operations are not permitted on Friday evening (between 4:00 PM and 9:00 PM), Saturday daytime (between 11:00 AM and 9:00 PM), or Sunday daytime (between 11:00 AM and 9:00 PM).

B.2.3.4 Driver Training and Qualifications

Manitoba requires that LCV drivers adhere to any safety requirements developed by the company safety supervisor. This is different from Alberta's requirements, where special training and education specifically concerning LCVs are required for their operation.

B.2.3.5 Speed Control

In Manitoba, the policy regarding the speed control of LCVs is that they are allowed to operate at the same maximum speed as any other vehicle. On two-lane highways where RMDs are permitted to operate, they may travel at a maximum speed of 100 km/h (or less if posted). Considering that the maximum speed limit on any highway in Manitoba cannot exceed 100 km/h, these speed limits for LCVs are the same as in Alberta.

B.2.3.6 Monitoring and Evaluation

Manitoba has no special requirements regarding auditing, incident or accident reporting, or performance analysis of LCV operations. Alberta, however, requires carriers to submit a Collision Investigation Report Form for any collisions involving LCVs to AIT within one week of occurrence.

B.2.3.7 Vehicle-related Requirements

Manitoba regulations require LCVs to be **". . .** designed, constructed, and coupled together so as to ensure that any such combination traveling on a level, smooth, paved surface will follow in the path of the towing vehicle without shifting, swerving or swaying from side to side over 10 cm to each side of the path of the towing vehicle when moving in a straight line." The sway requirements for LCVs in Alberta are the same as in Manitoba.

B.2.3.8 Enforcement Issues

Limited enforcement specifically targeted to LCV operations is conducted in Manitoba. The province has found that carriers are compliant with permit requirements and regulations since the cost of LCV incidents outweigh the benefit of operating one of these units.

B.2.4 MONTANA

Montana has allowed LCVs since the 1970's; however this only included Rocky Mountain doubles and Turnpike doubles. Triple trailer combinations were introduced in 1993. The allowable size and weight limits of LCVs operating in Montana are provided in Table B-9.

Table B-9: Size and weight limits of LCVs operating in Montana

Configuration	Length (cargo-carrying units)		Gross Vehicle Weight	
	(ft)	(m)	(lb)	(kg)
Double Trailer	95.0	29.0	131,060	59,500
Triple Trailer[1]	100.0	30.5	131,060	59,500
Triple Trailer[2]	95.0	29.0	131,060	59,500

Source: 23 CFR 658 App. C

Note a: Maximum allowable GVWs are a function of various factors. Details of size and weight limits are contained in the Montana regulations and 23 CFR 658 App. C

Note b: Cargo-carrying unit is defined by 23 CFR 658 App C as " . . . any portion of a commercial motor vehicle combination (other than a truck tractor) used for the carrying of cargo, including a trailer, semitrailer, or the cargo-carrying section of a single unit truck. The length of the cargo-carrying units of a commercial motor vehicle with two or more such units is measured from the front of the first unit to the rear of the last (including the hitch(es) between the units)."

1 With conventional tractor, within a maximum overall length of 110 feet (33.5 m)
2 With cab-over tractor, within a maximum overall length of 105 feet (32.0 m)

In addition to the above vehicle limits, the state has defined a configuration called “combination doubles” where the overall vehicle length is between 95 feet (29.0 m) and 100 feet (30.5 m). Combination doubles include Turnpike doubles with twin 45-foot trailers. Permits to operate combination doubles are issued for Interstate highways only.

According to Montana state officials, LCV collision rate and frequency can be obtained; however there has been no study conducted using this data. Although state officials do not believe LCVs are dangerous, there is generally a natural negative reaction to LCVs from the public. Two years ago, an attempt was made by Montana to investigate LCV collision rates through a National Cooperative Highway Research Project (NCHRP) study. The proposal, which was similar to the safety study conducted by Alberta in 2001, was unsuccessful due to lack of funding by NCHRP. Currently the Montana Department of Transportation has a research contract with the University of Montana to look at necessary LCV collision reporting information. This project is still in the early stages of development.

The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Montana.

B.2.4.1 Extent of Network

Montana has a Memorandum of Understanding (MOU) with Alberta that allows heavier LCVs to operate on Interstate 15 (I-15) between Alberta and Shelby. This MOU required an exemption to U.S. Federal law since I-15 is part of the National Highway System (NHS). More recently, Montana added another highway (U.S. 93 from Roosville to Eureka) that allows LCVs with the same size and weight limits as the Alberta/Montana MOU. This highway did not require an exemption to federal law since it is a state highway. Table B-10 shows the allowable size and weight limits of LCVs operating under the Alberta/Montana MOU.

Table B-10: Alberta/Montana MOU size and weight limits

Configuration	Length (cargo-carrying units)		Gross Vehicle Weight	
	(ft)	(m)	(lb)	(kg)
A-train[1]	95.0	29.0	118,000	53,500
B-train (8-axles)[1]	95.0	29.0	137,800	62,500
B-train (7-axles)[1]	95.0	29.0	124,600	56,500

Source: 23 CFR 658 App. C

1 Includes RMD

LCVs are allowed to operate on many routes within Montana as shown in Table B-11. State officials indicate that at this time, Montana does not have any plans to extend the current LCV network for fully-loaded Canadian LCVs operating under the Alberta/Montana MOU due to concerns about weight loadings on road infrastructure and bridges.

Table B-11: Montana highways allowing LCVs

Cargo-carrying length		Routes
(ft)	(m)	
88 – 100	26.8 – 30.5	Interstate System
<88	<26.8	National Network; except U.S. 87 from milepost 79.3 to 82.5
MOU	MOU	I-15 from Canadian border to Shelby

Source: 23 CFR 658 App. C

B.2.4.2 Weather and Road Conditions

Similar to Alberta, Montana does not have striping, minimum shoulder width, or specific road geometry requirements for roads that allow LCVs. Montana officials have not experienced increased LCV collisions caused by weather or road conditions.

Double trailer LCV operations can be restricted or prohibited based on inclement weather and poor road conditions as determined by either the carrier or the maintenance staff of the DOT. This regulation has similarities to Alberta's where carriers (not AIT) determine if driving conditions are appropriate while authorized AIT staff or peace officers patrol the highways to ensure that LCVs are not operated during adverse weather. In Montana, if carriers decide that weather and road conditions are undesirable, they can refrain from sending out LCVs. If the DOT decides that weather and road conditions are unsafe, a notification is posted on the Montana DOT website informing carriers about which routes are closed. Triple trailers, however, are prohibited to operate during adverse weather conditions as required by the Code of Federal Regulations. Roads may also be closed to LCVs or have time restrictions during spring thaw.

B.2.4.3 Temporal Restrictions

Unlike Alberta, there are no temporal restrictions for LCVs in Montana.

B.2.4.4 Driver Training and Qualifications

Double trailer LCV drivers must have a commercial driver's license with an endorsement to operate LCVs in Montana. Triple trailer drivers must have a commercial driver's license, endorsement to operate LCVs, and certification which includes a driving test and knowledge of Federal Motor Carrier Safety Regulations and State law pertaining to triple trailer operations. The training and qualifications applicable to operating triple trailers in Montana are similar to those required to operate any type of LCV in Alberta.

B.2.4.5 Speed Control

Unlike the case in Alberta, Montana has specific speed limits for different vehicle types and times of day as shown in Table B-12. Daytime hours begin one-half hour before sunrise and end one-half hour after sunset. Lower speed limits for large trucks are implemented since Montana recognizes that these vehicles are much heavier than other vehicles and therefore have longer braking distances and less ability to avoid hazards. Lower speed limits are believed to address these large truck operating characteristics.

Although Alberta does not have time-of-day speed limits for LCVs, there are roads in the province where the speed limit for LCVs is less than for other vehicles. LCVs in Alberta are limited to a maximum speed of 100 km/h even though they are allowed to operate on highways where the speed limit is 110 km/h. As illustrated in Table B-12, the speed differential in Montana between LCVs and passenger vehicles is greater than the speed differential occurring in Alberta, especially when comparing triple trailer operations.

Table B-12: Speed limits for Montana in miles per hour

Vehicle Type	Daytime Speed Limit		Nighttime Speed Limit	
	Interstate	U.S. Highway	Interstate	U.S. Highway
Passenger Vehicles	75	70	75	65
Trucks (including RMD)	65	60	65	55
Triple Trailers	55	NA	55	NA

Source: Montana DOT

B.2.4.6 Monitoring and Evaluation

Montana does not have specific enforcement resources to monitor and evaluate LCV safety performance. The state is interested in developing methods to monitor and evaluate LCV safety performance, but currently does not have sufficient funding to operate this type of program.

