EXPOSURE MODELLING OF PRODUCTIVITY-PERMITTED GENERAL FREIGHT TRUCKING ON UNCONGESTED HIGHWAYS

By

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ABSTRACT

The research designs, develops, validates, and applies an exposure model of productivity-permitted general freight trucking on uncongested highways. Productivity-permitted general freight trucks (long trucks) are multiple trailer configurations, consisting of van trailers, which exceed basic vehicle length limits but operate within basic weight restrictions. The three predominant long trucks in North America are Rocky Mountain doubles (Rockies), Turnpike doubles (Turnpikes), and triple trailer combinations (triples). Long trucks have been used in Canada since the late 1960s. Recent highway investments in the Canadian Prairie Region have effectively completed the network on which long trucks are allowed to operate. Despite widespread use of long trucks for many years and these recent infrastructure investments, there is a knowledge deficiency about long truck exposure.

The research uses the transportation systems analysis approach to design, develop, and validate the long truck exposure model. Exposure is expressed as an explanatory variable in three principal dimensions (volume, weight, and cube), which is needed for predicting transportation system impacts of long truck operations. The research applies the model to clarify issues that should be considered in establishing charges for long truck permits, determining long truck safety performance, and developing load spectra for long trucks.

The exposure model relies on a unique dataset that integrates output from a classification algorithm, field observations, and industry intelligence. The results indicate that long trucks travelled 67 million kilometres on a 10,000 centreline-kilometre highway network

in the Canadian Prairie Region in 2006. The model demonstrates strong temporal and geographic concentration of long truck travel on the network. Application of the results reveals the following findings:

- Decisions about establishing long truck permit charges are supported by consideration of options within a revenue adequacy rationale that are sensitive to freight density and the distance travelled by long trucks.
- The exposure-based collision rate for Turnpikes is half of the collision rate for Rockies, about one-third of the rate for legal-length articulated trucks, and one-quarter of the rate for triples.
- The model provides loading indicators required for pavement and bridge design and evaluation procedures and demonstrates the cubic orientation of long truck operations.

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GLOSSARY OF ACRONYMS AND SYMBOLS

Acronyms

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ACIS	Alberta Collision Information System
ADT	Average daily traffic
ALS	Axle load spectra
ATR	Automatic traffic recorder
ATRI	American Transportation Research Institute
AVC	Automatic vehicle classifier
CCL	Cargo-carrying length
EEMV	Energy efficient motor vehicle
ELV	Extended length vehicle
ESAL	Equivalent single axle load
FAF	Freight Analysis Framework
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GAO	General Accounting Office (now the Government Accountability Office)
GIS	Geographic information system
GVW	Gross vehicle weight
ISTEA	Intermodal Surface Transportation Efficiency Act
LCV	Longer combination vehicle
LTL	Less than truckload
NAD 83	North American 1983 geodetic datum
NCHRP	National Cooperative Highway Research Program
PCE	Passenger car equivalent
PDO	Property damage only
PTH	Provincial Trunk Highway
RALS	Representative axle load spectra
RGC	Rolling gross cube
RGW	Rolling gross weight
SQL	Structured Query Language
TEU	Twenty-foot equivalent unit
TIFA	Trucks Involved in Fatal Accidents
TRB	Transportation Research Board
U.S. DOT	United States Department of Transportation
UTM	Universal Transverse Mercator
VKT	Vehicle-kilometres of travel
WIM	Weigh-in-motion
3-S2	Five-axle tractor semitrailer
3-S3	Six-axle tractor semitrailer
53EU	53-foot equivalent unit

Symbols

A	Activity system
c	Transportation analysis context
C	Payload cube
C_{MAX}	Container or vehicle cubic capacity for payload
D	Freight density
D_{DESIGN}	Design density of a container or vehicle
E	Exposure
F	Flow system
P	Performance indicator
R	Resources consumed by exposure
S	Services provided by exposure
t	Time
T	Transportation system
TSI	Latent transportation system impact
W_{MAX}	Container or vehicle weight capacity for payload
X	Exogenous environment

CREDITS

Portions of the thesis are published or accepted for publication as articles by the author in academic journals. They are reproduced in the thesis in accordance with the journals' copyright agreements. Citation details for these articles follow:

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The geographic information system (GIS) platform developed for the research uses GeoMedia Professional® Version 6.0. Microsoft® Access® and Excel® are used for data screening, analysis, and storage, and are designed to fully integrate with the GIS platform. All maps presented in the thesis are produced with GeoMedia Professional®, using the Universal Transverse Mercator (UTM) Zone 14 projection and the North American 1983 (NAD 83) geodetic datum.

1. INTRODUCTION

1.1. THE RESEARCH

The research designs, develops, validates, and applies an exposure model of productivity-permitted general freight trucking on uncongested highways. Productivity-permitted general freight trucks are multiple trailer configurations, consisting of van trailers (sometimes containers) which exceed basic vehicle length limits but operate within basic weight restrictions. They are referred to as long trucks in the thesis. The research uses the transportation systems analysis approach to design, develop, and validate the long truck exposure model. It applies the model results to clarify issues that should be considered in establishing charges for long truck permits, determining long truck safety performance, and developing load spectra for long trucks.

The research defines exposure as the number and nature of traffic events at a point or along a segment, in a specified time. The model considers exposure as an explanatory variable needed for predicting transportation system impacts related to long truck activity. It provides and applies indicators of long truck exposure in terms of three principal dimensions: volume, weight, and cube. These indicators support exposure-based analysis of productivity-permitted general freight trucking.

1.2. BACKGROUND AND NEED

Long trucks have been used on the North American highway system since the late 1950s (GAO 1992). The three predominant long trucks in North America are Rocky Mountain doubles (Rockies), Turnpike doubles (Turnpikes), and triple trailer combinations (triples).

Long trucks operate on a network of over 100,000 centreline-kilometres of public highways in Canada and the western United States, and are also permitted on some toll roads in the U.S., many highways in Mexico, and in parts of Central America and Australia (Western Highway Institute 1992; Maze, Walter, and Smadi 1994; National Transport Commission 2005; Regehr and Montufar 2007). Recent highway investments in the Canadian Prairie Region and eastern provinces have expanded and in some cases effectively completed the network on which long trucks are allowed to operate. One example is the recent completion of the divided Trans Canada Highway between Winnipeg, Manitoba and Regina, Saskatchewan. In the U.S., the federal regulations designating the public highway network on which long trucks are allowed to operate have been frozen since the passage of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). However, ever-increasing demand for transporting low-density commodities[1] (Bingham 2008), growth in truck volumes (AASHTO 2007), concerns about congestion, system efficiency, and global warming (McNally 2007; Schulz 2007), and possible implementation of truck only lanes subject to a relaxed size and weight regulatory structure (Samuel, Poole, Jr., and Holguín-Veras 2002; Poole, Jr. and Samuel 2004; Forkenbrock and March 2005) have given rise to new possibilities for long truck operations in the U.S.

Despite widespread use of long trucks for many years, and these more recent developments, there is a knowledge deficiency about long truck exposure in Canada and

[1] Low-density commodities (i.e., general freight) reach the cubic capacity of the truck without exceeding basic axle or gross vehicle weight restrictions. Freight with a density up to about 240 kg/m^3 (about 15 lb/ft^3) "cubes-out" in long trucks and conventional five-axle tractor van semitrailers. See Section 2.3 for further details about "cube-out" and "weigh-out" freight.

the U.S. (GAO 1992; Nix 1995; U.S. DOT 2000; Forkenbrock and Hanley 2003; U.S. DOT 2004; Regehr, Montufar, and Rempel 2009). The model developed in the research helps to close this knowledge gap by quantifying and characterizing long truck exposure in the Canadian Prairie Region. Application of the model demonstrates its capability to provide indicators of exposure required for:

- analysis of options for establishing charges for long truck permits based on revenue adequacy and cost recovery rationales (TRB 1996; U.S. DOT 1997; TRB 2002; National Transport Commission 2005; Fekpe, Gopalakrishna, and Woodrooffe 2006; Applied Research Associates 2007; Regehr, Montufar, and Clayton, forthcoming);
- determination of the safety performance (in terms of collision rates) of long trucks relative to other vehicle types (Hauer 1995; U.S. DOT 2000; Forkenbrock and Hanley 2003; U.S. DOT 2004; Regehr, Montufar, and Rempel 2009); and
- mechanistic-empirical pavement design (Hajek et al. 2002; Haas et al. 2007; AASHTO 2008) and the design and evaluation of bridge structures (TRB 1990; GAO 1994; Laman and Nowak 1995; Ghosn and Moses 2000; TRB 2002; NCHRP 2003; U.S. DOT 2004), through the development of load spectra for long trucks.

In addition, modelling long truck exposure supports more informed and transparent analysis and decision-making about:

- productivity impacts of long trucks compared to traditional tractor semitrailer configurations for hauling general freight on current and potentially expanded highway networks (Sydec, Inc. 1990; U.S. DOT 2000; U.S. DOT 2004);

- long truck network planning, and the development of truck only lanes or roads—including toll facilities—designed to permit long truck operations (Samuel, Poole, Jr., and Holguín-Veras 2002; Poole, Jr. and Samuel 2004; Forkenbrock and March 2005);

- energy, fuel, and emissions impacts of long trucks compared to standard tractor semitrailer configurations (Woodrooffe and Ash 2001; U.S. DOT 2004; Tunnel and Brewster 2005; L-P Tardif & Associates 2006; ATRI 2008);

- truck-to-truck and rail-to-truck freight shifts induced by long truck operations (Burns 1983; U.S. DOT 2000; TRB 2002; U.S. DOT 2004);

- road geometry and traffic operations impacts of long trucks such as turning movements, passing sight distance, lane and paved shoulder width, and centreline and edge line striping (Harkey and Robertson 1989; Harkey, Council, and Zegeer 1996; Elefteriadou, Torbic, and Webster 1997; Barton and Morrall 1998; Middleton et al. 2003; McCutchon, Regehr, and Montufar 2006); and

- enforcement and regulation of long truck dimensions, weights, safety requirements, and credentials (Fekpe and Clayton 1995; Fekpe 1997; Malbasa, Regehr, and Clayton 2005).

1.3. MODELLING APPROACH

The long truck exposure model is designed, developed, and validated using the transportation systems analysis approach. This approach stems from a systems analysis perspective, which is a formal inquiry conducted to help clarify issues and provide information that should be considered by decision-makers in identifying and evaluating impacts of alternative courses of action (de Neufville and Stafford 1971; Manheim 1979). Systems analysis requires a holistic view of a complex or adaptive process or operation and the interactions between elements within the process or operation (Manheim 1979; Checkland 1999).

The transportation systems analysis approach involves three interrelated elements: (1) the transportation system, *T*, which is expressed by a service function and consists of vehicles, technologies, networks, links, nodes, and operating and organizational policies; (2) the activity system, *A*, which is expressed by a demand function and is defined by the social, economic, and political environment; and (3) the flow system, *F*, which measures the quantity of people, freight, and vehicular movements, the resources they consume, and the level of service they provide (Manheim 1979). The short-term equilibration of the transportation service and demand functions define *F* as a function of *T* and *A*. Manheim labels this the Type 1 relation. Over time, characteristics of *F* stimulate changes in *A* (the Type 2 relation) and *T* (the Type 3 relation), eventually creating a new equilibrium point for *F*. These changes can also be imposed exogenously, for example, by purposeful shifts in transportation policies and regulations, infrastructure changes, or adoption of new vehicle technologies.

Based on these fundamentals, the research adopts the analysis framework depicted in Figure 1. In the figure, initial conditions at time t_0 are given by T_0, A_0, and F_0, associated through the (short-term) equilibration of the Type 1 relation. These conditions are affected by exogenous variables, X_0, relevant to or imposed on various aspects of transportation system performance. The research expresses F_0 in terms of three components: (1) exposure, E_0; (2) the services, S_0, that E_0 provides; and (3) the resources, R_0, consumed by E_0. These three components induce transportation system impacts; however, E_0 is the fundamental link between T_0, A_0, and transportation system impacts, as service provision and resource consumption only occur subsequent to exposure. Characteristics of F_0 stimulate changes in A_0 (via the Type 2 relation) and T_0 (via the Type 3 relation) such that at time t_1 the system is expressed by T_1 and A_1, which are affected exogenously by X_1 and equilibrate to determine F_1 (in terms of E_1, R_1, S_1). These interrelationships continue to evolve in this manner as time proceeds.

A contextual perspective on the transportation systems analysis approach helps to focus its scope, simplify the relationships, and direct data requirements. A road safety analysis, for example, may benefit from a transportation systems analysis approach, but may only require characterization of those aspects of T, A, F, and X that are relevant to the context of road safety. Analyses in other contexts, such as road use charging or pavement and bridge design and evaluation, are similarly refined.

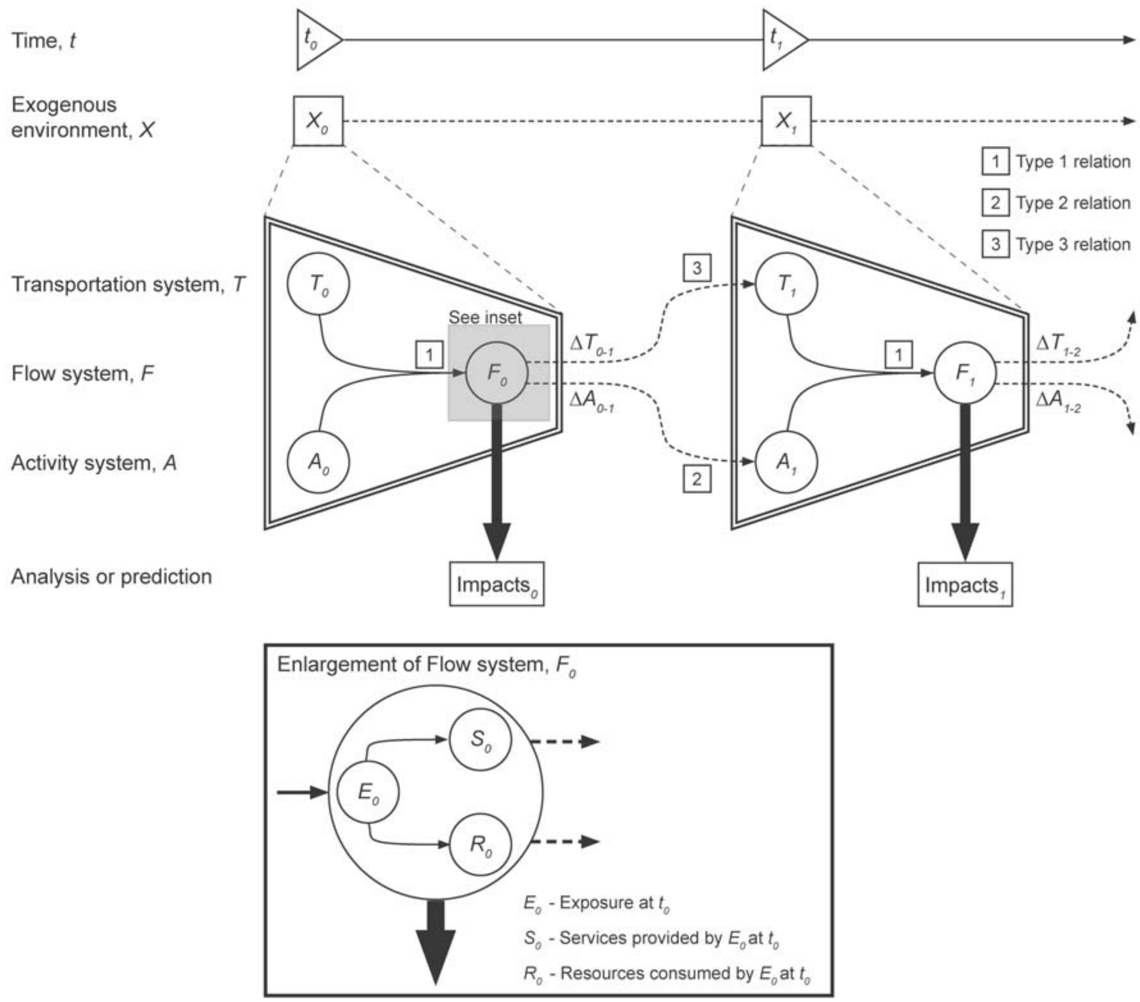

Figure 1: Transportation systems analysis approach.