B.2.4.7 Vehicle-related Requirements

Triple trailer LCVs are required to maintain a minimum speed of 20 mph (32 km/h) on any grade where they operate and must maintain a minimum distance between other vehicles of 100' (30.5 m) per 10 mph (16 km/h) traveling speed, except when passing. No special requirements beyond compliance with Federal Motor Carrier Safety Regulations apply to Rocky Mountain double operation.

B.2.4.8 Enforcement Issues

Montana does not have a special enforcement division for LCVs. Trucks are inspected at various Port of Entry locations on the state border. They find that most LCV carriers operate in compliance with state and federal regulations.

B.2.5 IDAHO

Idaho has allowed LCVs since the 1970's, including double and triple trailer combinations. A summary of LCV size and weight limits is provided in Table B-13. Unlike Alberta, Idaho has not explicitly evaluated the safety performance of LCV operations in the state. Although some legislators perceive LCVs to be more dangerous than regular tractor-trailer trucks, according to state officials, LCV safety performance is not a problem.

The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Idaho.

Table B-13: Size and weight limits of LCVs operating in Idaho

Configuration	Length (cargo-carrying units)		Gross Vehicle Weight	
	(ft)	(m)	(lb)	(kg)
Rocky Mountain double	95.0	29.0	105,500	47,850
Turnpike double	95.0	29.0	105,500	47,850
Triple Trailer	95.0	29.0	105,500	47,850

Source: 23 CFR 658 App. C

Note a: the cargo-carrying unit refers to the box length and excludes the power unit.

Note b: Maximum allowable GVWs are a function of various factors. Details of size and weight limits are contained in the Idaho regulations and 23 CFR 658 App. C

B.2.5.1 Extent of Network

Idaho permits LCVs to operate on all National Network routes in the state.

Similar to Alberta, LCVs are permitted to operate on two-lane and four-lane highways. Compared to the extensive LCV network in Idaho, there are relatively few LCVs operating in the state and according to state officials, safety performance of these vehicles is not a problem due to this low exposure. Nonetheless, improvements to two-lane routes such as U.S. 95 continue to better accommodate LCVs. Improvements consist of straightening road alignment, modifying two-lane roads to four-lane, and other enhancements to help improve safety and capacity. At this time, there is no plan to extend the LCV network in the state.

Idaho has designated four categories of routes to allow the operation of LCVs. These routes are identified as blue code, red code, black code, and green code. Each code has specific limits on overall length and off-tracking as shown in Table B-14.

In 2004, Idaho initiated a 10-year pilot project to increase GVW from 105,500 lb (47,850 kg) to 129,000 lb (58,500 kg) on selected routes including I-15 which is part of the CANAMEX corridor. The project requires submission of progress reports every three years that document the results to date.

Table B-14: Maximum overall vehicle lengths and off-tracking for LCV routes

Highway Code	Maximum Overall Vehicle Length		Maximum Off-tracking	
	(ft)	(m)	(ft)	(m)
Blue	90.0	27.0	5.50	1.67
Red	115.0	35.0	6.50	2.00
Black	115.0	35.0	6.50 – 8.75	2.00 – 2.67
Green	85.0	26.0	3.00	1.00

Source: Idaho DOT

B.2.5.2 Weather and Road Conditions

Idaho officials have not experienced any noticeable difference in LCV collisions as a result of weather or road conditions. Similar to Alberta, LCV permits issued by Idaho instruct LCV operators to exercise extreme caution when conditions such as snow, ice, sleet, fog, mist, rain, dust or smoke adversely affect visibility or traction. Permits issued by Idaho also state that LCV operation is prohibited when visibility is less than 500 feet (150 m) and when state officials judge weather conditions to make LCV operation unsafe. This is different than Alberta where specific ranges of visibility are not provided.

Similar to Alberta, Idaho does not have a mandatory chain-up law that requires LCVs to attach traction improving devices to tires during icy or snowy conditions. According to state officials, a chain-up law could reduce the number of instances that LCVs are restricted or prohibited to operate during inclement weather.

B.2.5.3 Temporal Restrictions

Unlike Alberta, Idaho does not have temporal operating restrictions, other than those discussed above for LCVs. Idaho officials indicate that the state has not experienced increased collision frequency involving LCVs during any specific season, day of week, or hour of day.

B.2.5.4 Driver Training and Qualifications

No special training is required to operate LCVs in Idaho other than a commercial driver's license. This contrasts Alberta driver training and qualification requirements such as completing LCV driving tests and having minimum experience with articulated vehicles.

B.2.5.5 Speed Control

Idaho has imposed differential speed limits for vehicles operating on the Interstate highway system. Vehicles with less than five axles and a GVW less than 26,000 lb (11,800 kg) can travel 75 mph (120 km/h) while all other traffic is limited to 65 mph (105 km/h). The 65 mph speed limit was arbitrarily set by legislators because there was a perception that heavier vehicles are more dangerous than smaller vehicles. Although there is a 65 mph speed limit for LCVs, Idaho officials have observed that most LCVs actually operate at 70 mph. However, speed has not been attributed to increased LCV collision frequency. Currently there is a Bill in legislature that is proposing to set the speed limit for all vehicles on Interstate highways at 70 mph (110 km/h).

B.2.5.6 Monitoring and Evaluation

Idaho has no special requirements regarding auditing, incident or accident reporting, or performance analysis of LCV operations. However, LCV collisions must be reported to the local police department or county sheriff office for inclusion in the state collision information system. In addition, when applying for overlegal permits, LCV operators must provide information regarding origin-destination, and preferred route.

B.2.5.7 Vehicle-related Requirements

Idaho regulations specify that LCVs must have adequate power and traction to maintain a minimum of 15 mph (25 km/h) under normal operating conditions on any up-grade over which the combination is operated. Alberta also has regulations similar to these that require LCVs to have a power-to-weight ratio of one horsepower per 160 kg (120 kg/kW). In addition, similar to Alberta, Idaho regulations instruct LCV operators to ensure that the loading of any trailer cannot be more than 4,000 lb (1,800 kg) heavier than any trailer preceding it. Unlike the case in Alberta, LCVs in Idaho must maintain a minimum distance of 500 feet (150 m) between other combination vehicles except when overtaking or passing. Idaho requires LCVs to avoid routes with unpaved shoulders and narrow roads where vehicles cannot remain on the right side of center line at all times for two-lane operation. Four-lane operation of LCVs requires vehicles to remain on the right side of all lane markings. Unlike Alberta, Idaho does not have maximum sway regulations.

B.2.5.8 Enforcement Issues

Enforcement of regulations and inspection of commercial vehicles, including LCVs, is performed at Port of Entry locations on state boundaries. Temporary inspection stations throughout the state are also set up to conduct inspections. State officials have found that most carriers comply with regulations, especially large interstate carriers. Most violations experienced result from small independent trucking companies.

B.2.6 UTAH

Utah has allowed LCVs since the 1970's. Rocky Mountain doubles were introduced in 1973 followed by Turnpike doubles and triple trailers shortly after. A summary of LCV size and weight limits is provided in Table B-15.

Table B-15: Size and weight limits of LCVs operating in Utah

Configuration	Length (cargo-carrying units)		Gross Vehicle Weight	
	(ft)	(m)	(lb)	(kg)
Rocky Mountain double	95.0	29.0	129,000	58,500
Turnpike double	95.0	29.0	129,000	58,500
Triple Trailer	95.0	29.0	129,000	58,500

Source: 23 CFR 658 App. C

Note a: the cargo-carrying unit refers to the box length and excludes the power unit.

Note b: Maximum allowable GVWs are a function of various factors. Details of size and weight limits are contained in the Utah regulations and 23 CFR 658 App. C

Unlike Alberta, Utah has not explicitly evaluated the safety performance of LCV operations in the state. Although LCV collision rates are not available, several minor concerns from the public regarding LCVs have been expressed. The majority of these concerns concentrate around motorists becoming scared while traveling next to an LCV.

The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Utah.

B.2.6.1 Extent of Network

Utah allows LCVs on selected highways as shown in Table B-16. LCVs with a combined trailer length of 81 feet (25 m) or less are allowed to operate on two-lane roads while LCVs with trailer lengths greater than 81 feet (25 m) and less than 95 feet (29 m) are only permitted on Interstate highways identified in Table B-16. Although there are currently no infrastructure issues that would limit LCV operation on Utah highways, the state is not considering expansion of the LCV network.

Table B-16: Utah LCV routes

Highway	From	To
I-15	Arizona state border	Idaho state border
I-70	Jct I-15	Colorado state border
I-80	Nevada state border	Wyoming state border
I-84	Idaho state border	Jct I-80
UT-201	I-80 Exit 102 Lake Point Jct	300 West St., Salt Lake City
I-215	Entire length	

Source: 23 CFR 658 App. C

B.2.6.2 Weather and Road Conditions

State law requires LCV operators to exercise extreme caution and reduce speeds when hazardous conditions caused by snow, ice, sleet, fog, mist, rain, dust, or smoke adversely affect visibility or traction. When conditions become sufficiently dangerous, LCVs are instructed to discontinue service. The term “sufficiently dangerous” is not explicitly defined and relies on the judgment of state officials. Similar regulations regarding weather and road conditions exist in Alberta.