Source: After Manheim 1979; Montufar 2002.

The research develops a model of long truck exposure, *E*, by measuring and estimating *E* in terms of three principal dimensions: volume, weight, and cube. This is done empirically through analysis and fusion of truck traffic data from various sources, and pragmatically through the integration of industry intelligence. Understanding *T* is critical—particularly in the context of civil engineering—because it defines the means by which traffic is conveyed. Therefore, the research provides a description of the long truck transportation system, *T*, and validates the exposure model by analyzing its interrelationship with *E* (i.e., the component of the Type 1 relation linking *T* and *F* and the Type 3 relation between *F* and *T*). The social, industrial, economic, and political mechanisms (i.e., aspects of *A*) used to forecast freight flow (Holguín-Veras and Thorson 2000; Sorratini and Smith, Jr. 2000) are not specifically addressed by this approach. Rather, they are understood as underlying factors influencing and generating the exposure, *E*, that is ultimately measured.

The model is designed to predict present exposure characteristics of productivity-permitted general freight trucking, and establish a basis for conducting sensitivity analyses, extrapolating trends, and forecasting future exposure (Wigan and Southworth 2006). The model follows a trend in travel modelling, which emphasizes understanding the relationships that influence travel, over providing accurate predictions of the future (Hensher and Button 2000).

1.4. OBJECTIVES AND SCOPE

The objectives of the research are to:

- design a model that quantifies present characteristics of long truck exposure in terms of volume, weight, and cube;
- develop a comprehensive knowledge base for the model about the long truck transportation system and long truck exposure in the Canadian Prairie Region;
- validate the long truck exposure model by analyzing its responsiveness to actual conditions in the transportation system; and

- apply the long truck exposure model to demonstrate its capability to provide indicators of exposure required for: (1) the analysis of options for establishing charges for long truck permits; (2) the determination of the safety performance in terms of collision rates of long trucks relative to other types of articulated trucks; and (3) pavement and bridge design and evaluation through the development of load spectra for long trucks.

The research scope is defined as follows:

1. The transportation and flow system elements of the transportation systems analysis approach are described and analyzed as they pertain to productivity-permitted general freight trucking. A specific description of the activity system is not provided.

2. The transportation and flow systems are described and analyzed for the provinces of Manitoba, Saskatchewan, and Alberta (referred to collectively as the Canadian Prairie Region).

3. The exposure model relies on available empirical observations and pragmatic understanding about long truck activity in the Canadian Prairie Region. Raw, semi-processed, and fully processed truck traffic datasets collected during the time period of 2003 to 2008, inclusive, are utilized. The datasets are subject to standard data screening techniques and engineering judgment. Automated data collection equipment is assumed to be properly installed and calibrated. Specific limitations with the datasets are considered, but are not discussed in the thesis.

4. The exposure model is designed, developed, and validated for rural, primary highways in the Canadian Prairie Region. The research considers these highways as uncongested.

1.5. THESIS ORGANIZATION

The thesis consists of seven chapters. Chapter 2 defines the transportation system for productivity-permitted general freight trucking in the Canadian Prairie Region in terms of: (1) the current and historical long truck highway network; (2) long truck types and their size and weight limits; (3) the density of freight transported by long trucks and their design density; and (4) permit conditions governing long truck operations.

Chapter 3 designs an exposure model for productivity-permitted general freight trucking in terms of volume, weight, and cube. It outlines the modelling background and approach, structure, and definition.

Chapter 4 develops the long truck exposure knowledge base. It describes: (1) exposure data sources; (2) the long truck classification algorithm; and (3) the methodology used to assign exposure data to network segments.

Chapter 5 presents the results of the long truck exposure model in terms of its three principal dimensions and validates these results by analyzing the model's responsiveness to actual conditions in the long truck transportation system.

Chapter 6 applies the exposure model to demonstrate its capability to provide indicators of exposure required for: (1) the analysis of options for establishing exposure-based charges for long truck permits; (2) the determination of the safety performance of long trucks relative to other types of articulated trucks; and (3) pavement and bridge design and evaluation through the development of load spectra for long trucks.

Chapter 7 provides conclusions and recommendations for future research.

1.6. TERMINOLOGY

- *Exposure:* the number and nature of traffic events at a point or along a segment, in a specified time. Traffic exposure is the fundamental link between the transportation and activity systems and their transportation system impacts.

- *Model:* a representation of a complex system that can be manipulated to support the analysis and evaluation of alternative courses of action (Manheim 1979). The model developed in the research represents long truck exposure in the present (and recent past).

- *Productivity-permitted general freight trucks:* multiple trailer configurations, consisting of van trailers (sometimes containers), which exceed basic vehicle length limits but operate within basic weight restrictions. They are referred to as long trucks in the thesis. The three predominant long truck configurations are Rockies, Turnpikes, and triples. These vehicles are often referred to as longer combination vehicles (LCVs) in Canada and the U.S., although the U.S. definition also includes other vehicle types (see definition of U.S. longer combination vehicle). They are also called Extended Length Vehicles (ELVs) in Manitoba and Energy Efficient Motor Vehicles (EEMVs) in Saskatchewan and Alberta. Rockies and Turnpikes are sometimes referred to as intermediate and long doubles, respectively.

- *General freight:* low-density, often palletized commodities that reach the cubic capacity of the truck without exceeding axle or gross vehicle weight restrictions. General freight is transported in truck configurations consisting of van trailers or containers. Freight with a density up to about 240 kg/m^3 (about 15 lb/ft^3) "cubes-out" in long trucks and conventional five-axle tractor van semitrailers.

- *Basic truck size and weight limits:* regulations that govern truck operations without the requirement for a special overweight or over-dimension permit, or seasonal exemptions (Montufar and Clayton 2002).

- *U.S. longer combination vehicle (LCV):* In the U.S., the 1991 Intermodal Surface Transportation Efficiency Act (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 gross vehicle weight greater than 80,000 lb (36,300 kg). This is the definition used by U.S. federal law 23 USC Section 127(d)(4).

- *Uncongested highways:* highways on which there is no increase in average process time per unit because of demand for service (Manheim 1979).

- *Systems analysis:* a formal inquiry conducted to help clarify issues and provide information that should be considered by decision-makers in identifying and evaluating impacts of alternative courses of action (de Neufville and Stafford 1971; Manheim 1979). Systems analysis requires a holistic view of a complex or adaptive process or operation and the interactions between elements within the process or operation (Manheim 1979; Checkland 1999).

- *Industry intelligence:* information obtained from field observations and by dealing with the requirements and consequences of truck traffic in practical ways.

2. LONG TRUCK TRANSPORTATION SYSTEM

This chapter defines the transportation system, *T*, for productivity-permitted general freight trucking in the Canadian Prairie Region in terms of: (1) the highway network on which long trucks are permitted to operate and how it has evolved over the last four decades; (2) long truck types and their size and weight limits; (3) the density of freight transported by long trucks and their design density; and (4) permit conditions governing long truck operations.

2.1. LONG TRUCK HIGHWAY NETWORK

2.1.1. Current Long Truck Highway Network

The Canadian Prairie Region rural long truck highway network measures over 10,000 centreline-kilometres, serves a population base of over six million people, and consists primarily of uncongested highways. Manitoba, Saskatchewan, and Alberta routinely permit long trucks on major highways. Turnpikes and triples are permitted on divided highways and some undivided sections. These routes comprise 3800 centreline-kilometres or about 35 percent of the region's network. Rockies are permitted on all divided highways plus certain two-lane highways that: (1) meet specific geometric criteria (e.g., paved shoulder width); (2) provide connectivity to key freight generators or attractors; or (3) represent a critical link for northern or remote regions. The two-lane Rocky network totals 6500 centreline-kilometres or about 65 percent of the region's network.

Figure 2 shows the Canadian Prairie Region rural long truck network as of October 31, 2008. This network is distributed as follows:

- Manitoba's long truck network measures a total of 900 centreline-kilometres (nine percent of the regional total). Turnpikes and triples are permitted on 700 of these centreline-kilometres (78 percent of the provincial total).

- Saskatchewan's long truck network measures a total of 4100 centreline-kilometres (40 percent of the regional total). Turnpikes and triples are permitted on 1100 of these centreline-kilometres (27 percent of the provincial total).

- Alberta has the largest long truck network, with a total of 5300 centreline-kilometres (51 percent of the regional total). Turnpikes and triples are permitted on 2000 of these centreline-kilometres (38 percent of the provincial total).

Network connectivity between the Canadian Prairie Region and neighbouring jurisdictions is dependent on whether these jurisdictions permit long truck operations and if so, the extent to which their long truck size and weight regulations are harmonized with those in the Canadian Prairie Region. Regulatory prohibitions or differences affect long truck travel to and from neighbouring jurisdictions and also render certain sections of the long truck network within the region impractical from an operational perspective. For example, there is (effectively) no long truck traffic on the Trans Canada Highway (Highway 1) in Alberta west of Calgary and in Manitoba east of Winnipeg because the provinces of British Columbia and Ontario do not permit long trucks on the connecting routes. Similarly, Provincial Trunk Highway (PTH) 75 in Manitoba and Highway 4 in

Alberta are major U.S. connections, and are thus governed in practice by U.S. federal and state truck size and weight regulations. Certain types of U.S. LCVs are allowed in the neighboring states, particularly on the CANAMEX and Mid-Continent trade corridors, but are typically constrained by more restrictive size and weight limitations (Upper Great Plains Transportation Institute 2005). In contrast, the long truck regulations in the Northwest Territories (north of the region) are essentially harmonized with Alberta's regulations, which allows Rockies uninhibited access as far as Yellowknife.

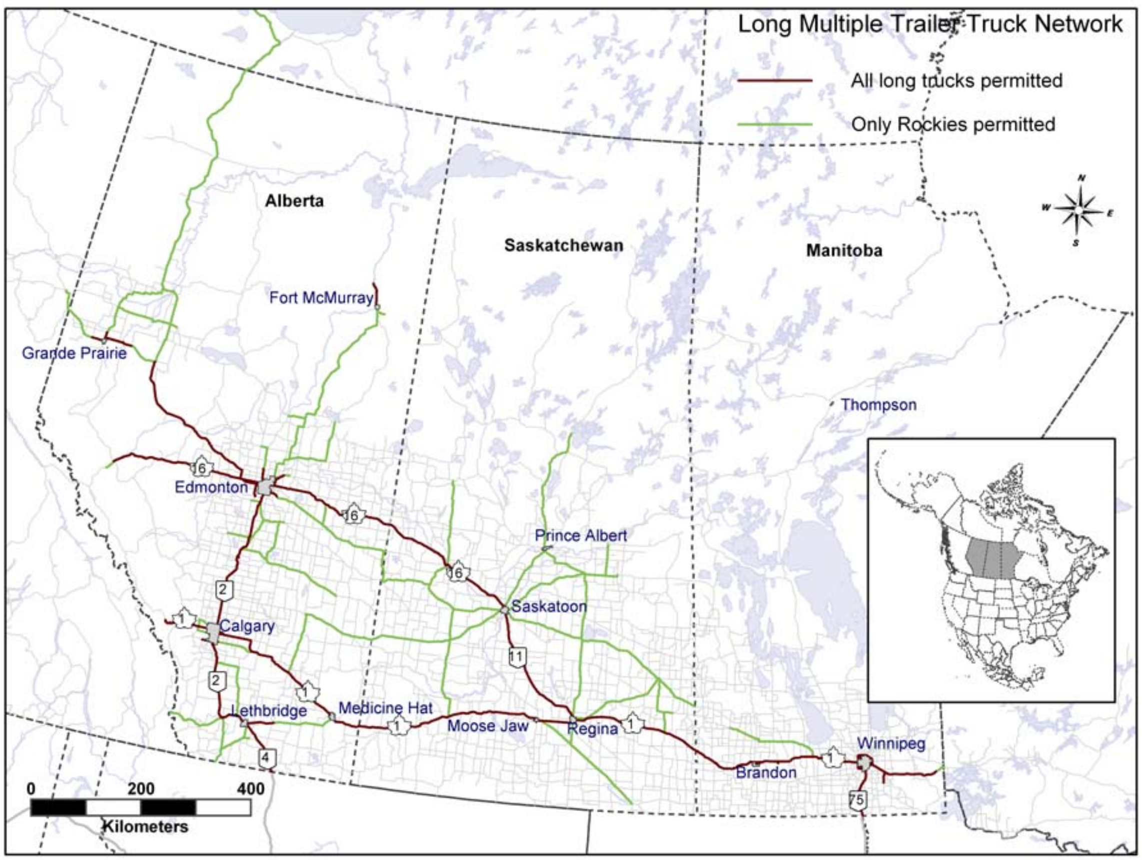

Figure 2: Canadian Prairie Region long truck network as of October 31, 2008.

Source: Adapted from a figure originally published in *Intelligent Transport Systems* by Regehr, Montufar, and Middleton, forthcoming.

2.1.2. Long Truck Highway Network Evolution

Alberta was the first Canadian jurisdiction to allow long trucks, with the establishment of a test program for triples in 1969 (Nix 1995). Circa 1982, Saskatchewan permitted all three types of long trucks (Burns 1983), Alberta only permitted triples (Nix 1995), and Manitoba permitted triples and Rockies on selected routes (Nix 1995). Alberta joined Saskatchewan in allowing all three types of long trucks by 1988, and the Northwest Territories also began permitting Rockies at this time (Girling 1988). By 1995, Manitoba and Québec also permitted all three types of long trucks (Nix 1995).

More recently, other provinces have followed the Canadian Prairie Region's and Québec's lead by conducting studies on long trucks and permitting their operation. In 2007, British Columbia commenced a pilot project for Rocky operations on a portion of the Coquihalla Highway (Westell 2008). New Brunswick began pilot testing Turnpike operations in 2005, and now routinely permits these vehicles on selected divided routes (New Brunswick Department of Transportation 2008). Nova Scotia initiated their own pilot project for Turnpikes in 2008, with the intent to connect the New Brunswick network to the Port of Halifax (Nova Scotia Department of Transportation and Infrastructure Renewal 2008). Ontario, which had considered but previously prohibited long truck operations (Phaneuf 2007), agreed in June of 2008 to work with Québec in harmonizing regulations for long trucks (*Truck News* 2008). One proposal is to permit long truck operations from Toronto, Ontario to the existing networks in Québec and the maritime provinces by the spring of 2009 (Kalinowski 2008).