Utah has experienced some collisions where an LCV has left the roadway during adverse weather conditions. The state has implemented a program called Winter Weather Command (WWC) that stipulates types of weather conditions during which LCVs with a cargo-carrying unit greater than 81 feet (25 m) are not allowed to operate. There are three conditions specified in the WWC that prohibit LCV operation: (1) wind in excess of 45 mph (72 km/h) for empties and 50 mph (80 km/h) for loaded trailers; (2) any accumulation of snow and ice on the roadway; (3) visibility reduced to less than 1000 feet (305 m). When any of these conditions exist, the WWC instructs LCV operators to drop a trailer at a safe and appropriate location and proceed with caution or to cease operations until conditions improve. Violators identified by state troopers or Port of Entry officials are cited and the state has the option to confiscate permits, issue a warning letter, revoke permitting privileges, and/or impose civil action.

Direct comparisons between Alberta and Utah weather and road condition regulations exist, however there are some key differences. During adverse weather conditions, Alberta still allows LCVs to operate on multi-lane highways. Although Alberta regulations include provisions for reduced visibility, Utah provides specific visibility criteria that instruct carriers when they can operate LCVs. Also, Alberta does not have any regulations that prohibit LCVs from operating during high speed winds.

B.2.6.3 Temporal Restrictions

Utah officials have not experienced increased LCV collisions during any particular time and therefore temporal restrictions for operating LCVs do not exist, other than those specified above.

B.2.6.4 Driver Training and Qualifications

Utah requires LCV operators to have a commercial driver's license with appropriate endorsement to operate LCVs. Endorsement requires operators to have special training from the carrier and pass a road test from a safety supervisor. In addition, carriers must certify that LCV drivers have a safe driving record. Utah officials believe that these qualifications in addition to carriers only allowing their best and most experienced drivers operate LCVs, has greatly improved the safety record of these vehicles. These training and qualification requirements are similar to those required by Alberta.

B.2.6.5 Speed Control

Unlike Alberta and some other jurisdictions, Utah does not have special speed controls for LCVs. Although Utah officials acknowledge that speed may have been a factor in some collisions, they indicate that it is typically not the LCV that is at fault in these cases.

B.2.6.6 Monitoring and Evaluation

Utah has no special requirements regarding auditing, incident or accident reporting, or performance analysis of LCV operations. However, LCV collisions that cause injury, death, or property damage greater than $1,000 must be reported to the Utah Highway Patrol for inclusion in the state collision information system. In the last few years Utah has modified collision report forms to include a section where the length of each trailer (up to three trailers) can be reported. Currently Alberta does not have collision report forms that specify the length of trailers involved in a collision.

B.2.6.7 Vehicle-related Requirements

Utah requires LCVs to comply with the following:

- Ability to maintain a speed of 20 mph (32 km/h) under normal operating conditions and on grades less than five percent (except in extreme weather conditions)
- Ability to accelerate to 20 mph after stopping on a five percent grade
- Ability to operate at speeds compatible with other traffic,
- Operation of LCV with less than three inches of sway when towing vehicle is traveling in a straight path

- Maintaining at least 500 feet (150 m) between other commercial vehicles in the same direction on the same highway, and

- Ensuring that no trailer is positioned ahead of another trailer that carries an appreciably heavier load.

The terms “normal operating conditions”, “extreme weather conditions”, and “appreciably heavier loads” are not explicitly defined in the Code of Federal Regulations.

Although these requirements have always been part of Utah’s LCV program, the state modified the specification from “overall length” regulations to “combined trailer length” regulations in 2001. Utah has found that this change has helped improve LCV safety by allowing these vehicles to use larger tractors with more power, another drive axle, and increased braking capacity. This change in regulation was not in response to LCV collisions, but a proactive effort to avoid any possible safety problems.

B.2.6.8 Enforcement Issues

Utah has ten permanent Ports of Entry which require commercial vehicles, including LCVs, to stop for inspection. The Port of Entry division monitors violations and reviews carrier safety programs. Outreach training programs educate industry owners, safety managers, vehicle drivers and vehicle maintenance personnel in proper safety policies, procedures and practices in the state.

Utah has established the Truckers-n-Troopers (T-n-T) program that combines the Utah Motor Transport Association and the Utah Highway Patrol in the effort to improve commercial motor vehicle safety. This program helps truck drivers to gain better understanding of the Federal Motor Carrier Safety Regulations through training received from state troopers. Companies participating in the T-n-T program appear to have a greater desire to voluntarily comply with regulations, especially as they become more familiar with them. T-n-T has helped prevent safety-related equipment problems before trucks even get on the road. As a result of this program, Utah has experienced enhanced cooperation between commercial vehicle operators and enforcement agencies.

B.2.7 NEVADA

Nevada has allowed LCVs since the 1970’s. The allowable size and weight limits of LCVs operating in Nevada are provided in Table B-17. Nevada experienced that carriers were using conventional tractors instead of cab-over tractors for LCV operations and recently changed the maximum cargo-carrying length of LCVs from 105 feet (32 m) to 98 feet (30 m).

Table B-17: Size and weight limits of LCVs operating in Nevada

Configuration	Length (cargo-carrying units)		Gross Vehicle Weight	
	(ft)	**(m)**	**(lb)**	**(kg)**
Rocky Mountain double	98.0	30.0	129,000	58,500
Turnpike double	98.0	30.0	129,000	58,500
Triple Trailer	98.0	30.0	129,000	58,500

Source: 23 CFR 658 App. C

Note a: the cargo-carrying unit refers to the box length and excludes the power unit.

Note b: Maximum allowable GVWs are a function of various factors. Details of size and weight limits are contained in the Nevada regulations and 23 CFR 658 App. C

Unlike Alberta, Nevada has not explicitly evaluated the safety performance of LCV operations in the state. At this time, Nevada has not experienced a problem with LCV safety and the State believes that a safety performance evaluation is not warranted.

The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Nevada.

B.2.7.1 Extent of Network

LCVs are allowed to operate on all National Network highways in the state. This includes all routes under the jurisdiction of Nevada Department of Transportation with the exception of the routes identified in Table B-18.

Table B-18: Nevada highways not allowing LCVs

Highway	From	To
State Route 28	U.S. 50 at Spooner Summit	California state line
State Route 208	Mason	California state line
State Route 226	Jack Creek, Owyhee	Mountain City
State Route 431	Timberline Drive	State Route 28
U.S. 93	SR 500 north of Boulder City	Arizona state line

Source: 23 CFR 658 App. C

B.2.7.2 Weather and Road Conditions

Unlike Alberta, Nevada does not have specific weather or road restrictions directed at LCV operation. However, U.S. federal law specifies that the state may suspend operation on roads deemed unsafe or impracticable. Nevada officials have not found that weather conditions have affected LCV collisions.

B.2.7.3 Temporal Restrictions

Unlike the case in Alberta, there are no temporal restrictions for LCVs operating in Nevada.

B.2.7.4 Driver Training and Qualifications

LCV drivers operating in Nevada must have a commercial driver's license with the appropriate endorsement, be at least 25 years old, and have had a medical exam within the previous 24 months. But unlike the case in Alberta, they are not required to have special training involving the operation of LCVs.

B.2.7.5 Speed Control

LCVs in Nevada must be able to accelerate and operate on a level highway at speeds which are compatible with other traffic and posted speed limits. LCVs must not exceed posted speed limits on any highway and must be able to maintain a minimum of 20 miles per hour on any grade on which they may operate. This is slightly different in Alberta where LCVs are not permitted to exceed 100 km/h even though the speed limit may be 110 km/h. Nevada officials indicate that speeding has not been a problem with collisions involving LCVs.

B.2.7.6 Monitoring and Evaluation

Nevada does not have special resources specifically assigned to enforcement, monitoring, and evaluation of LCV safety performance. This is because LCVs are not perceived to be dangerous and do not warrant special attention. Similar to all motor vehicles, LCV carriers are responsible to report collisions to the Nevada Department of Motor Vehicles.

B.2.7.7 Vehicle-related Requirements

U.S. federal and state laws state that no trailer may be longer than 48 feet; however, if one trailer is 48 feet the other trailer cannot exceed 42 feet. Towed vehicles must not shift or sway more than four inches to the right or left and must track in a straight line on a level, smooth paved highway. Nevada requires the shortest trailer to be in the rear of a combination unless it is heavier than the longer trailer. LCVs must keep a distance of at least 500 feet from each other and cannot operate on roads where they cannot at all time stay on the right side of the center line.

Similar to Alberta, Nevada regulations specify that heavier trailers must be located ahead of lighter trailers. Alberta also has the same maximum sway of 10 cm (four inches).