Figure 3 depicts the evolution of the long truck highway network in the Canadian Prairie Region from the early 1970s to 2008; Table 1 provides details by jurisdiction and long truck type. The long truck network began as independent intra-provincial initiatives designed to serve specific industries or major origin-destination pairs within each jurisdiction (e.g., Calgary-Edmonton in Alberta, Regina-Saskatoon in Saskatchewan, and Winnipeg-Brandon in Manitoba). By the late 1980s, substantial expansion (in terms of centreline-kilometres) of the two-lane undivided highway network allowed regional, long distance trips between provinces by Rockies (e.g., the Trans Canada Highway from Calgary to Winnipeg, and the Yellowhead Highway from Edmonton to Saskatoon). This network also enabled Rockies to access smaller population centres (e.g., Grande Prairie, Alberta and Prince Albert, Saskatchewan) and northern areas. As each of the provinces expanded their divided highway network, Turnpikes and triples were, by 2008, also permitted on a regional basis, although this was typically not the primary intention of twinning highways. This expansion permitted Turnpike and triple operations on more centreline-kilometres of the network, but did not increase the total extent of the network. A corollary of this network regionalization is an increasing demand for regulatory harmonization from carriers involved in inter-provincial trips.

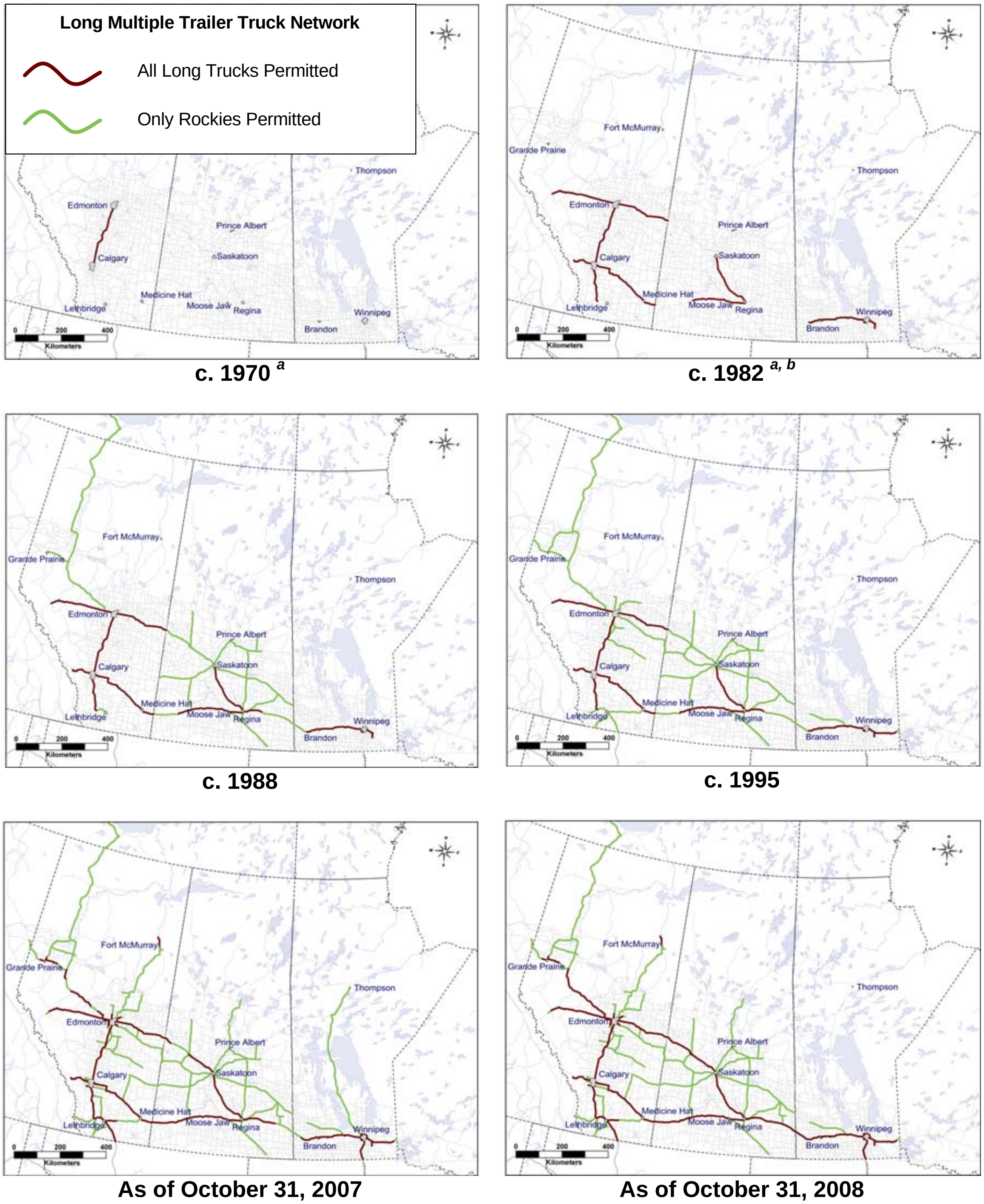

Figure 3: Evolution of the Canadian Prairie Region long truck network, 1970-2008.

Notes: [a] Only triples permitted in Alberta.
[b] Only triples and Rockies permitted in Manitoba.

Sources: Burns 1983; Girling 1988; Nix 1995; Regehr and Montufar 2007.

Table 1: Kilometres of Long Truck Highway Network in the Canadian Prairie Region, 1970-2008

Date	**Manitoba**		**Saskatchewan**		**Alberta**		**Regional Total**
	Only Rockies	All long trucks	Only Rockies	All long trucks	Only Rockies	All long trucks	
c. 1970	0	0	0	0	0	300 [b]	300
c. 1982	0	300 [a]	0	500	0	1300 [b]	2100
c. 1988	100	300 [a]	2500	600	1100	1300	5900
c. 1995	300	400	3000	600	2600	1300	8200
31 Oct 2007	1000	600	3100	1000	3400	1900	11,000
31 Oct 2008	200	700	3000	1100	3300	2000	10,300

Notes: [a] Only triples and Rockies permitted.
[b] Only triples permitted.

Important changes in the region's long truck network have occurred in the last few years, and the network will continue to evolve in the foreseeable future. The recent twinning of the Trans Canada Highway between the cities of Winnipeg and Regina provides regional connectivity for Turnpike and triple operations[2]. Similar effects resulted from the completion of the divided highway between Saskatoon and Edmonton. Provincial regulatory agencies are also under pressure to permit Rocky operations on a larger undivided highway network. One recent example of this is a one-year pilot program[3] beginning in 2006 for Rocky operations on PTH 6 between Winnipeg and Thompson, Manitoba (Macleod 2006). In the near-term future, Alberta plans to complete the divided highway between Edmonton and Grande Prairie, and has also begun twinning portions of Highway 63 between Edmonton and Fort McMurray (Kilburn 2007).

[2] At the time of publication, the twinning of the Trans Canada Highway was complete except for the planned bypass around Moosomin, Saskatchewan. As of the beginning of 2008, Turnpikes and triples were nevertheless permitted to operate through Moosomin during specified times of the day.

[3] At the time of publication, the one-year pilot program has not been extended.

2.2. VEHICLE TYPES AND REGULATIONS

In Canada, size and weight limits for long trucks are defined by provincial regulatory agencies. Figure 4 depicts typical configurations and trailer dimensions of the predominant long trucks operating in the Canadian Prairie Region, and Table 2 summarizes the length and gross vehicle weight (GVW) limits for these vehicles. Long trucks have van (sometimes container) body types. Length and GVW limits vary by jurisdiction; the GVW limit depends on the type of connection used between the trailers. Three routinely permitted long truck configurations dominate:

- Rockies typically consist of a tractor with one 16.2-m van semitrailer and one 8.5-m van pup trailer, are subject to vehicle length limits between 31.0 and 34.0 m, and operate at maximum GVWs between 53,500 and 63,500 kg.

- Turnpikes typically consist of a tractor with one 16.2-m van semitrailer and one 16.2-m van trailer, are subject to vehicle length limits between 38.0 and 41.0 m, and operate at maximum GVWs between 60,500 and 63,500 kg.

- Triples typically consist of one 8.5-m van pup semitrailer followed by two 8.5-m van pup trailers, are subject to vehicle length limits between 35.0 and 38.0 m, and operate at a maximum GVW of 53,500 kg.

Canadian long truck regulations differ from those specified for U.S. LCVs, which are regulated at the federal and state levels. The U.S. Department of Transportation (2004) provides details about regulations for U.S. LCVs.

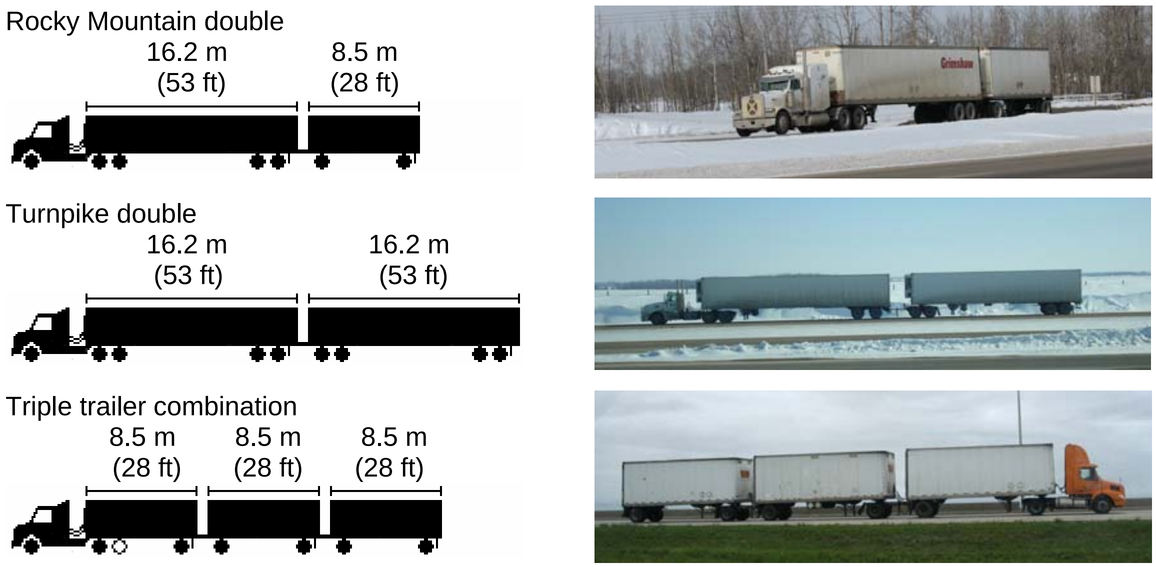

Figure 4: Routinely-permitted long trucks in the Canadian Prairie Region.

Source: Regehr and Montufar 2007.

Photo credits: J. Montufar 2007 (Rocky); G. Rempel 2007 (Turnpike); B. Jablonski 2007 (triple).

Table 2: Length and Gross Vehicle Weight Limits for Long Trucks in the Canadian Prairie Region as of October 31, 2008

Configuration	Manitoba		Saskatchewan		Alberta	
	Length (m)	GVW (t)	Length (m)	GVW (t)	Length (m)	GVW (t)
Rocky Mountain doubles [a]						
A converter dolly	31.5	53.5 [d]	31.0 [e]	53.5 [f]	31.0	53.5
B connection	31.5	62.5 [d]	31.0 [e]	62.5 [g]	31.0	63.5
C converter dolly	31.5	60.5 [d]	31.0 [e]	60.5 [h]	31.0	60.5
Turnpike doubles [b]						
A converter dolly	38.5	62.5 [d]	41.0 [e]	62.5 [i]	38.0	63.5 [d]
B connection	38.5	62.5 [d]	41.0 [e]	62.5	38.0	63.5 [d]
C converter dolly	38.5	62.5 [d]	41.0 [e]	60.5	38.0	63.5 [d]
Triple trailer combinations [c]						
A converter dolly	35.0	53.5	38.0	N/A [j]	35.0	53.5
B connection	35.0	53.5	38.0	53.5	38.0	53.5
C converter dolly	35.0	53.5	38.0	53.5	35.0	53.5

Notes:
[a] Rockies consist of one 16.2-m (53-ft) trailer and one 8.5-m (28-ft) trailer (maximum)
[b] Turnpikes consist of two 16.2-m (53-ft) trailers (maximum)
[c] Triples consist of three 8.5-m (28-ft) trailers (maximum)
[d] For eight or more axles
[e] Saskatchewan officials advised that the length limit for Rockies (on divided highways only) and Turnpikes was changed from 31.0 to 34.0 m and 38.0 to 41.0 m, respectively, in 2008. This enables carriers to use sleeper cabs instead of day cabs in long truck configurations.
[f] Ranges from 41.0 to 53.5 t depending on axle arrangement
[g] Ranges from 54.6 to 62.5 t depending on axle arrangement
[h] Ranges from 46.0 to 60.5 t depending on axle arrangement
[i] Except for nine-axle single axle dolly converters, for which the maximum GVW is 54.6 t
[j] Not allowed

2.3. FREIGHT DENSITY AND LONG TRUCK DESIGN DENSITY

2.3.1. Freight density

Information about commodities hauled by long trucks in the Canadian Prairie Region are synthesized from two sources: (1) a survey of long trucks operating on the Trans Canada Highway in Manitoba conducted in 2003; and (2) interviews with trucking company representatives.

A roadside survey of long trucks was conducted by compliance officers during two weeks in November of 2003 at the Headingley Weigh Scale, located on the Trans Canada Highway eight kilometres west of Winnipeg, Manitoba. A total of 204 long truck drivers were surveyed. A frequency analysis of commodities hauled by these trucks (on a per trailer basis) shows that more than half (54 percent) of long truck trailers carried general freight. Other commodities hauled by long truck trailers are distributed as follows: 13 percent hauled less than truckload (LTL) freight, 10 percent hauled food products, nine percent carried pork[4], seven percent were empty, three percent hauled recyclables, less than one percent hauled dangerous goods, and three percent carried a range of other commodities[5]. Based on the definition of general freight used in the research, it is reasonable to consider LTL freight, food products, and recyclables as general freight, in which case the proportion of loaded long truck trailers hauling general freight is 86 percent.

[4] At the time of the survey, pork products were hauled by principally one long truck carrier between Brandon and Winnipeg, Manitoba.

[5] The other commodities listed in the survey are tires, rental equipment, seed, power tools, furniture, furnaces, tanks, steel, batteries, and machinery.

Interviews with representatives of long truck carriers in the Canadian Prairie Region confirm the results of the commodity surveys. These representatives indicate that long trucks nearly always operate under cube-out conditions as they routinely haul general freight for retail shippers (Siemens 2008; Weiss 2008). Product densities have become so low that shipper-driven efforts are underway to increase the density of loads to bring the operating characteristics of long trucks closer to the dividing line between weigh-out and cube-out freight (see Section 2.3.2).

For certain commodities, it is useful to consider density in terms of effective density. Whereas the density of bulk, divisible, and typically weigh-out commodities (such as gravel or petroleum) is an inherent and easily-measured characteristic of the commodity, this is not so for many types of cube-out freight. For example, the density of plastic toys, electronics, or snack food is not readily apparent. However, if one assumes, for example, that these items are packaged into boxes, which are stacked on standard pallets, then the effective density can be determined by dividing the total weight of the loaded pallet by the space it occupies[6]. Some typical freight densities, not accounting for packaging materials, are given in Table 3.

Table 3: Typical Commodity Densities

Commodity	Density (kg/m^3) [a]	Commodity	Density (kg/m^3) [a]
Gravel	1618	Footwear	192
Water	1000	Cigarettes	176
Newspapers	465	Small packaged freight	176
Canned goods	401 to 561	Pillows	48
Sanitary tissue paper	272		

Source: Nix 1995.