B.2.7.8 Enforcement Issues

Enforcement of LCV compliance in Nevada is conducted by inspection officers as part of the regular commercial vehicle enforcement program in the state. Nevada has found that most LCV carriers comply with regulations. A major reason for this compliance is that carriers violating regulations more than three times are no longer issued permits for LCVs.

B.2.8 ARIZONA

Arizona has allowed LCVs since the 1970's, but only on a particular section of I-15 at the northwest corner of the state and a few short sections of other highways. The allowable size and weight limits of LCVs operating in Arizona are provided in Table B-19.

Table B-19: Size and weight limits of LCVs operating in Arizona

Configuration	**Length (cargo-carrying units)**		**Gross Vehicle Weight**	
	(ft)	**(m)**	**(lb)**	**(kg)**
Rocky Mountain double	95.0	29.0	129,000	58,500
Turnpike double	95.0	29.0	129,000	58,500
Triple Trailer	95.0	29.0	123,000 (129,000 on I-15)	55,800 (58,500 on I-15)

Source: 23 CFR 658 App. C
Note a: the cargo-carrying unit refers to the box length and excludes the power unit.
Note b: Maximum allowable GVWs are a function of various factors. Details of size and weight limits are contained in the Arizona regulations and 23 CFR 658 App. C

Unlike Alberta, Arizona has not explicitly evaluated the safety performance of LCV operations in the state. Because of the state's limited LCV network, there is limited experience regarding their operation and safety. Currently there is no data available to suggest that LCVs have a higher or lower collision rate, however, it appears the overall safety performance of LCVs is similar to other tractor-trailer configurations.

The following sections discuss operating characteristics and/or requirements involving the safety of LCVs operating in Arizona.

B.2.8.1 Extent of Network

LCVs are only allowed on a short section of I-15 and portions of U.S. 89, U.S. 160 and U.S. 163 in Arizona. A major reason that LCVs are allowed on I-15 is because this highway connects Utah and Nevada; both of which allow LCVs. U.S. 89, U.S. 160, and U.S. 163 allow LCVs because these highways connect Arizona to other states operating LCVs. A summary of the routes allowing LCVs is shown in Table B-20. LCV access is also allowed for 20 miles from I-15 Exits 8 and 27.

Table B-20: Arizona LCV routes

Highway	From	To
I-15	Nevada state border	Utah state border
US 89 (two-lane)	20 miles south of Utah state border	Utah state border
US 160 (two-lane)	US 163	New Mexico state border
US 163 (two-lane)	US 160	Utah state border

Source: 23 CFR 658 App. C

According to Arizona officials, the Arizona highway system is designed for common tractor trailer configurations such as tractors with 48-foot or 53-foot trailers. Unlike Alberta, LCVs are not allowed on two-lane roadways, aside from those identified in Table B-20. Overall, the Arizona infrastructure system cannot accommodate LCVs; however, with increased highway construction there may be some consideration toward the allowance of LCVs on a wider network in the future. At this time there are no plans to extend the LCV network in Arizona.

B.2.8.2 Weather and Road Conditions

LCV travel in Arizona is restricted or prohibited during periods when weather creates unsafe conditions. This is similar to regulations in Alberta that restrict or prohibit LCVs from traveling during adverse weather or driving conditions. State officials indicate that there have not been enough LCV collisions to date to require tracking statistics for LCV collisions.

B.2.8.3 Temporal Restrictions

Arizona may restrict or prohibit operations when traffic or other safety considerations make such operations unsafe or inadvisable. According to state officials, temporal restrictions have never been applied to LCVs.

B.2.8.4 Driver Training and Qualifications

Truck drivers operating Rocky Mountain doubles or Turnpike doubles in Arizona require special endorsement on their commercial driver's license. The application for endorsement, which has been in effect since the 1970's, does not require special training beyond that required to obtain a commercial driver's license.

Truck drivers operating triple trailer combinations must be trained by an experienced driver of a triple trailer combination. Training should be through special instructions or by traveling with the new driver until such time as the new driver is deemed adequately qualified by the trainer on the use and operation of these combinations.

B.2.8.5 Speed Control

Arizona has a minimum speed requirement of 20 mph for LCVs on grades where they are operated. The speed limit for LCVs is the same as the limit for other truck types and passenger traffic. This is different than Alberta where the maximum allowable speed for LCVs is 100 km/h even on highways where the posted speed limit is 110 km/h. There has been no indication that LCV speed has caused any collisions in Arizona.

B.2.8.6 Monitoring and Evaluation

Arizona has no special requirements regarding auditing, incident or accident reporting, or performance analysis of LCV operations. However, all collisions involving LCVs must be reported to the Department of Public Safety.

B.2.8.7 Vehicle-related Requirements

Arizona regulations require LCVs to operate at speeds compatible with other traffic on level roads and maintain 20 miles per hour speed on grades where operated. When traveling on a smooth, paved surface, trailers must follow in the path of the towing vehicle without shifting or swerving more than three inches to either side when the towing vehicle is moving in a straight line. Also, mud flaps or splash guards are required on all LCVs. These requirements are similar to those in Alberta, but Alberta has a minimum weight-to-power ratio (one horsepower per 160 kg) instead of a minimum speed requirement.

B.2.8.8 Enforcement Issues

Arizona has enforcement officers in the field that weigh and measure trucks. Although most carriers abide by state regulation and carry appropriate permits, some carriers are recurrently in violation. One of the most common violations is that carriers do not have the appropriate insurance required by Arizona to obtain an LCV permit.

APPENDIX C: COLLISION ANALYSIS DETAILS

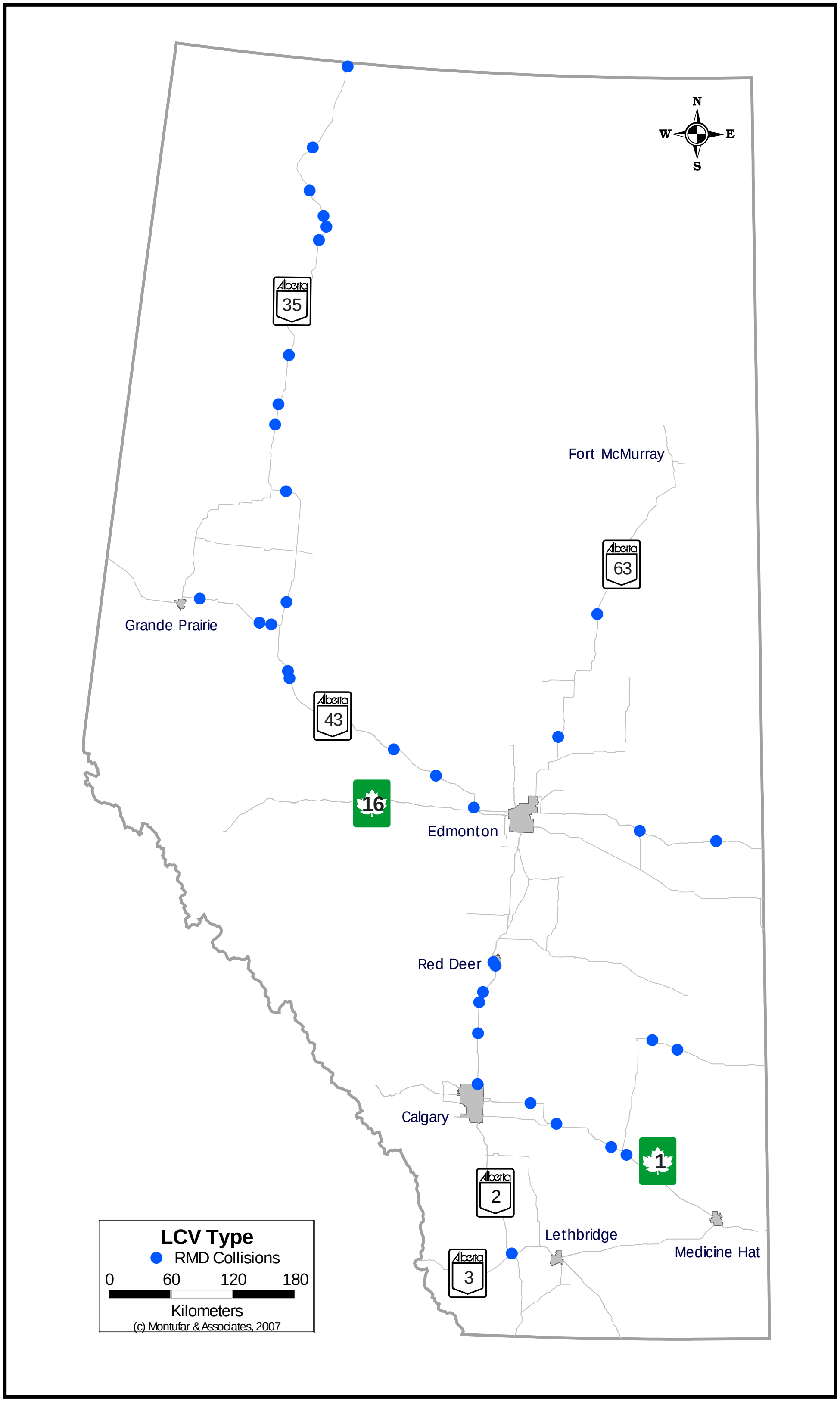


Figure C-1: Geographic location of collisions involving RMDs

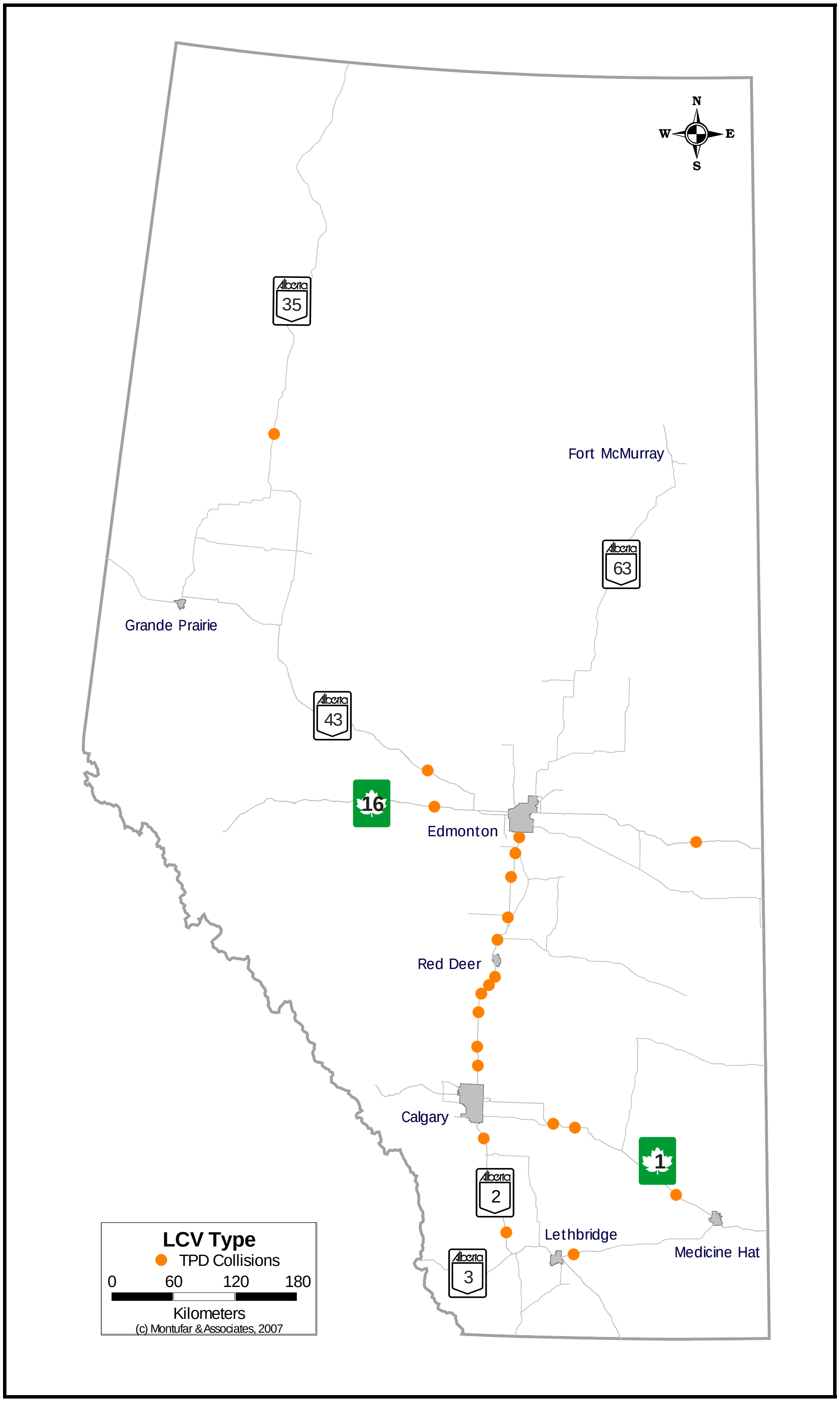


Figure C-2: Geographic location of collisions involving TPDs

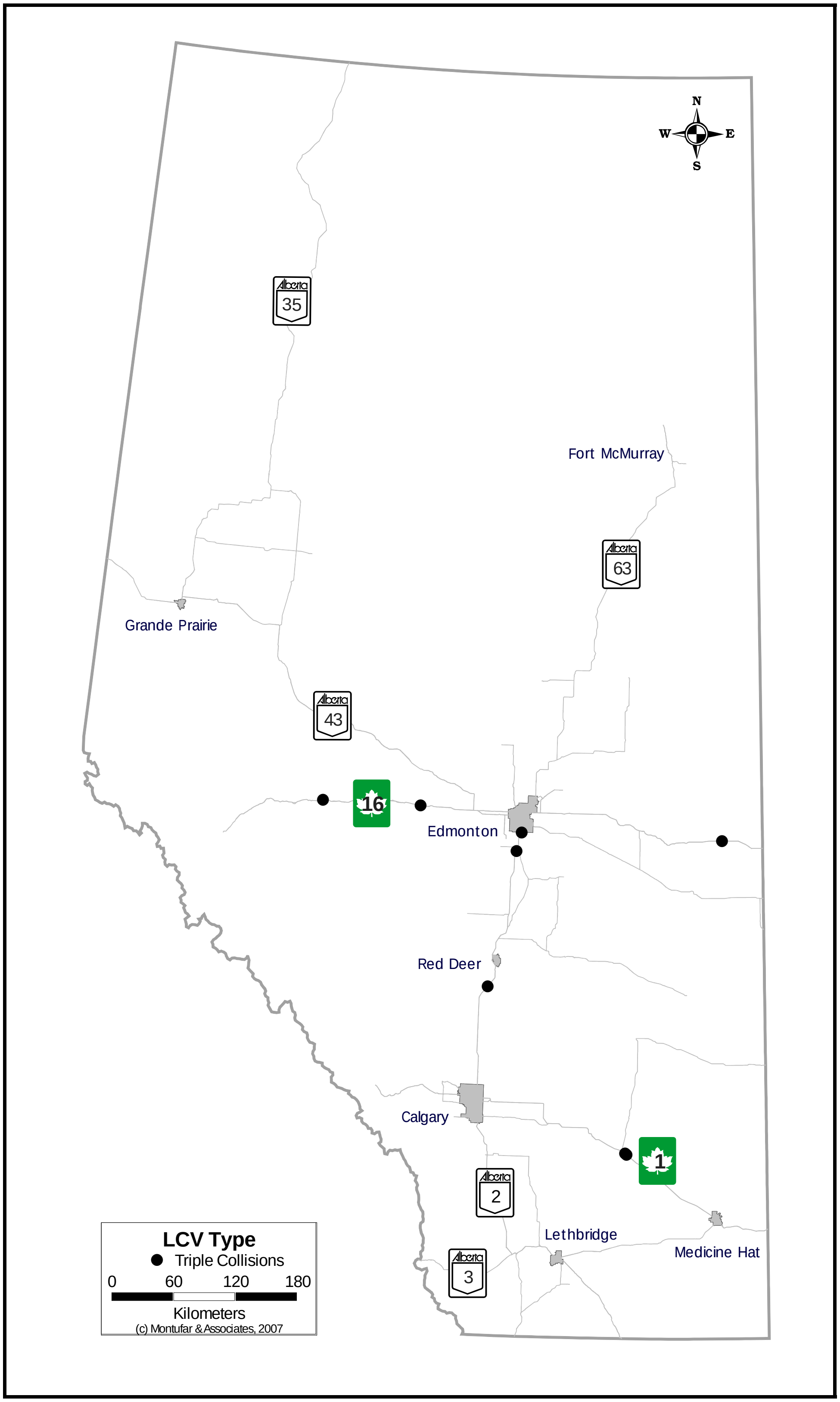


Figure C-3: Geographic location of collisions involving triple trailers

Table C-1: Alberta collision report form – TSS284/TSS284A code definitions

(Please note that throughout the code 97 identifies missing information unless otherwise stated)

OCCURRENCE DATE

ccyy/mm/dd

OCCURRENCE DAY

01 = Sunday
02 = Monday
03 = Tuesday
04 = Wednesday
05 = Thursday
06 = Friday
07 = Saturday