Note: [a] 1 kg/m^3 = 0.062 lb/ft^3. Densities do not account for packaging materials.

[6] Not all cubic freight is palletized.

2.3.2. Design density of long trucks

Morlok (1978) defines the design density of a container or vehicle as the density at which a vehicle both cubes-out and weighs-out. Design density is given by Equation 1:

$$D_{DESIGN} = \frac{W_{MAX}}{C_{MAX}} \tag{1}$$

where: D_{DESIGN} = design density of a container or vehicle
W_{MAX} = container or vehicle weight capacity for payload
C_{MAX} = container or vehicle cubic capacity for payload

If the freight density, D, is greater than the design density, D_{DESIGN}, the vehicle weighs-out; if D is less than D_{DESIGN}, the vehicle cubes-out; if D equals D_{DESIGN}, the vehicle both cubes-out and weighs-out.

A truck's weight and cubic capacity for payload, W_{MAX} and C_{MAX}, are controlled by the GVW limit, the vehicle tare weight, and the dimensional limits of a vehicle. Figure 5 presents size and weight limit envelopes currently in effect in Canada for three truck configurations: (1) five-axle tractor semitrailers (3-S2s); (2) Rockies; and (3) Turnpikes. The graph plots the payload cube, C, expressed in terms of the number of 1.2-m (4-ft) cargo-carrying lengths, as a function of the GVW limit in tonnes (equal to W_{MAX} plus the vehicle tare weight). Each 1.2-m (4-ft) cargo-carrying length is assumed to accommodate four standard pallets or their equivalents (i.e., the pallets are stacked two high and two wide). For simplicity, the research refers to one 1.2-m (4-ft) cargo-carrying length as one CCL.

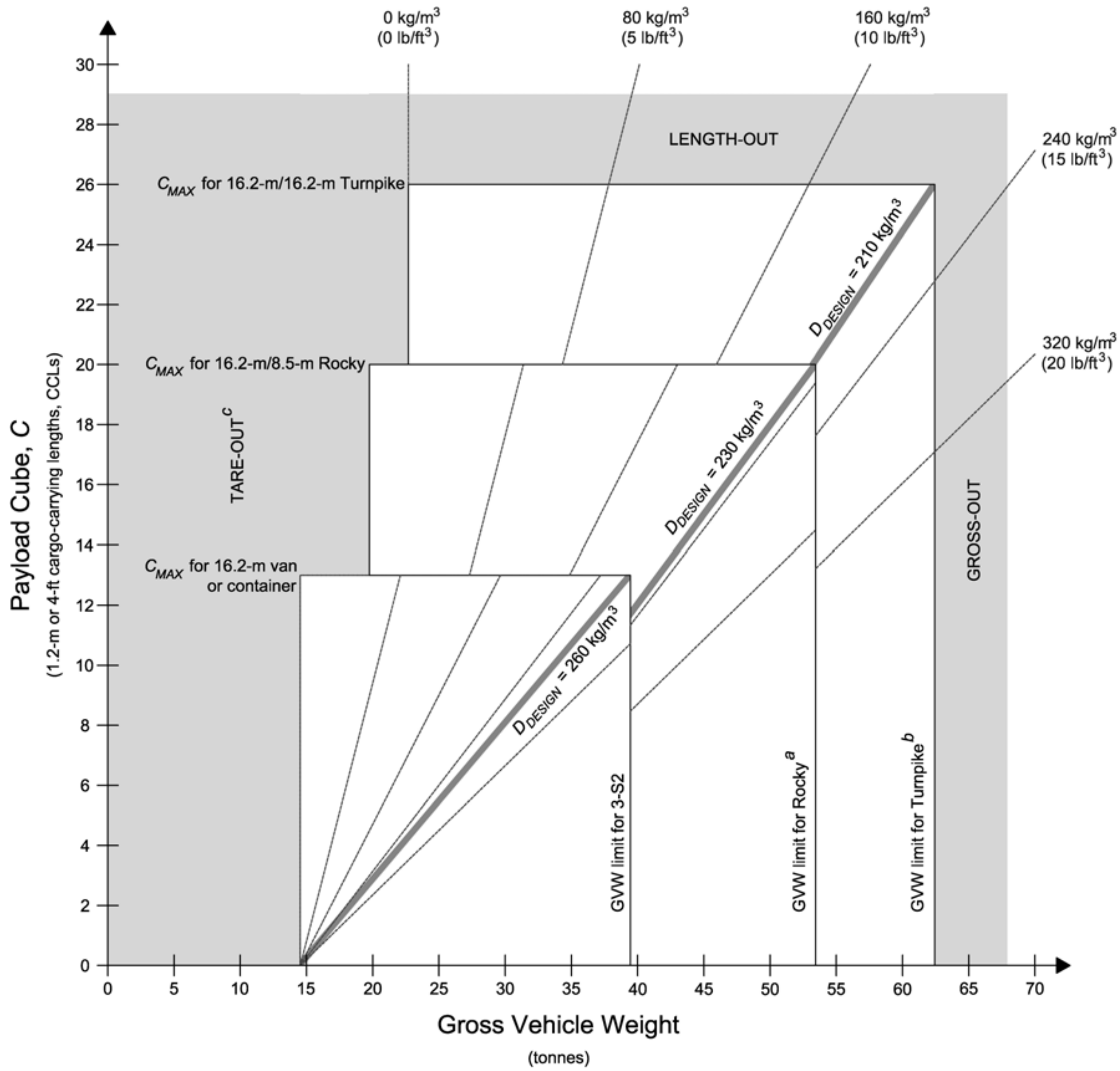

Figure 5: Truck size and weight envelopes for truck configurations in the cubic domain.

Notes: [a] In the Canadian Prairie Region, Rockies with A converter dollies are limited to 53,500 kg. Most Rockies operate with A converter dollies, and typically have seven or eight axles.

[b] In the Canadian Prairie Region, the GVW limit of 62,500 kg applies for Turnpikes, and Rockies with B connections only (except in Alberta, where the GVW is 63,500 kg for these configurations). Turnpikes typically have nine or 10 axles.

[c] Assumed tare weights are (ATRI 2008): (*a*) 14,550 kg for 3-S2s; (*b*) 19,770 kg for Rockies; and (*c*) 22,730 kg for Turnpikes.

The envelopes, viewed contiguously, comprise the cubic trucking domain. The payload cube dimension of the domain is bounded at the minimum when the vehicle is empty (when C equals zero), and is controlled at the maximum by prescribed box and vehicle length limits (when *C* equals 26 CCLs, which is the cubic capacity for payload of a Turnpike). The area above the domain is designated as "length-out", meaning that it is not possible to further increase *C* without violating vehicle length limits. Similarly, the weight dimension of the domain is controlled at the minimum by the vehicle tare weight, and at the maximum by the prescribed GVW limit, which equals 62,500 kg for Turnpikes. The area to the left of the domain is designated as "tare-out", since the GVW of an empty vehicle cannot be reduced below the vehicle tare weight. Vehicles "gross-out" in the area to the right of the domain, meaning that it is not possible to further increase the GVW without violating the GVW limit.

The truck size and weight envelopes for each individual configuration are also bounded in the cube dimension at the minimum when *C* equals zero, and at the maximum by C_{MAX} for each configuration (13 CCLs for 3-S2s, 20 CCLs for Rockies, and 26 CCLs for Turnpikes). Vehicle tare weights define the minimum GVW for each truck, and the GVW limits define the maximum allowable GVW.

The figure shows the design density curves—the density at which a vehicle cubes-out and weighs-out—for the three vehicle configuration envelopes in the cubic domain. These curves are plotted relative to iso-density curves at 0, 80, 160, 240, and 320 kg/m^3 (0, 5, 10, 15, and 20 lb/ft^3), which are rendered discontinuous by the different configurations. A standard 39,500-kg 3-S2 with a 16.2-m (53-ft) van has a design density of 260 kg/m^3 (16 lb/ft^3). In other words, the vehicle cubes-out when it carries freight with a lower density than this, and weighs-out if the freight density is higher. This calculation assumes that one 16.2-m (53-ft) van accommodates 52 standard pallets (two high, two wide, and 13 long), and has a tare weight of 14,550 kg. By comparison, a 46,500-kg six-axle tractor semitrailer with a 16.2-m (53-ft) van has a design density of 330 kg/m^3 (20 lb/ft^3). This vehicle has the same cubic capacity as the 3-S2, but the extra axle allows it to operate at higher GVW limits (despite marginally increasing its tare weight), making it more suitable than a 3-S2 for hauling relatively high density freight.

Rockies, which typically consist of one 16.2-m (53-ft) van semitrailer and one 8.5-m (28-ft) van pup trailer, have a tare weight of approximately 19,770 kg and operate under a GVW limit of 53,500 kg (for configurations connected with an A converter dolly). These limits correspond to a design density of 230 kg/m^3 (14.5 lb/ft^3). Turnpikes consist of one 16.2-m (53-ft) van semitrailer and one 16.2-m (53-ft) van trailer, have a tare weight of approximately 22,730 kg, and typically operate under a GVW limit of 62,500 kg. Their design density is 210 kg/m^3 (13.1 lb/ft^3). As such, these long trucks—and particularly Turnpikes, which are the prominent long truck in the Canadian Prairie Region—are best suited for hauling relatively low density freight.

The proximity of the design density curves for each of the three individual configurations to the 240 kg/m^3 (15 lb/ft^3) iso-density curve demonstrates that trucks in the cubic domain are ideally suited for freight densities up to about this level. Higher freight densities will cause these vehicles to weigh-out, and may induce a shift to a more suitable vehicle for this freight (e.g., fuel transported in tankers, grain in hopper bottoms).

2.4. PERMIT CONDITIONS

A survey of the three Canadian Prairie Region jurisdictions conducted in 2007 (reported in Montufar et al. 2007) reveals the following about long truck permitting practices[7]:

- There is no standard approach in the application of weather and road condition restrictions for long truck operations in these provinces. Alberta requires carriers operating on multi-lane highways to exercise caution when operating in hazardous weather and road conditions. Operation of Rockies on two-lane highways is not permitted under adverse conditions due to rain, snow, sleet, fog, smoke, or others. Saskatchewan prohibits long truck operations when visibility is 1000 m or less, when the highway is icy or heavily snow covered, or when they pose a particular safety hazard. Manitoba requires long truck drivers to operate in a reasonable and prudent manner, having regard for road and weather conditions.

- All three provinces apply temporal restrictions on long truck operations for statutory holidays, weekends, and times of the day. Saskatchewan and Manitoba also restrict operations according to season; however, Alberta does not specify seasonal restrictions.

- Alberta and Saskatchewan require special training or qualifications for long truck drivers. Manitoba requires long truck drivers to adhere to safety requirements developed by the carrier safety supervisor, but does not mandate special education or qualifications. Survey respondents indicate that more stringent driver training

[7] Montufar et al. (2007) provide a detailed description of permit conditions. This report also describes permit conditions for U.S. LCVs in five U.S. jurisdictions in the CANAMEX trade corridor: Montana, Idaho, Utah, Nevada, and Arizona.

and qualifications standards for long truck drivers compared to other commercial drivers contribute positively to long truck safety performance. These standards are sometimes instituted by long truck carriers, whether or not special requirements are mandated by the permit.

- The three provinces use different approaches to control the operating speed of long trucks. These approaches vary due to the tradeoff between the perceived safety improvement of lowering long truck speeds, and the perceived safety reduction of the resulting speed differentials between long trucks and other vehicles in the traffic stream. Alberta restricts long truck speeds to the lesser of 100 km/h or the posted speed limit; Saskatchewan restricts speeds to the lesser of 90 km/h or the posted speed limit; Manitoba permits long trucks to operate at the same maximum speed as any other vehicle[8].

- None of the three provinces restricts the minimum following distance or passing activity for long trucks.

- Each province specifies vehicle-related requirements for long truck 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, heavy trailers preceding lighter trailers, and off-tracking limitations.

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[8] At the time of the survey, there were no highways in Manitoba on which speeds greater than 100 km/h were permitted. In contrast, both Alberta and Saskatchewan had highways with posted speed limits of 110 km/h. As such, speed restrictions for long trucks in Alberta and Saskatchewan imposed speed differentials between long trucks and other vehicles, but no speed differentials were imposed by permit conditions in Manitoba.

3. DESIGN OF THE LONG TRUCK EXPOSURE MODEL

This chapter designs an exposure model for productivity-permitted general freight trucking in terms of volume, weight, and cube. It outlines the modelling background and approach, structure, and definition.

3.1. BACKGROUND AND APPROACH

Truck traffic exposure modelling occurs within two lines of research and practice: (1) truck traffic measurement and estimation programs; and (2) freight demand modelling (Holguín-Veras and Thorson 2000; Regehr, Montufar, and Middleton, forthcoming). Truck traffic measurement and estimation programs are oriented towards three types of truck traffic exposure data: volume, vehicle classification, and weight. The U.S. Department of Transportation *Traffic Monitoring Guide* (2001) recommends that these programs be based on permanent traffic data typically collected by weigh-in-motion (WIM) devices, automatic vehicle classifiers (AVCs), and automatic traffic recorders (ATRs), supplemented as necessary by short duration counts. Utilization of on-board electronic transponders and global positioning systems (GPS) to measure truck traffic can provide additional information about truck traffic volumes and travel time reliability for highway segments (McCormack and Hallenbeck 2006).

Freight demand models estimate exposure using methods based on the classical four-step demand modelling process[9], a direct demand modelling approach, or input-output

[9] The classical approach involves four steps: (1) trip generation (and attraction); (2) trip distribution; (3) modal split; and (4) assignment. In some freight demand models (e.g., trip-based models), step three may be omitted if mode split is negligible or not of concern.

models, with either a commodity-based or trip-based orientation (Holguín-Veras and Thorson 2000). These approaches forecast truck traffic exposure (in terms of commodity weight converted into truck trips for commodity-based models, or directly in terms of truck trips for trip-based models) by establishing explanatory relationships between exposure and a set of independent demand variables. A principal example of a freight demand model is the Freight Analysis Framework (FAF) developed by the Federal Highway Administration of the U.S. Department of Transportation. The FAF integrates a variety of data sources to estimate commodity flows between origin and destination zones. The current generation of the framework (FAF^2) provides commodity flow forecasts on U.S. national corridors and international gateways through to the year 2035 (GAO 2008; Schmitt 2008).

Modelling freight demand is a complex task because of: (1) the multidimensional nature of the freight demand unit (vehicle trips, freight weight, and freight volume) (Holguín-Veras and Thorson 2000); (2) multifaceted interactions between different freight agents within the supply chain (Agrawal and Ziliaskopoulos 2006; Wisetjindawat et al. 2006; McCabe, Kwan, and Roorda 2007); and (3) different values and transport costs associated with different types of freight (NCHRP 1997).

As discussed in Section 1.3, the transportation systems analysis framework distinguishes between demand modelling and the measurement and estimation exposure modelling approach used in the research. This latter exposure modelling approach is guided by the following perspectives:

- It is designed within the context of transportation systems analysis, for the purpose of synthesizing information and revealing issues that should be considered in engineering and regulating productivity-permitted general freight trucking.

- It focuses on understanding the component of the Type 1 relation linking *T* and *F*, and the Type 3 relation between *F* and *T* (see Figure 1). The demand variables used to forecast freight flow are not specifically addressed by this approach, but rather, they are understood as underlying factors influencing and generating the exposure, *E*, that is ultimately measured.

- It predicts present characteristics of long truck exposure in terms of volume, weight, and cube. Understanding current conditions is essential for conducting sensitivity analyses, extrapolating trends, or forecasting future exposure.