OCCURRENCE HOUR

hh

IN/NEAR

01 = In
02 = Near

COLLISION TYPE

Angle
01 = left turn across path
02 = passing on left turn
08 = all others

Head-on
11 = cross through median
12 = wrong way on one-way
18 = all others

Rear-end
21 = parked vehicle
28 = all others

Sideswipe
31 = cross through median
32 = wrong way on one-way
33 = parked vehicle
34 = opposite direction sideswipe
36 = same direction sideswipe
38 = all others

Run-off-road-only
41 = left/median side
42 = 'T' intersection
48 = all others

Run-off-road and overturn
51 = left/median side
52 = 'T' Intersection
58 = all others

Run-off-road and strike fixed object
61 = left/median side
62 = 'T' intersection
68 = all others

Run-off-road & strike fixed object & overturn
71 = left/median side
72 = 'T' intersection
78 = all others

Miscellaneous
90 = pedestrian
91 = over turn on roadway
92 = strike fixed object while traveling on roadway
93 = strike non-fixed object on roadway (include trains)
94 = strike animal
97 = multi-vehicle collision off roadway
98 = others
99 = unknown

Table C-1 continued

VEHICLE DIRECTION OF TRAVEL

01 = Northbound
02 = Northeastbound
03 = Eastbound
04 = Southeastbound
05 = Southbound
06 = Southwestbound
07 = Westbound
08 = Northwestbound
09 = Unknown

VEHICLE MANEUVER

01= Post-Collision Maneuver
05 = Parked
10 = Passing Maneuver
15 = Being Passed
20 = Merging
22 = Diverging
24 = Avoiding A Vehicle
26 = Avoiding Other Objects
28 = Other Lane - Changing Maneuver
30 = Backing
32 = Making A U-Turn
34 = Making A Left Turn
36 = Making A right Turn
45 = Stopped/Stopping in Traffic
47 = Moving Ahead
48 = Unusual Maneuver
49 = Unknown
51 = Post-Collision Maneuver
55 = Parked
60 = Passing Maneuver
65 = Being Passed
70 = Merging
72 = Diverging
74 = Avoiding A Vehicle
76 = Avoiding Other Objects
78 = Other Lane - Changing Maneuver
80 = Backing
82 = Making A U-Turn
84 = Making A Left Turn
86 = Making A Right Turn
95 = Stopping/Stopped In Traffic
97 = Moving Ahead
98 = Unusual Maneuver
99 = Unknown

HIGHWAY TYPE

01 = Gravel
02 =2 Lane Undivided
03 = 4 Lane Undivided
04 = 4 Lane Div Expressway-At Grade
05 = 4 Lane Div Freeway-Not at Grade
06 = 6 or More Lanes

SURFACE TYPE

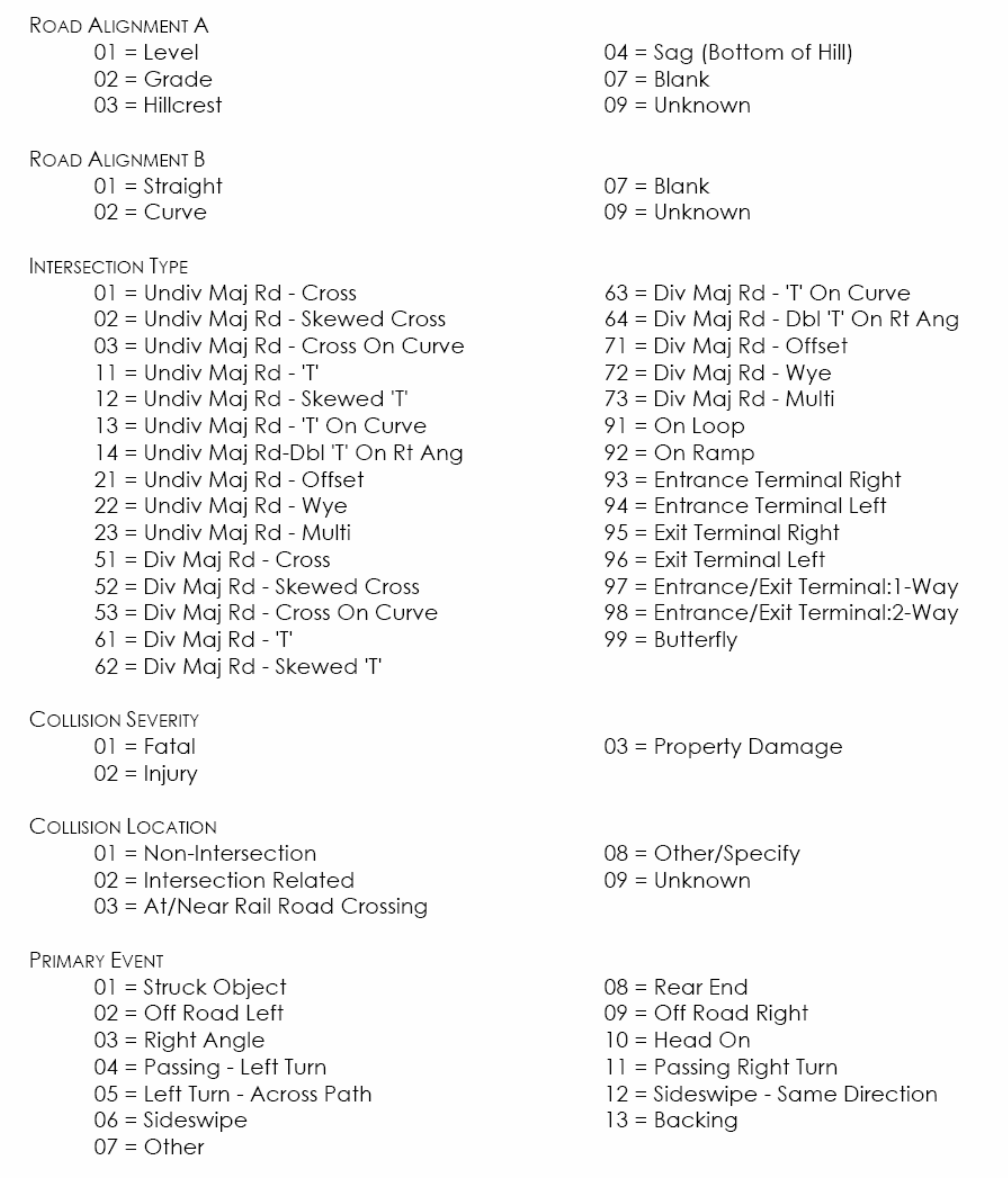
01 = None
02 = Gravel/Graded
03 = Double Surface Treatment
04 = Oiled/Dust Control
05 = Seal Coat
06 = Asphalt Concrete Pavement
07 = Concrete

SHOULDER TYPE

On all highway type, 01 = gravel the shoulder type will be 01 = none

01 = None
02 = Gravel
03 = Double Surface Base Course Treatment
04 = Oiled/Dust Control
05 = Chip Seal
06 = Pavement
07 = Concrete

Table C-1 continued



ROAD ALIGNMENT A

01 = Level
02 = Grade
03 = Hillcrest
04 = Sag (Bottom of Hill)
07 = Blank
09 = Unknown

ROAD ALIGNMENT B

01 = Straight
02 = Curve
07 = Blank
09 = Unknown

INTERSECTION TYPE

01 = Undiv Maj Rd - Cross
02 = Undiv Maj Rd - Skewed Cross
03 = Undiv Maj Rd - Cross On Curve
11 = Undiv Maj Rd - 'T'
12 = Undiv Maj Rd - Skewed 'T'
13 = Undiv Maj Rd - 'T' On Curve
14 = Undiv Maj Rd-Dbl 'T' On Rt Ang
21 = Undiv Maj Rd - Offset
22 = Undiv Maj Rd - Wye
23 = Undiv Maj Rd - Multi
51 = Div Maj Rd - Cross
52 = Div Maj Rd - Skewed Cross
53 = Div Maj Rd - Cross On Curve
61 = Div Maj Rd - 'T'
62 = Div Maj Rd - Skewed 'T'
63 = Div Maj Rd - 'T' On Curve
64 = Div Maj Rd - Dbl 'T' On Rt Ang
71 = Div Maj Rd - Offset
72 = Div Maj Rd - Wye
73 = Div Maj Rd - Multi
91 = On Loop
92 = On Ramp
93 = Entrance Terminal Right
94 = Entrance Terminal Left
95 = Exit Terminal Right
96 = Exit Terminal Left
97 = Entrance/Exit Terminal:1-Way
98 = Entrance/Exit Terminal:2-Way
99 = Butterfly

COLLISION SEVERITY

01 = Fatal
02 = Injury
03 = Property Damage

COLLISION LOCATION

01 = Non-Intersection
02 = Intersection Related
03 = At/Near Rail Road Crossing
08 = Other/Specify
09 = Unknown

PRIMARY EVENT

01 = Struck Object
02 = Off Road Left
03 = Right Angle
04 = Passing - Left Turn
05 = Left Turn - Across Path
06 = Sideswipe
07 = Other
08 = Rear End
09 = Off Road Right
10 = Head On
11 = Passing Right Turn
12 = Sideswipe - Same Direction
13 = Backing

Table C-1 continued

Road Class

01 = Undivided one-way
02 = Undivided two-way
03 = Divided with barrier
04 = Divided no barrier
08 = Other
09 = Unknown

Special Facility

01 = N/A
02 = Interchange Ramp
03 = Interchange Loop
04 = Bridge/Overpass
05 = Tunnel/Underpass
06 = Private Driveway
07 = Traffic Circle
08 = Service Road
09 = Parking Lot
10 = Divided Highway Crossover

Object Type

01 = Driver
02 = Pedestrian
03 = Motorcyclist
04 = Bicyclist
05 = Parked Vehicle
06 = Train
07 = Animal
08 = Other Vehicle
09 = Other Property

Object ID

01 = Passenger Car
02 = Pick-Up/Van<4500kg.
03 = Mini-Van/Mpv
04 = Truck>4500kg.
05 = Truck Tractor
06 = Motorcycle/Scooter
07 = Pedestrian
08 = Bicycle
09 = School Bus
10 = Transit Bus
11 = Intercity Bus
12 = Other Bus
13 = Fixed Object
14 = Train
15 = Animal
16 = Motorhome
17 = Construction Equipment
18 = Emergency Vehicle
19 = Farm Equipment
20 = Off-Highway Vehicle
21 = Motorized Snow Vehicle
22 = Moped
98 = Other
99 = Unknown

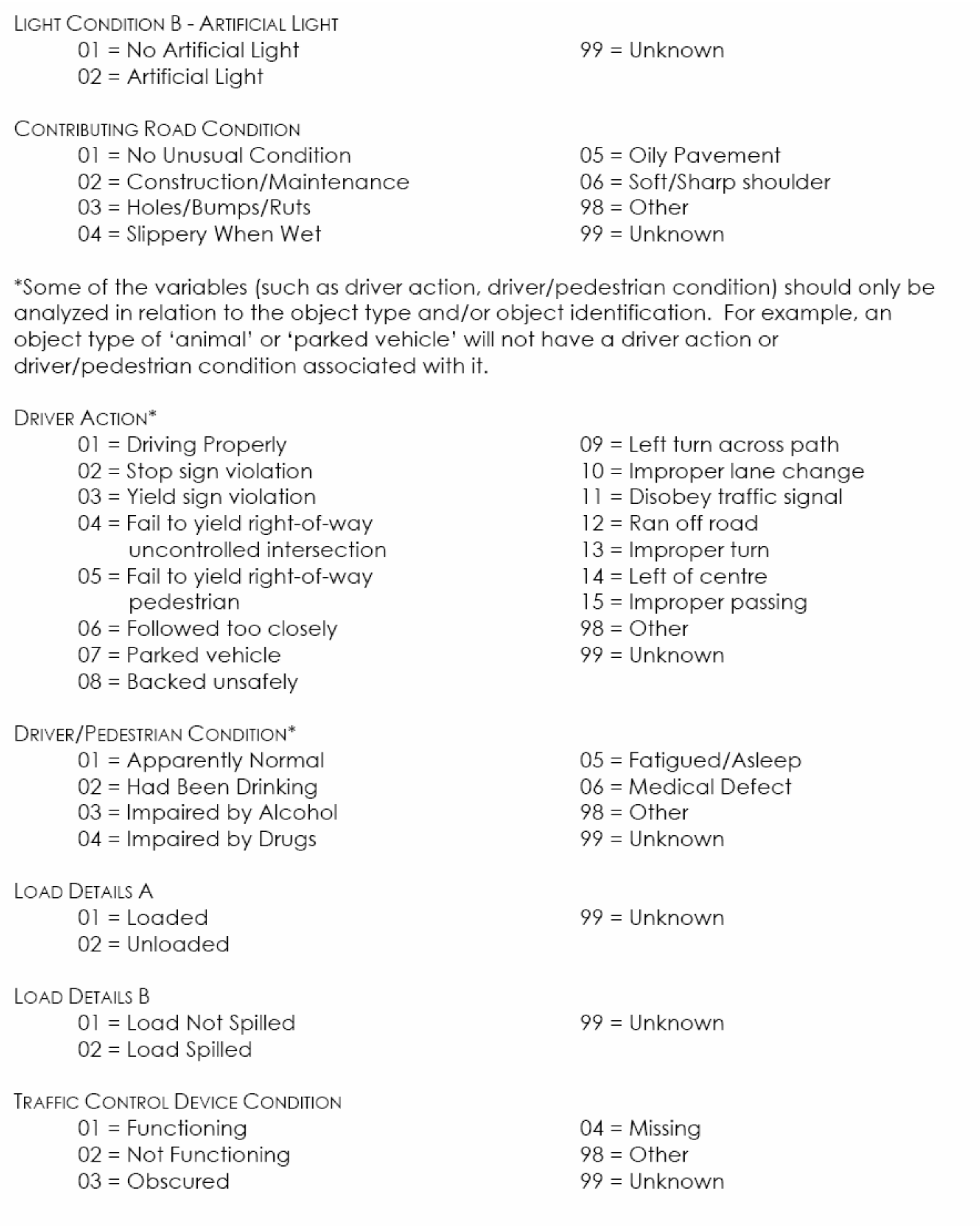
Attachment

01 = Large Single Trailer
02 = Large Double Trailer
03 = Large Triple Trailer
04 = Recreation Trailer
05 = Small Utility Trailer
06 = Farm Equipment
07 = Towed Motor Vehicle
08 = Oversize with Pilot
09 = Oversize without Pilot
98 = Other

Light Condition A - Natural Light

01 = Daylight
02 = Sunglare
03 = Darkness
99 = Unknown

Table C-1 continued



LIGHT CONDITION B - ARTIFICIAL LIGHT
01 = No Artificial Light
02 = Artificial Light
99 = Unknown

CONTRIBUTING ROAD CONDITION
01 = No Unusual Condition
02 = Construction/Maintenance
03 = Holes/Bumps/Ruts
04 = Slippery When Wet
05 = Oily Pavement
06 = Soft/Sharp shoulder
98 = Other
99 = Unknown

*Some of the variables (such as driver action, driver/pedestrian condition) should only be analyzed in relation to the object type and/or object identification. For example, an object type of ‘animal’ or ‘parked vehicle’ will not have a driver action or driver/pedestrian condition associated with it.

DRIVER ACTION*
01 = Driving Properly
02 = Stop sign violation
03 = Yield sign violation
04 = Fail to yield right-of-way uncontrolled intersection
05 = Fail to yield right-of-way pedestrian
06 = Followed too closely
07 = Parked vehicle
08 = Backed unsafely
09 = Left turn across path
10 = Improper lane change
11 = Disobey traffic signal
12 = Ran off road
13 = Improper turn
14 = Left of centre
15 = Improper passing
98 = Other
99 = Unknown

DRIVER/PEDESTRIAN CONDITION*
01 = Apparently Normal
02 = Had Been Drinking
03 = Impaired by Alcohol
04 = Impaired by Drugs
05 = Fatigued/Asleep
06 = Medical Defect
98 = Other
99 = Unknown

LOAD DETAILS A
01 = Loaded
02 = Unloaded
99 = Unknown

LOAD DETAILS B
01 = Load Not Spilled
02 = Load Spilled
99 = Unknown

TRAFFIC CONTROL DEVICE CONDITION
01 = Functioning
02 = Not Functioning
03 = Obscured
04 = Missing
98 = Other
99 = Unknown

Table C-1 continued

TRAFFIC CONTROL DEVICE PRESENT

01 = None Present
02 = Traffic Signals/Lights
03 = Stop Sign
04 = Yield Sign
05 = Merge Sign
06 = Pedestrian Cross-Walk
07 = School Bus
08 = Lane Control Signal
09 = Railway Crossing
98 = Other
99 = Unknown

PEDESTRIAN ACTION

01 = Xing with Right of Way
02 = Xing without Right of Way
03 = Walking/Working on Road
04 = Getting On/Off Vehicle
98 = Other

TRAILER TYPE (IF ATTACHMENT CODED AS 01, 02, 03)

01 = Van/Box Body
02 = Lowboy
03 = Highboy
04 = Tanker
05 = Dump
06 = Car Carrier
07 = Livestock Carrier
08 = Log Carrier
98 = Other

VEHICLE CONDITION / CONTRIBUTING FACTORS

01 = No Apparent Defect
02 = Defective Brakes
03 = Tires Failed
04 = Improper Load/Shift
05 = Lighting Defect
98 = Other
99 = Unknown

ENVIRONMENTAL CONDITION

01 = Clear
02 = Raining
03 = Hail/Sleet
04 = Snow
05 = Fog/Smog/Smoke/Dust
06 = High Wind
98 = Other
99 = Unknown