- It relies on a combination of empirical observations (gained through the analysis and fusion of long truck traffic data from various sources) and pragmatic understanding (gained through the integration of industry intelligence obtained by dealing with the requirements and consequences of truck traffic in practical ways).

- It emphasizes enhancing the understanding of relationships that influence long truck exposure, over the provision of accurate predictions of future exposure.

3.2. MODEL STRUCTURE

The research defines truck traffic exposure as the number and nature of truck traffic events at a point or along a segment, in a specified time. Truck traffic exposure and the inherent and exogenous characteristics of the transportation system induce transportation system impacts, which the research considers to be unobservable or latent variables. Consequently, the following structural model is proposed:

$$TSI_c = f(E_c, T_c, X_c) \tag{1}$$

where:

TSI_c: latent transportation system impact for context *c*
E_c: set of truck traffic exposure indicators for context *c*
T_c: set of inherent transportation system indicators for context *c*
X_c: set of exogenous transportation system indicators for context *c*

In proposing this structural model, the intent is to express truck traffic exposure as a common and unifying set of explanatory variables for analysis and decision-making in transportation engineering and planning contexts, rather than to predict latent transportation system impacts or to fully characterize transportation system variables. This idea is expressed schematically in Figure 6 for 10 contexts.

The model extends work conducted by Ben-Akiva and Ramaswamy (1993) and Ben-Akiva and Gopinath (1995), in which infrastructure performance is modelled using a latent performance approach. The dependent (latent) variable in the structural model is the transportation system impact, TSI_c, relevant for a particular analytical or decision-making context, *c*. In the transportation systems analysis approach, impacts are aspects that should be considered in evaluating or making changes to the transportation system because of their differential quality or effect on system stakeholders (Manheim 1979). Difficulties arise in transportation decision-making because evaluations depend on understanding impacts, which may not be directly observable. Rather, decision-makers rely on measurable performance indicators, P_c, which describe the condition of the transportation system within a specific context, and can be expressed by a measurement model as a function of the latent impact, TSI_c (Ben-Akiva and Ramaswamy 1993; Ben-Akiva and Gopinath 1995).

Figure 6: Exposure as a unifying explanatory variable.

Transportation system impacts are a function of three explanatory variables: a set of truck traffic exposure indicators, E_c, a set of inherent transportation system indicators, T_c, and a set of exogenous transportation system indicators, X_c. Selection of indicators within E_c,

T_c, and X_c depends on the analytical context, *c*. Examples of these contexts are road safety, road use charging, and pavement design and evaluation. Functional forms vary in complexity, from simple product or quotient calculations, to more complex situations which require many exposure and other types of indicators to determine one or more impacts.

The road safety context, which is traditionally associated with the concept of exposure, provides a useful illustration of the structural model. Despite a variety of definitions used within the safety field, exposure is used to help define the safety of a system because it is associated with the risk of a collision (Qin, Ivan, and Ravishanker 2004). Unlike actual collisions, the risk of a collision is not directly observable (Qin et al. 2005). The research therefore considers this a latent transportation system impact, *TSI*, for the road safety context. A typical, measurable indicator of a highway system's safety performance is the collision rate. The collision rate in a specified time period is calculated as the number of collisions (i.e., an inherent transportation system indicator, T_c) divided by an indicator of exposure, for example, as measured in terms of vehicles entering an intersection, or vehicle-distance travelled on a segment (Hauer 1995). Highway safety performance is also influenced by exogenous factors, X_c, such as political or physical environmental conditions.

The definition of exposure used in the research expands the conventional safety-related concept of exposure in two respects. First, it broadens the scope of application and need for exposure information beyond the context of road safety. For example, the structural model posits that the prediction of transportation system impacts in other contexts also relies on indicators of exposure, although these indicators encompass the *nature* of truck traffic events (i.e., weight and cube characteristics) not just the *number* of events (i.e., volume). Second, it extends the concept of risk to that of impact. The types of impacts depend on the specific analytical, evaluation, or decision-making context (e.g., collision risk in the context of road safety, revenue adequacy in the context of road use charging, or deterioration in the context of pavement design and evaluation). Table 4 provides examples of transportation system impacts, performance indicators, exposure indicators, and inherent transportation system indicators for three exposure-based analysis contexts.

Table 4: Example Impacts and Indicators for Three Exposure-Based Analysis Contexts

Context, *c*	**Transportation system impact, TSI_c**	**Performance indicators, P_c**	**Exposure indicators, E_c**	**Inherent transportation system indicators, T_c**
Road safety	Collision risk	- Collision rate by vehicle class - Safety performance function	- Distance of travel by vehicle class - Annual average daily traffic - Number of entering vehicles	- Collision frequency by vehicle class, collision type, and severity - Road geometry - Truck regulations and enforcement
Road use charging	Revenue adequacy	- Gas tax revenue generated by vehicle class - Revenue generated by other fees	- Distance of travel by vehicle class - Rolling gross weight - Rolling gross cube	- Charging rate and structure - Truck operating costs and business strategy - Truck regulations
Mechanistic-empirical pavement design and evaluation	Pavement deterioration	- Cracking - Spalling - Ravelling - Rutting	- Axle load spectra - Axle spacing - Load repetitions	- Maintenance variables - Construction variables - Pavement structure

Source: Adapted from a table originally published in *Intelligent Transport Systems* by Regehr, Montufar, and Middleton, forthcoming.

The exposure modelling structure supports results-based monitoring and evaluation approaches by providing indicators needed for exposure-based analysis in different transportation contexts—as illustrated in Figure 6 and Table 4. Results-based methodologies—sometimes referred to as performance-based methodologies—encourage fiscal responsibility, accountability, and transparency in governance, regulation, and decision-making by identifying and monitoring indicators needed to evaluate performance against specified objectives and goals (NCHRP 2000; Kusek and Rist 2004; Isaacs 2005).

3.3. MODEL DEFINITION

Truck traffic exposure, *E*, is expressed in three principal dimensions: volume, weight, and cube. These principal dimensions are further characterized by the following secondary dimensions: (1) time—for example, by year, month, day of week, hour, or into real-time; (2) space—for example, by location, segment, lane, or direction of travel; and (3) vehicle characteristics—for example, by class, body type, configuration, or axle group. The truck traffic exposure model is defined generically here; the exposure knowledge base, model results and validation, and model application in Chapters 4, 5, and 6 pertain specifically to long trucks.

3.3.1. Volume

Traffic volume is the base measure of truck exposure. The annual average daily traffic (AADT) is the fundamental indicator of traffic volume, and is calculated at a permanent counting station using the formulation presented in Equation 2 (U.S. DOT 2001).

$$AADT_x = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n}VOL_{ijkx}\right)\right] \quad (2)$$

where:

VOL:	daily traffic for class *x*, day *k*, day of week *i*, and month *j*
x:	vehicle class or group of classes
i:	day of week
j:	month
k:	one when the day is the first occurrence of that day of week in a month, two when it is the second occurrence, etc.
n:	the number of days of that day of week during that month

This formulation disaggregates traffic count data by month and day of week, and in practice, is often calculated by vehicle class, or for a group of classes. Depending on the counting device used, volume can be further expressed in terms of any combination of the secondary exposure dimensions (e.g., volume by month, by direction, or by configuration). The *Traffic Monitoring Guide* recommends the use of the Federal Highway Administration (FHWA) 13-category classification scheme, but recognizes that a wide variety of schemes are used in different jurisdictions (U.S. DOT 2001). Class definitions depend on: (1) the types of vehicles present in the jurisdiction for which the scheme is developed; (2) the ways in which the data is expected to be used; and (3) the monitoring equipment available (e.g., visual, axle sensors, presence sensors, optical sensors), and its expected performance. It is advantageous for different schemes used within a jurisdiction or region to be compatible with one another; that is, more specific classes should be collapsible into a single, more broadly defined class (Hallenbeck 2007).

It is often useful to transfer point-based volume estimates along the length of a road segment that has homogeneous volume—including its temporal, spatial, and vehicle characteristics. These transfers provide an indication of network effects and are typically expressed in terms of a vehicle-distance travelled metric such as vehicle-kilometres of travel (VKT).

3.3.2. Weight

The total vehicle loading for a specified time (e.g., one year) and location (e.g., a WIM station) is the sum of all passing axle weights, and is given by the rolling gross weight (RGW) indicator (Equation 3).

$$RGW_{year} = \sum_{a=1}^{n} W_a \qquad (3)$$

where:

W_a: dynamically measured axle weight
n: number of axle passages in one year

The RGW is a pragmatic, comparable indicator of total vehicle loading on a road. Like volume, it is possible to express RGW in terms of any combination of its secondary exposure dimensions (i.e., time, space, vehicle characteristics), and to attribute it to the length of a homogeneous road segment. The RGW concept is commonly used in the rail industry, but, despite its introduction in the *Traffic Monitoring Guide* (U.S. DOT 2001), has seldom been used in the context of truck loading on a highways. Regehr (2002) provides one example of developing and applying RGW estimates for highways, using them to rate highways based on the relative truck loading from a particular industry sector. In addition to sector-specific applications, dividing the total RGW into its payload weight and vehicle tare weight components provides additional information about vehicle productivity and transport efficiency.

More refined weight indicators are required in certain applications—particularly for mechanistic-empirical pavement design (Haas et al. 2007; AASHTO 2008) and methods to determine bridge deterioration (NCHRP 2003). These indicators need to be sensitive to the fact that axles are arranged into axle groups (i.e., singles, tandems, tridems), axle groups are configured into vehicles, and the particular axle arrangement and magnitude of the axle loads impact pavement and bridge structures. Load spectra provide this information by explicitly representing axle or gross vehicle loads in terms of their frequency of occurrence within a series of weight ranges. Axle load spectra are given by Equation 4 (Hajek et al. 2002).

$$ALS_{year} = \sum_{i=1}^{n} \left(AADT_i \times RALS_i \times 365 \right) \qquad (4)$$

where:

ALS_{year}:	annual combined axle load spectra for all vehicle classes i
$AADT_i$:	annual average daily traffic of vehicle class i
$RALS_i$:	representative axle load spectrum for vehicle class i
n:	number of vehicle classes i

Equation 4 is a simplification of the actual expression used to calculate ALS. The ALS_{year} and $RALS_i$ terms represent several axle weight distributions, where a single distribution exists for each type of axle group (Hajek et al. 2002). The weight summation of the ALS_{year} term for all vehicle classes and axle groups is equivalent to the RGW in that year.

3.3.3. Cube

The total cubic capacity of trucks in a specified time (e.g., one year) at a point is the sum of the cubic capacity of all trucks, and is given by the rolling gross cube (RGC) indicator (Equation 5).

$$RGC_{year} = \sum_{i=1}^{n} \left(AADT_i \times CCF_i \times 365 \right) \tag{5}$$

where:

$AADT_i$:	annual average daily traffic for vehicle class i
CCF_i:	cubic capacity factor for vehicle class i
n:	number of vehicle classes i

RGC is analogous to the RGW indicator in that it provides a comparative indicator of the total cubic capacity of trucks on a road. The AADT (by vehicle class) is factored by CCF_i, which is a function of truck body type. RGC is measured in terms of 53-ft equivalent units (53EUs). For example, a tractor semitrailer with a 53-ft (16.2-m) van body type is one 53EU (i.e., $CCF_i = 1$). Similarly, a Turnpike is two 53EUs ($CCF_i = 2$), a Rocky is 1.53 53EUs ($CCF_i = 1.53$), and a triple is 1.58 53EUs ($CCF_i = 1.58$). For analyses involving intermodal movements or specific payload types, it may be convenient to convert from 53EUs to 20-ft (6.1-m) equivalent units (TEUs) or a pallet-based metric such as the cargo-carrying length (CCL). The cubic capacity of one 53EU is equal to 2.65 TEUs or 13 CCLs. Cubic capacity factors for body types other than vans and containers apply the same concept, but are not considered here.

In addition to cubic capacity, it is useful to develop indicators of payload cube—that is, the amount of space occupied by a truck's payload. The payload cube equals a vehicle's cubic capacity when it is completely full. Payload cube can be represented in terms of the frequency of occurrence of different cubic quantities of payload within a series of cube ranges for a vehicle class.

4. DEVELOPMENT OF THE KNOWLEDGE BASE FOR THE LONG TRUCK EXPOSURE MODEL

This chapter develops the knowledge base for the long truck exposure model. It describes: (1) long truck exposure data sources; (2) the long truck classification algorithm; and (3) the methodology used to assign exposure data to network segments.

4.1. LONG TRUCK EXPOSURE DATA SOURCES

Three sources of long truck exposure data are used in the research: permanent classification counts, sample classification counts, and industry intelligence.

4.1.1. Permanent Classification Counts

Weigh-in-motion devices provide the primary data source for modelling long truck exposure. Most WIM devices in the Canadian Prairie Region consist of two piezoelectric axle sensors and one or two inductive loops. The axle sensors record axle weight, vehicle speed, and measure the spacing between consecutive axles for each vehicle passage. The inductive loops sense the presence of the vehicle and provide a measure of overall vehicle length. Previous research and field-based calibration tests in the Canadian Prairie Region have demonstrated that axle spacing measurements can be used to accurately distinguish between single, tandem, and tridem axle groupings (Fekpe and Clayton 1994).

The structure of WIM datasets depends on the equipment manufacturer and the particular setup used by the jurisdiction. Raw WIM datasets have the following characteristics:

- Each record in the dataset corresponds to one vehicle passage in one travel lane[10].

- Records have at least the following attributes: station number, lane or flow direction, date, time, speed, vehicle length, GVW, axle weights, and the separation between subsequent axles.

- Depending on the particular equipment configuration, some WIM records have the following additional attributes: number of axles, vehicle classification (based on either a predefined or user-defined classification scheme), and equivalent single axle load (ESAL).

Data from the 24 WIM stations on the Canadian Prairie Region long truck network are used to develop the long truck exposure knowledge base. The locations of these installations are shown in Figure 7; details about the sites are in Appendix A.

4.1.2. Sample Classification Counts

Two types of sample classification counts are utilized in the research: (1) data obtained from specially-configured automatic vehicle classifiers (AVCs); and (2) manual classification counts. AVCs are conventionally configured to sum the number of vehicles in each class passing a site for every hour. Similar to WIMs, AVCs use axle spacing measurements to classify vehicles, but these measurements are typically not provided in the binned hourly data. Also, axle and gross vehicle weights are not measured by AVCs.

[10] Some WIM installations do not measure traffic in all the lanes. For example, several WIMs in Manitoba only measure traffic in the drive lanes, and are supplemented by classification data from AVCs installed in the passing lanes. The proportion of long trucks travelling in the passing lanes is negligible.

Because most vehicle classification schemes—including the commonly-used FHWA 13-category classification scheme (see Appendix B)—do not isolate long trucks as a separate vehicle class, it is necessary to reconfigure the AVC equipment to retain the detailed axle separation data, which can then be mined to isolate long trucks. For the purposes of the research, six AVCs[11] were specially-configured for a one- to two-week sampling period. Figure 7 shows the locations of these AVCs; details are in Appendix A.