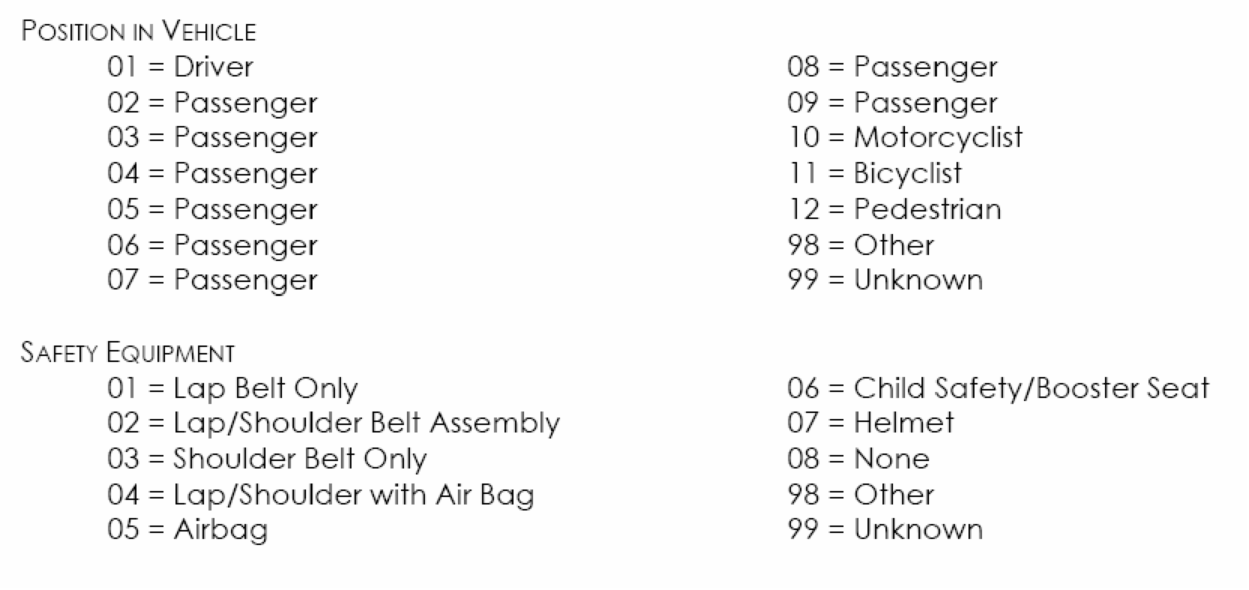
SURFACE CONDITION

01 = Dry
02 = Wet
03 = Slush/Snow/Ice
04 = Loose Surface Material
05 = Muddy
98 = Other
99 = Unknown

INJURY SEVERITY

01 = None
02 = Minor Injury
03 = Major Injury
04 = Fatal

Table C-1 continued



Position in Vehicle

01 = Driver
02 = Passenger
03 = Passenger
04 = Passenger
05 = Passenger
06 = Passenger
07 = Passenger
08 = Passenger
09 = Passenger
10 = Motorcyclist
11 = Bicyclist
12 = Pedestrian
98 = Other
99 = Unknown

Safety Equipment

01 = Lap Belt Only
02 = Lap/Shoulder Belt Assembly
03 = Shoulder Belt Only
04 = Lap/Shoulder with Air Bag
05 = Airbag
06 = Child Safety/Booster Seat
07 = Helmet
08 = None
98 = Other
99 = Unknown

APPENDIX D: SOURCE DATA FOR EXPOSURE ESTIMATES

This appendix provides details about the traffic databases used to determine exposure estimates by vehicle type on the Alberta LCV network between 1999 and 2005, inclusive.

No single data source is available to develop exposure estimates by vehicle type on Alberta's LCV network for the study period. As such, the exposure methodology utilizes a variety of data sources and integrates them using a hierarchical scheme. The following data sources were used in the exposure analysis:

- *AIT traffic database*: This database provides traffic volumes by traffic control section for five vehicle classes on the LCV network for each year in the study period. Traffic volumes are expressed as the weighted annual average daily traffic (WAADT), which is the average daily two-way traffic volume (vehicles per day) for a section of highway for the period January 1 to December 31. Fleet mix distributions are provided as a percentage of the WAADT for passenger vehicles, recreation vehicles, buses, single unit trucks, and tractor trailer combinations.

- *Raw Alberta WIM data for 2005*: These datasets provide a vehicle-by-vehicle record of traffic passing over a WIM device by travel lane. The time of passage, vehicle speed, inter-axle spacing measurements, and axle weights are given for each record. Five WIM stations are located on the Alberta LCV network; they are situated on Highway 2 near Red Deer and near Leduc, Highway 3 near Fort McLeod, Highway 16 near Edson, and Highway 2A near Leduc.

- *Highway 63 AVC survey*: This specialized two-week survey conducted by AIT provides vehicle length data at one location on Highway 63 for the period between November 5 and November 29, 2005.

- *Raw Saskatchewan WIM data for 2005 and 2006*: These datasets provide a vehicle-by-vehicle record of traffic passing over a WIM device by travel lane. The time of passage, vehicle speed, inter-axle spacing measurements, and axle weights are given for each record. The WIM stations are located on Highway 1 east of the Saskatchewan-Alberta boundary, Highway 7 (which becomes Highway 9 in Alberta), just east of the Saskatchewan-Alberta boundary, and Highway 16 east of Lloydminster, Saskatchewan.

- *Industry interviews*: Interviews were conducted by Montufar & Associates with several AIT Commercial Vehicle Enforcement Branch officers based in various parts of the province. The dataset resulting from these interviews provides LCV daily volume estimates on each highway in the Alberta LCV network.

- *AIT 12-hour vehicle classification counts*: These specially-requested classification counts were conducted by AIT at selected locations on the Alberta LCV network in 2007. They provide short-term samples of passenger vehicle, single unit truck, tractor trailer combination, RMD, TPD, and triple volumes at 17 locations. Table shows further details.

- *Montufar & Associates short-term vehicle classification counts*: These classification counts were conducted by the project team at selected locations on the Alberta LCV network in 2007. These counts provide short-term samples of straight trucks and bobtails, tractor semitrailers, legal-length tractor double trailers, RMDs, TPDs, and triples. The project team conducted screenline counts at several intersections, and also conducted counts while traveling along the LCV network. Counts were taken at locations or along segments of the following LCV network highways: 1, 2, 2A, 3, 4, 12, 13, 16, 21, 28, 28A, 36, 43, 49, and 63.

- *1999 Canadian Council of Motor Transport Administrators (CCMTA) National Roadside Survey (NRS)*: The results of this survey (provided by AIT) show the distribution of tractor semitrailers, legal-length tractor double trailers, RMDs, TPDs, and triples within the tractor trailer category. The surveys were conducted at the following nine commercial vehicle weigh scales on the Alberta LCV network: Coutts (Highway 4), Burmis (Highway 3), Jumping Pound (Highway 1), Strathmore (Highway 1), Balzac (Highway 2), Leduc (Highway 2), Hinton (Highway 16), Beaverlodge (Highway 43), and Grimshaw (Highway 35).

Table D-1: 12-hour vehicle classification counts

Count Location	Date	Day of Week	Time of Day
2 & 5 N. of Cardston N. Jct.	Feb. 6, 2007	Tuesday	0700-1900
28 & 63 & 829 W. of Radway	Feb. 7, 2007	Wednesday	0700-1900
9 & 36 E. of Hanna E. Jct.	Feb. 7, 2007	Wednesday	0700-1900
3 & 999 Rge Rd 190, Chin Access	Feb. 8, 2007	Thursday	0700-1900
2 & 35 N. of Grimshaw	Feb. 8, 2007	Thursday	0700-1900
12 & 21 S.E. of Alix W. Jct.	Feb. 8, 2007	Thursday	0700-1900
8 & 22 N.E. of Bragg Creek	Feb. 9, 2007	Friday	0700-1900
13 & 21 W. of Camrose	Feb. 9, 2007	Friday	0700-1900
14 & 36 S.W. of Viking	Feb. 9, 2007	Friday	0700-1900
2 & 49 E. of Rycroft	Feb. 12, 2007	Monday	0700-1900
23 & 24 & 542 N. of Vulcan	Feb. 12, 2007	Monday	0700-1900
2 & 49 S.W. of Donnelly	Feb. 12, 2007	Monday	0700-1900
43 & 49 at Valleyview	Feb. 12, 2007	Monday	0700-1900
1 & 901 E. of Gleichen	Feb. 13, 2007	Tuesday	0700-1900
16 & 631 N.W. of Royal Park	Feb. 13, 2007	Tuesday	0700-1900
16 & 893 S. of Islay	Feb. 14, 2007	Wednesday	0700-1900
3 & 887 N.E. of Seven Persons	Feb. 14, 2007	Wednesday	0700-1600