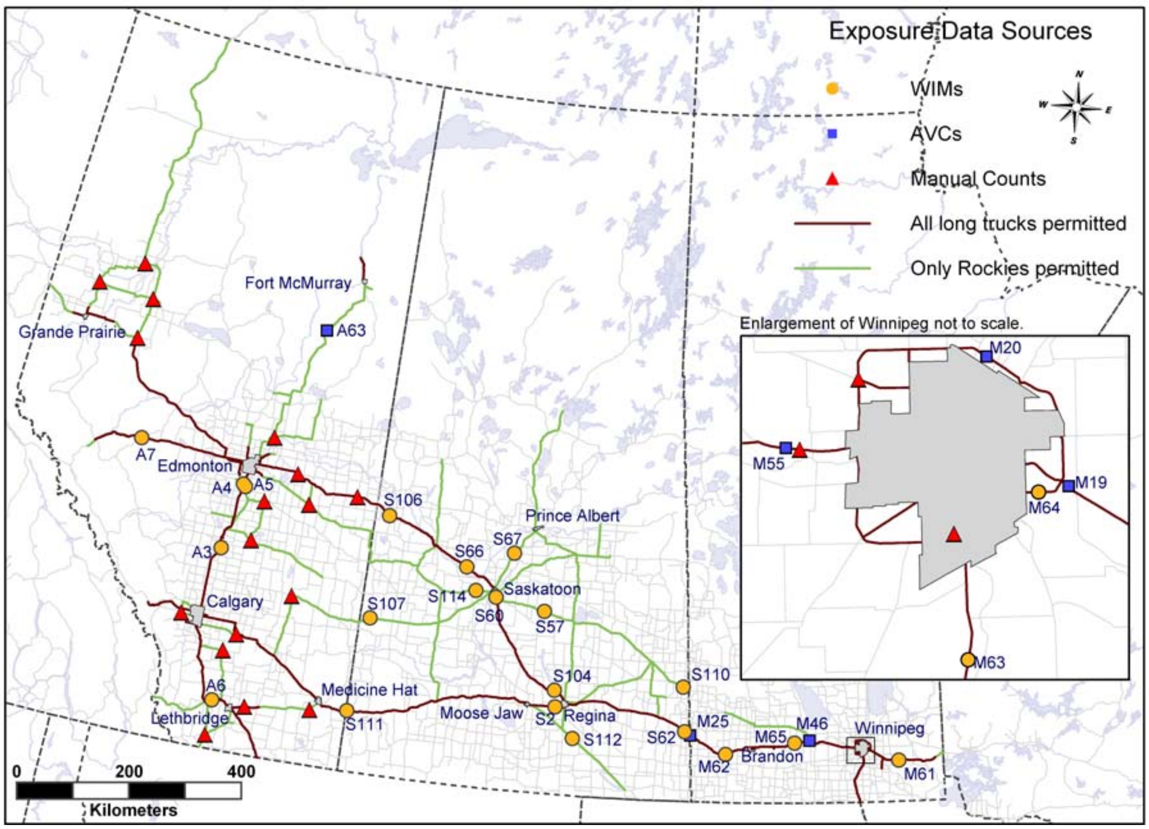

Figure 7: Data sources on the Canadian Prairie Region long truck network used for the exposure model.

Note: WIM N2, which is not shown on this map, is located at kilometre 2.3 of Highway 3 near Fort Providence, Northwest Territories.

[11] AVC A63 in Alberta was specially-configured to capture total vehicle lengths only; axle separation details are not available at this location.

Manual truck classification counts were conducted at 20 locations on the Canadian Prairie Region long truck network in 2007 and 2008. The counts provide short-term samples of Rockies, Turnpikes, triples and other types of articulated trucks. Figure 7 indicates the locations of these counts; details are in Appendix A.

In addition to these sample classification counts, route-based classification surveys were conducted while travelling on:

- Manitoba highways 1, 75, 100, and 101;
- Saskatchewan highways 1, 4, 7, 11, and 16; and
- Alberta highways 1, 2, 2A, 3, 4, 12, 13, 16, 21, 28, 28A, 36, 43, 49, and 63.

4.1.3. Industry Intelligence

The development of system-wide exposure estimates requires the integration of industry intelligence into the exposure knowledge base. Local industry knowledge about long truck operations supplements data obtained from WIMs, AVCs, or manual classification counts and enables interpretation of patterns, trends, and anomalies observed in these data (Fortowsky and Humphries 2006).

Industry intelligence was gathered from:

- government officials from each of the three Canadian Prairie Region jurisdictions involved with the measurement and estimation of truck traffic exposure, the administration of freight and truck policy, the development and implementation of trucking programs, and the on-road enforcement of truck size, weight, and safety regulations;

- representatives from trucking companies that operate long trucks in the region;
- truck drivers with experience operating long trucks;
- researchers with expertise in freight transport systems and trucking; and
- field-based observations of actual long truck operations (and trucking in general) made during the course of the research.

Industry expertise is integrated in an iterative manner at four stages of the modelling process:

1. Industry experts provide direct estimates of long truck exposure where automated or manual survey data are not available.

2. The design, development, and application of the classification algorithm requires industry knowledge of the long truck network, vehicle configurations, and operating conditions (as discussed in Section 4.2).

3. Interpretation and calibration of the algorithm results, and the hierarchical integration of these results into the exposure model relies on expertise obtained through interviews with industry experts, and is supported by field-based engineering observations (as discussed in Section 4.2). One example of this is the establishment of the cubic capacity factors for long truck configurations. These

factors are not evident from WIM datasets, but can be ascertained through industry intelligence and field observations.

4. Validation and application of model results demand industry-based checks for reasonableness (as discussed in Chapters 5 and 6, respectively).

4.2. LONG TRUCK CLASSIFICATION ALGORITHM

The long truck classification algorithm developed in the research is the primary tool used to extract data for the development of the long truck exposure model. The algorithm isolates and classifies 31 different long truck configurations as Rockies, Turnpikes or triples using axle spacing measurements from WIMs and AVCs. These vehicles are seldom uniquely identified by conventional classification schemes. For example, in North America, the most commonly used scheme is the FHWA 13-category classification scheme. In this scheme, nearly all long trucks are allocated to class 13 (multiple trailer trucks with seven or more axles), but are not easily isolated from other multiple trailer trucks in this class (see Appendix B).

4.2.1. Algorithm Description

The classification algorithm is developed and executed in a database environment, and uses Structured Query Language (SQL) to isolate vehicles from the WIM database. The isolation criteria are developed from dimensions specified in long truck permits in the Canadian Prairie Region and confirmed by industry intelligence. The algorithm has six steps designed to isolate and classify long trucks based on criteria defined for three parameters: vehicle wheelbase, the number of axles on the vehicle, and axle spacing (centre-to-centre distance between subsequent axles).

Step 1 isolates all vehicles that have a total wheelbase (distance between the steering axle and the rearmost axle) greater than 24 m. The total wheelbase is calculated by summing the axle spacing measurements recorded directly by the axle sensors. This wheelbase criterion is based on analysis of the cumulative distributions of the wheelbases of multiple trailer trucks. Figure 8 shows the cumulative wheelbase distribution for all multiple trailer trucks passing one of the WIM sites on the Trans Canada Highway (WIM M65, located about 110 km west of Winnipeg, Manitoba) in 2005, with reference to the total vehicle length limits for Rockies, Turnpikes, and triples. The distribution indicates that 80 percent of multiple trailer trucks (primarily eight-axle B-trains) operate with a total wheelbase of less than or equal to 24 m. The remaining 20 percent of vehicles have a longer wheelbase, and thus an overall length beyond the basic length limit of 25 m. Long trucks operate in this domain.

Step 2 isolates vehicles based on the number of axles in the configuration. This parameter is not always automatically provided by WIM devices, but can be determined from the number of axle spacing or axle weight measurements in each record. All vehicles with between seven and 11 axles, inclusive, are considered candidates for classification as Rockies, Turnpikes, or triples. Five- and six-axle vehicles rarely operate as multiple trailer configurations, and almost never exceed basic vehicle length limitations. Vehicles with 12 or more axles are also rare and are utilized for special hauling purposes.

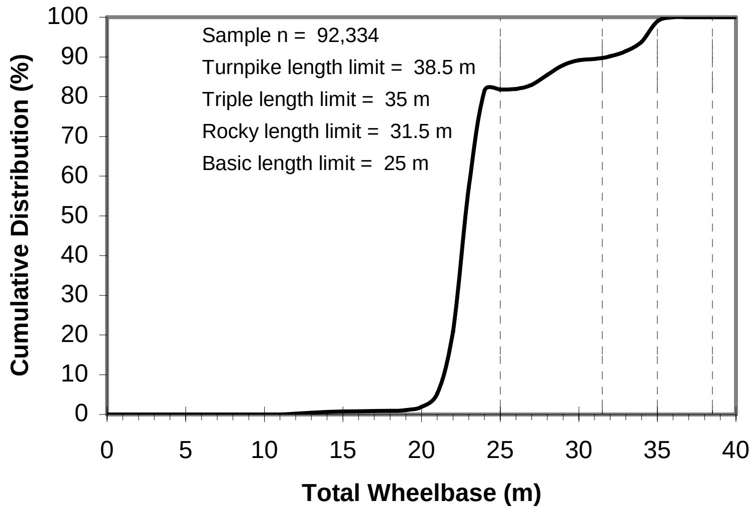

Figure 8: Cumulative distribution of total wheelbase for multiple trailer trucks travelling in the eastbound and westbound drive lanes at M65 in 2005.

Note: The figure plots the total wheelbase (distance between the steering axle and the rearmost axle) of multiple trailer trucks with reference to the basic vehicle and long truck length limits (the maximum length of the vehicle from the front to the back). A vehicle's length equals its wheelbase plus the front and rear overhang.

Step 3 uses axle spacing measurements to determine the positions of tandem and tridem axle groups within the configuration. Commercial vehicle regulations in Manitoba, Saskatchewan, and Alberta limit the tandem and tridem axle spreads to a maximum of 1.85 and 3.7 m, respectively. Consecutive axles within 2.0 m are considered a tandem axle group. Similarly, tridem axle groups are defined as any three axles with a total separation of less than or equal to 4.0 m.

Step 4 uses inter-axle spacing[12] measurements to determine the presence of short (7.3 to 8.5 m) and long (12.2 to 16.2 m) trailers or semitrailers. Trailer and semitrailer lengths

[12] Inter-axle spacing is the distance separating two axle groups as determined from the centres of each of the axles that is the closest to the other axle group.

are regulated in terms of maximum box length[13], maximum and minimum trailer wheelbase[14], and minimum inter-axle spacing. The algorithm uses inter-axle spacing dimensions to distinguish between long and short trailers since these measurements are directly available from the WIM dataset. Inter-axle spacing limits are a function of the vehicle type, but are never permitted below 3.0 m. Maximum inter-axle spacing is not regulated specifically, but is governed by maximum trailer wheelbase, box length, and/or overall vehicle length. These limits and the results of a post-processed sensitivity analysis of long truck data indicate that, from an operational perspective, the inter-axle spacing on long trailers exceeds 8.0 m. Thus, trailers with an inter-axle spacing between 3.0 and 8.0 m are considered short, and those with an inter-axle spacing greater than 8.0 m are considered long.

Step 5 uses the results of the previous steps to verify vehicle connectivity by identifying the trailer connections. A and C converter dollies are the most common types of connections used for long trucks[15]. The dimensions of these connections are controlled by minimum inter-axle spacing. However, for this classification algorithm, it is not necessary to specifically limit this dimension beyond ensuring that it exceeds the maximum tandem axle spacing of 2.0 m. From an operational perspective, this distance

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[13] Box length is the distance measured from the front of the semitrailer, excluding any auxiliary equipment attached to the front of the semitrailer that is not designed for the transportation of goods, to the rear of the semitrailer or any load carried by it, whichever is the greater distance from the front of the semitrailer.

[14] Trailer wheelbase is the distance measured from the centre of the kingpin of a semitrailer or the turntable of a full trailer to the geometric centre of the rear axle group.

[15] A converter dollies are towed from a single hitch located on the centreline of the towing vehicle. C converter dollies are equipped with a self steering axle and a rigid double hitch assembly located on a horizontal transverse plane. B connections use a fifth wheel coupler mounted on the rear of the lead semitrailer to attach a second semitrailer.

rarely exceeds 5.0 m. The dimensions of B connections, which consist of a tridem or tandem axle group, are limited by the maximum axle spreads for these groups.

Step 6 classifies the vehicle as a Rocky, Turnpike, or triple with a specified axle configuration.

In summary, the criteria used to isolate and classify long trucks in the algorithm are:

- total wheelbase (distance between the first and last axles on a vehicle) > 24 m;
- number of axles between seven and 11, inclusive;
- tandem group axle spacing ≤ 2.0 m;
- tridem group axle spacing ≤ 4.0 m;
- long trailer inter-axle spacing > 8.0 m;
- short trailer inter-axle spacing > 3.0 m and ≤ 8.0 m; and
- inter-axle spacing for A and C converter dollies > 2.0 m.

The application of these criteria enables the unique identification of 31 long truck configurations, shown in Figure 9.

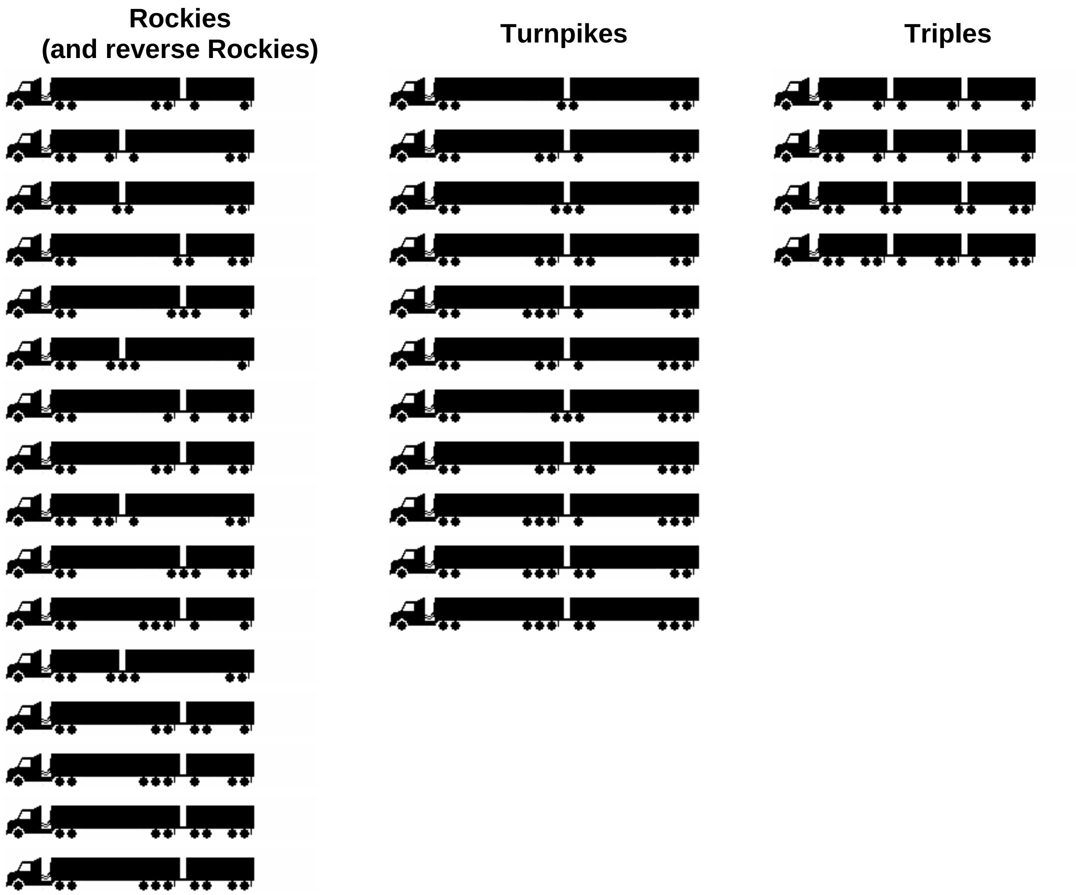


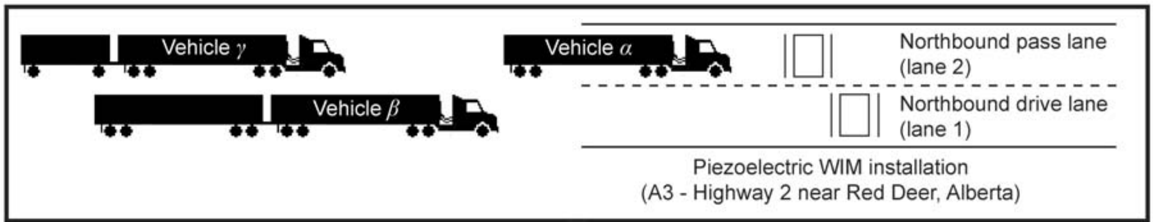
Figure 9: Rocky, Turnpike, and triple configurations identified by the algorithm.

4.2.2. Example Application of the Algorithm

The long truck classification algorithm is illustrated for three raw data records taken from the two northbound lanes of WIM A3 (located on Highway 2 near Red Deer, Alberta) in July of 2005. Figure 10 shows the raw data records generated by the passage of a five-axle tractor semitrailer (vehicle α), a nine-axle Turnpike (vehicle β), and a seven-axle Rocky (vehicle γ). The following steps are conducted to classify these vehicles:

1. The total wheelbase is calculated by summing the axle spacing measurements in each record. These are 18.70, 32.43, and 28.51 m for vehicles α, β, and γ,

respectively. Vehicles *β* and *γ* have wheelbases greater than 24 m, and therefore are considered for further classification.



WIM A3 (Red Deer) raw data records

Vehicle	Date (dd/mm/yy)	Time (hh:mm:ss)	Lane	Speed (km/h)	Wt1 (kg)	Sep1 (m)	Wt2 (kg)	Sep2 (m)	Wt3 (kg)	Sep3 (m)	Wt4 (kg)
α	19/07/05	11:16:19	2	111	5200	4.91	4300	1.41	4700	11.12	4200
β	19/07/05	23:01:56	1	103	4900	3.68	7100	1.29	5200	10.06	6200
γ	20/07/05	08:20:55	2	109	7200	3.96	4600	1.32	4500	11.29	4200

WIM A3 (Red Deer) raw records (cont...)

Sep4 (m)	Wt5 (kg)	Sep5 (m)	Wt6 (kg)	Sep6 (m)	Wt7 (kg)	Sep7 (m)	Wt8 (kg)	Sep8	Wt9	Sep9
1.26	4300	-	-	-	-	-	-	-	-	-
1.24	7300	3.61	6200	1.24	6600	10.07	2700	1.24	2000	-
1.22	4800	4.25	5800	6.47	5200	-	-	-	-	-

Notes: 1. Only data in grey cells are used for vehicle classification
2. *Wt1* is the weight of axle 1, *Wt2* is the weight of axle 2, etc.
3. *Sep1* is the separation between axle 1 and axle 2, *Sep2* is the separation between axle 2 and axle 3, etc.
4. Dash (-) denotes null cell

Figure 10: Generation of raw weigh-in-motion data records from A3 in July 2005.

Source: Adapted from a figure originally published in *Intelligent Transport Systems* by Regehr, Montufar, and Middleton, forthcoming.

2. The number of axles for each vehicle is determined by counting the number of axle spacing measurements recorded and adding one. Vehicle *β* has eight axle spacing measurements (*Sep1*, *Sep2*, *Sep3*, *Sep4*, *Sep5*, *Sep6*, *Sep7*, and *Sep8*) and therefore has nine axles. Vehicle *γ* has seven axles. Both vehicles *β* and *γ* pass the number of axles criterion and are considered for further classification.

3. Each axle spacing measurement is tested against the axle group criteria to determine the presence and location of tandem and tridem axle groups. Vehicle *β* has four tandem axle groups as indicated by *Sep2*, *Sep4*, *Sep6*, and *Sep8*. Vehicle

γ has two tandem axle groups as indicated by *Sep2* and *Sep4*. There are no tridem axle groups present.

4. The remaining axle spacing measurements are tested against the trailer inter-axle spacing criteria to determine the presence of short and long trailers. The first axle spacing (*Sep1*) measures the distance between the front steering axle and the foremost axle of the tractor's drive tandem. This measurement is not required for the algorithm as it does not uniquely distinguish the classification of a vehicle. For vehicle *β*, *Sep3* and *Sep7* indicate the potential presence of long trailers. For vehicle *γ*, *Sep3* indicates the potential presence of a long trailer and *Sep6* indicates the potential presence of a short trailer.

5. The axle spacing arrangement is checked for vehicle connectivity. The previous step indicates that both vehicles *β* and *γ* potentially have two trailers. To verify the presence of these trailers, the algorithm uses the axle spacing measurements to determine the type of connection between the trailers. *Sep5* meets the inter-axle spacing criterion defined for an A or C converter dolly connection for both vehicles *β* and *γ*. Thus, vehicle connectivity is verified.

6. The algorithm classifies vehicle *β* as a nine-axle Turnpike (a tractor with one long semitrailer and one long trailer connected by an A or C converter dolly) and vehicle *γ* as a seven-axle Rocky (a tractor with one long semitrailer and one short trailer connected with an A or C converter dolly).

4.2.3. Algorithm Calibration

The long truck classification algorithm is calibrated to capture long truck configurations operating in the Canadian Prairie Region for the period between 2005 and 2008, inclusive. Thirty-one different long truck configurations have been coded into the algorithm, based on vehicles specifically defined by provincial regulations and field-based observations. Utilization of the classification algorithm outside the region requires further calibration to enable the algorithm to identify different vehicles operating in other jurisdictions. Further, since trucking regulations and technology are constantly evolving to create and permit new vehicle configurations, there may be a need in the future to incorporate these changes in the algorithmic process.

A second aspect of calibration affecting the utility of the classification algorithm involves the level of accuracy of measurements made by WIM or AVC axle sensors. This issue has been addressed by other research and is not dealt with here. There is specific concern with the accuracy of dynamically-collected weight measurements (Dahlin 1992; Gillman 1992; Papagiannakis, Senn, and Huang 1996; Raz et al. 2004)—particularly for enforcement and infrastructure-related applications. Vehicle length measurements made by inductive loops (which measure overall vehicle length by sensing the presence of the passing vehicle) are also prone to inaccuracies. For example, field calibration tests from WIM installations in Manitoba indicate vehicle length measurements from inductive loops with relative errors of up to 10 percent (nearly four metres for a typical Turnpike). The classification algorithm developed in the research, however, relies only on axle spacing measurements made by axle sensors to classify long trucks, without reliance on overall vehicle length readings, built-in classification schemes, or axle weight measurements. Test results from various Canadian Prairie Region WIM installations show centimetre-grade accuracy on axle spacing measurements taken by the axle sensors, independent of the magnitude of the measurement (Fekpe and Clayton 1994).

4.3. METHODOLOGY FOR ASSIGNING EXPOSURE DATA TO NETWORK SEGMENTS

The methodology developed in the research to assign exposure data to network segments involves three components: (1) segmenting the long truck network according to defined principles; (2) establishing a hierarchy for the sources of exposure data; and (3) applying techniques for assigning exposure data to network segments.

4.3.1. Principles of Highway Network Segmentation

The research divides the long truck network into segments on which the exposure—in terms of volume, weight, cube, and related temporal and vehicle classification distributions—of each type of long truck is assumed homogeneous along the segment length. Adjacent segments are connected by nodes, which occur at:

- the intersection of two or more long truck network highways;
- locations where the divided/undivided nature of the highway changes;
- locations where the temporal restrictions on the highway change (e.g., Saskatchewan distinguishes between routes with minor, seasonal, and year round temporal restrictions on long truck operations);

- urban area boundaries; and

- provincial boundaries.

Each long truck segment established by these five criteria is uniquely identified in the database and geographic information system (GIS) environments by the highway number and a three digit segment designation. The first digit in the designation is jurisdiction-specific (numeral "7" in Manitoba, "8" in Saskatchewan, and "9" in Alberta), and precedes a two digit sequential even numbering of segments (i.e., 902, 904, 906, etc. in Alberta). The segmentation topology runs west to east and south to north. The schematic in Figure 11 demonstrates the application of the criteria and the segmentation method. Figure 12 shows the segmented long truck network in the Canadian Prairie Region. Appendix C provides details about each long truck segment in the region.

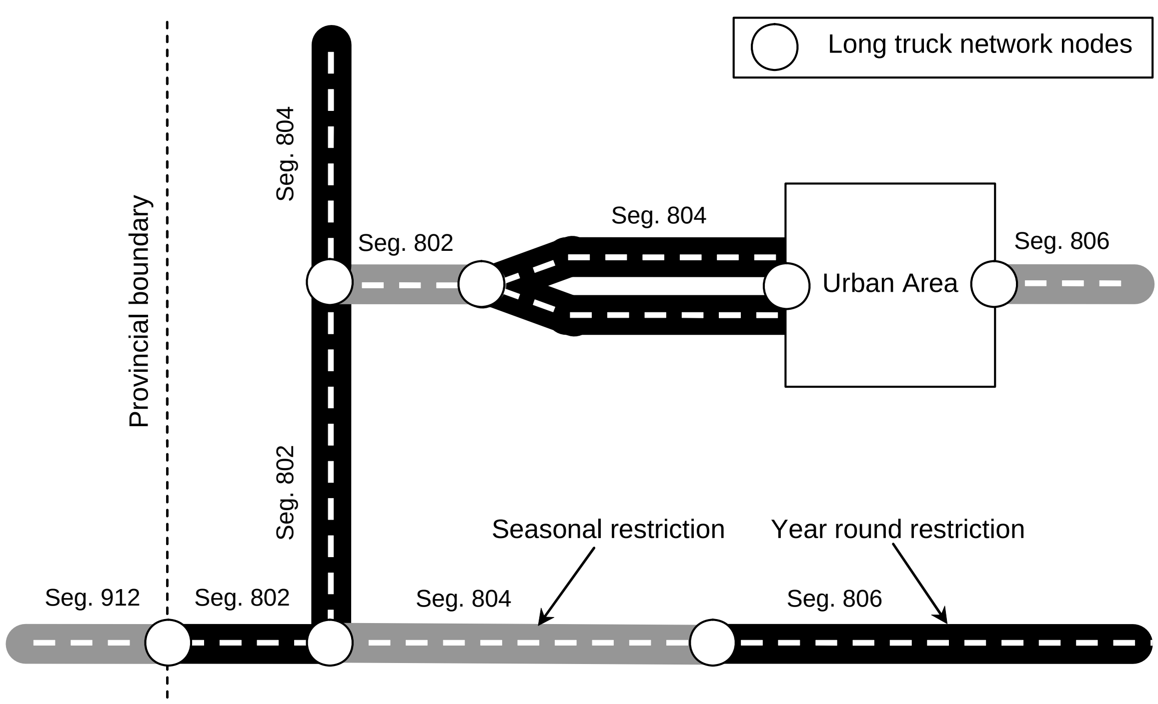


Figure 11: Long truck network segmentation criteria.

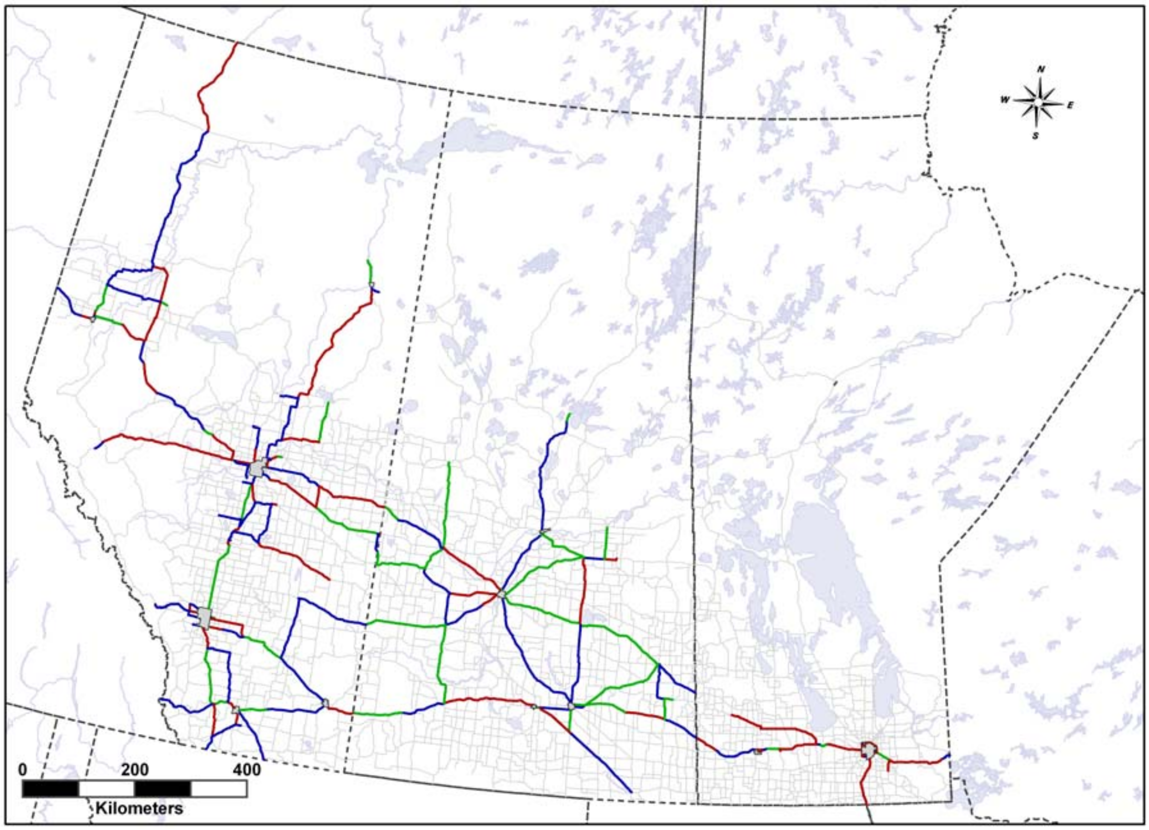


Figure 12: Canadian Prairie Region long truck network segments.

Note: The three colours used in the figure distinguish adjacent long truck segments. Segments with the same colour are not interrelated in any way.

4.3.2. Exposure Data Hierarchy

The development of a hierarchical scheme guides the process of integrating different data sources in two ways. First, it formally ranks different data sources according to their quality, accuracy, and capability to address particular requirements. For example, permanent classification data (i.e., WIMs) are generally ranked higher than data obtained from industry experts or short-duration classification counts. Data hierarchies help the analyst select the data source to use in cases where more than one source are available for a single location or highway segment. Second, it improves transparency in the decision-making process where elements of judgment are present. For example, short-duration classification counts are a commonly used component of truck traffic exposure estimates. Recommended practice for integrating them with permanent count data relies (in part) on expert knowledge and judgment (U.S. DOT 2001). The hierarchical approach recognizes and accepts the subjective nature of these decisions, and the reality that different decisions could be made by different experts or analysts.

The research establishes the following exposure data hierarchy, which ranks long truck exposure data sources from highest to lowest quality:

1. Exposure data from permanent classification counts at WIM stations—derived following processing with the classification algorithm—are ranked at the highest level in the hierarchy.

2. Sample classification data obtained from AVC stations are ranked second in the hierarchy. Long truck exposure data obtained based on the one- to two-week sample are processed using the classification algorithm.

3. Long truck volume estimates provided by industry experts are ranked third in the data hierarchy. Industry experts typically provided average daily volume estimates for Rockies, Turnpikes, and triples for specific long truck segments, or for several adjacent segments linking a major origin-destination pair or connecting two major intersections.

4. Manual classification counts are ranked last in the data hierarchy as they are only representative of a portion of a day, and thus do not capture temporal variations of long truck volume over a full day.

Figure 13 shows the data source used for each long truck segment in the network. Details about the distribution of the data sources used in the model follow:

- WIM data are used to develop long truck exposure estimates for 5000 km (nearly 50 percent) of the 10,300-km network.
- Sample AVC data are used to develop long truck exposure estimates for about 600 km (six percent) of the network.
- Data obtained through industry intelligence are used to develop long truck exposure estimates for 3700 km (36 percent) of the network.
- There are no segments for which manual classification counts are directly used to estimate long truck exposure. These counts, however, provide fleet mix distributions for flow balancing at certain intersections (see Section 4.3.3 for further details).
- Exposure estimates for segments on which long truck data are not available from WIMs, AVCs, industry intelligence, or manual classification counts are developed based on similar highway assignments (see Section 4.3.3 for further details). Total truck traffic volumes are taken from existing data sources (i.e., measurement and estimation programs for each jurisdiction). These data are the basis for the long truck exposure estimates for 900 km (nine percent) of the network.

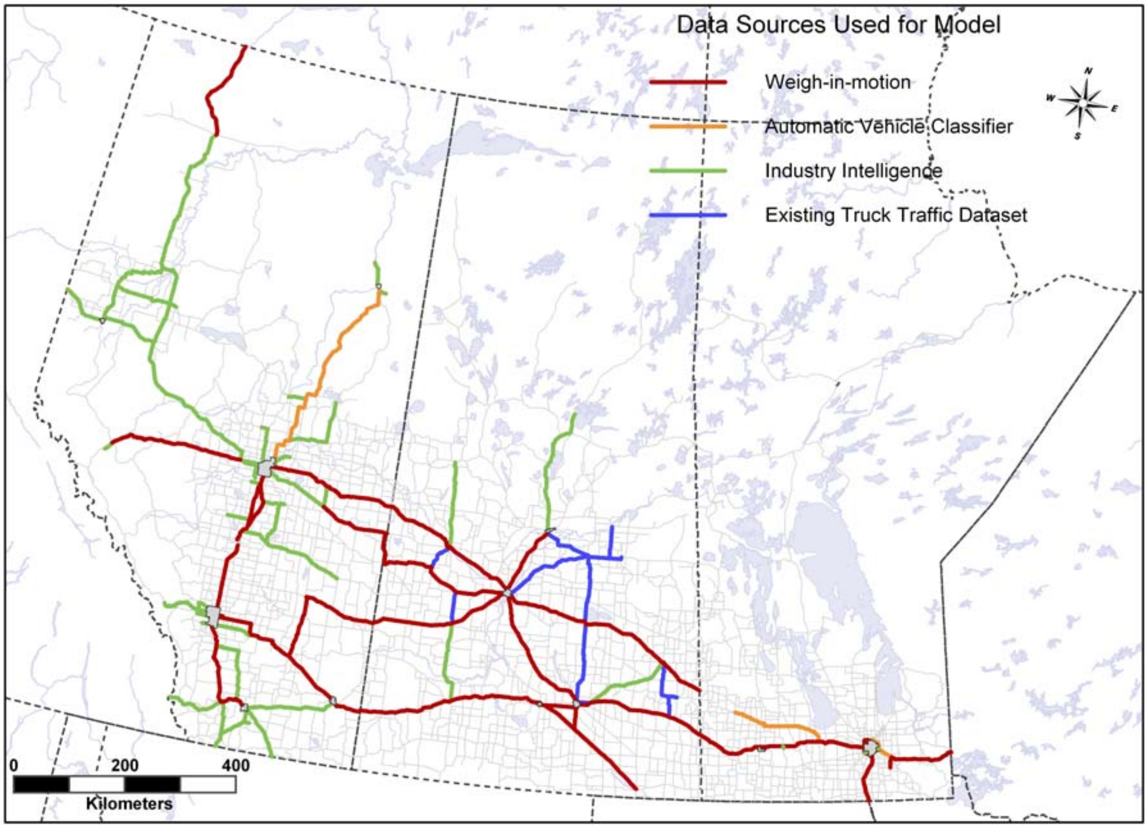


Figure 13: Data sources used for the long truck exposure model.

4.3.3. Techniques for Assigning Exposure Data to Network Segments

Four techniques are used to assign exposure estimates to network segments. These techniques are (after Tang 2003; Regehr, Montufar, and Rempel 2009): (1) direct assignment; (2) transferring; (3) intersection flow balancing; and (4) similar highway assignments.

Direct assignment: Permanent and sample classification counts and data obtained through industry intelligence are assigned directly to the long truck segment on which they are collected. In cases where more than one source of data are available for a single segment, the data hierarchy establishes precedence.

Transferring: Long truck exposure estimates based on direct assignment from WIM or AVC data sources are transferred to adjacent long truck segments on which direct measurements from these sources are not available[16]. The transferring technique extends the utilization of the two most reliable exposure data sources—WIM devices and AVCs. These transfers are made only if no material changes in long truck exposure are expected on the adjacent segments, and in some cases occur across jurisdictional boundaries.

Intersection flow balancing: The research applies intersection flow balancing techniques at intersections where a major origin-destination pattern is identified due to the presence of an urban area or an important regional trucking route. Intersection flow balancing is not applied in cases where the intersection node is an urban area or where one of the intersecting routes experiences fewer than five long trucks per day[17]. The intersection flow balancing technique is illustrated in the schematic diagram shown in Figure 14.

[16] There are two instances where exposure data obtained from industry intelligence are transferred to adjacent segments: (1) estimates of Rocky volumes on Highway 35 in Alberta; and (2) estimates of Turnpike volumes on a 100-kilometre section of Highway 16 northwest of Saskatoon, Saskatchewan.

[17] There are three exceptions to the 'five long trucks per day' criterion: (1) Highway 6 between Highway 39 and Regina, Saskatchewan; (2) Highway 39 between Highway 6 and Moose Jaw, Saskatchewan; and (3) PTH 12 between the Trans Canada Highway and Steinbach, Manitoba.

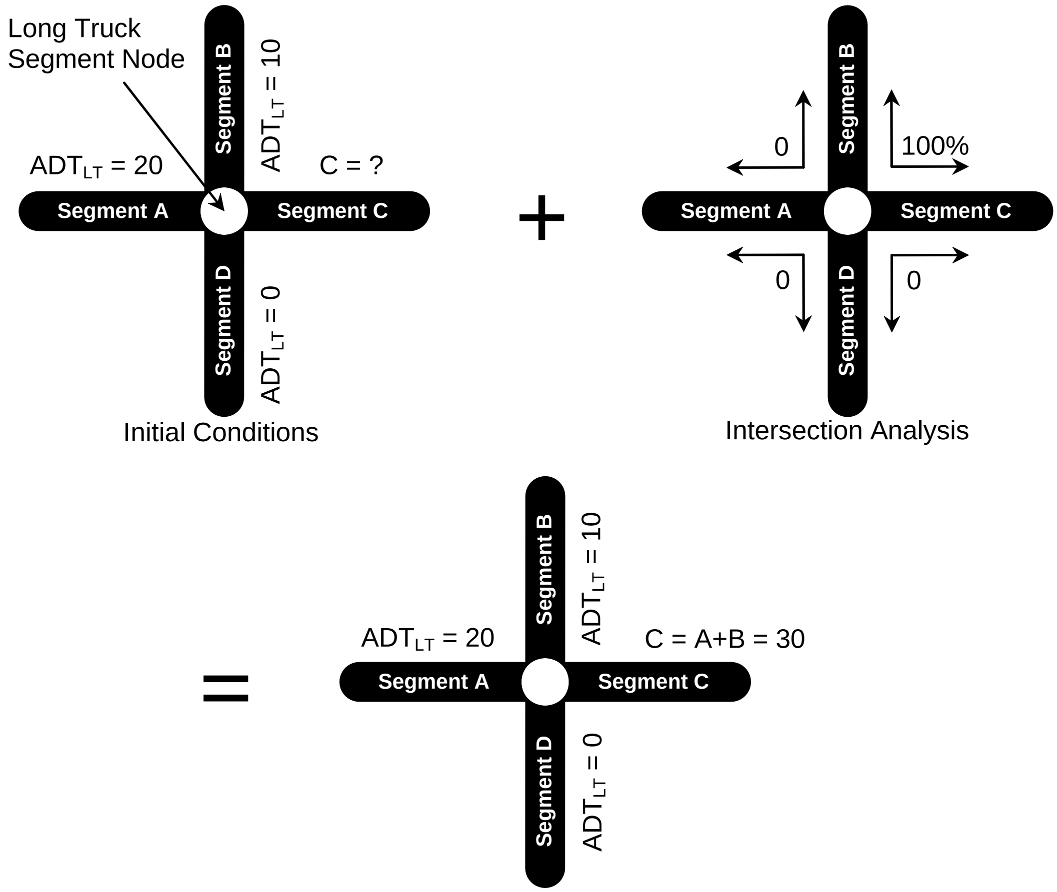


Figure 14: Long truck flow balancing technique at an intersection.

Note: ADT_{LT} is the average daily long truck traffic volume on a segment.

Source: After Tang 2003.

Similar highway assignments: Exposure estimates on segments for which long truck exposure data are not available directly, by transfer, or through flow balancing are developed from similar highway assignments. Highway segments (or groups of segments) on which the truck fleet distribution (including the percentage of Rockies, Turnpikes, and triples in the fleet) has been determined by another assignment technique are designated as control segments. The proportion of estimated long truck volume (by type) to the weighted average[18] of total truck volume for the control segments is multiplied by the weighted average of total truck volume on the target segment. Similar highway assignments are made in conjunction with industry experts and depend on:

- whether the target segment is located on the same highway as the control segments;
- whether the target segment has the same highway type (i.e., divided or undivided) as the control segments;
- the geographic proximity of the control segments to the target segment; and
- the functional similarity of the control and target segments (e.g., both convey east-west or north-south traffic, both function as a connection between two or more prominent long truck routes).

Figure 15 shows the assignment technique used for each of the long truck segments. Details about the distribution of the assignment techniques used in the model follow:

- The direct assignment technique is used for 5900 km (57 percent) of the 10,300-km network.
- Transferring is used for 2800 km (28 percent) of the network.
- Intersection flow balancing is used for about 700 km (six percent) of the network.

[18] The weighted average of total truck volume on a group of segments is calculated by summing the total kilometres of truck travel on those segments and dividing by the sum of the segment lengths.

- Similar highway assignments are used for 900 km (nine percent) of the network.

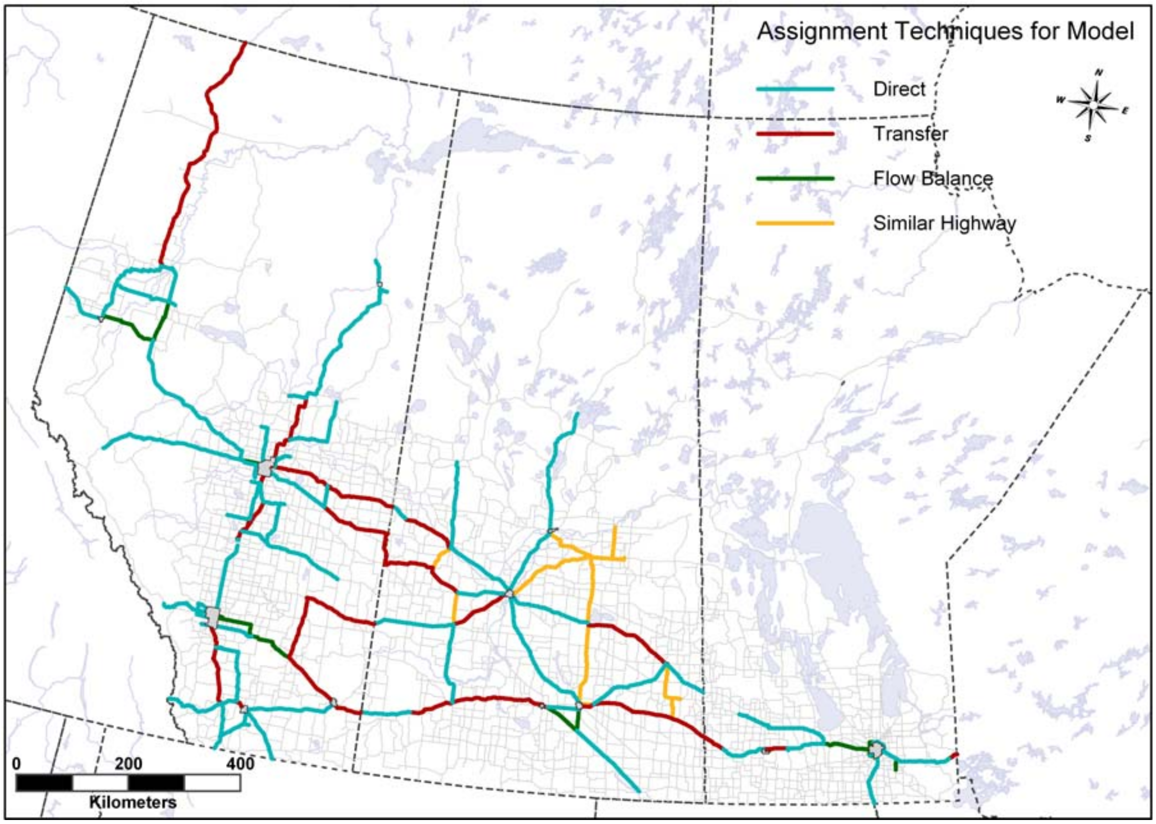


Figure 15: Assignment techniques used for the long truck exposure model.

5. LONG TRUCK EXPOSURE MODEL RESULTS AND VALIDATION

This chapter presents the results of the long truck exposure model in terms of its three principal dimensions, and validates these results by analyzing the model's responsiveness to actual conditions in the long truck transportation system.

5.1. MODEL RESULTS

The results of the long truck exposure model are composed from analyses of traffic data collected between 2003 and 2008, inclusive. WIM data obtained from Manitoba, Saskatchewan, and Alberta are the principal data source used in the model to quantify and characterize long truck exposure. For Manitoba and Alberta, long truck exposure estimates at all the WIM stations on the long truck network are based on 2007 data. At certain locations, recent trends in long truck exposure are revealed by additional analysis of WIM data from 2005, 2006, and 2008. For Saskatchewan, WIM data from 2005, 2006, and 2007 are utilized in the model since a complete set of data from WIM stations on the long truck network is not available for any single year. Consequently, at a regional scale, the model results comprise a blend of WIM data from 2005, 2006, and 2007. Data from sample classification counts and industry intelligence are primarily obtained in 2007. The research, therefore, considers the model results relevant to 2006, which is approximately the midpoint of the data collection time period.

5.1.1. Volume

Long truck volume is presented in terms of: (1) travel by truck type and jurisdiction; (2) temporal variations at selected locations; and (3) spatial variations.

Long truck travel by truck type and jurisdiction

The daily long truck volume shown in Figure 16 comprised an annual total of 67 million kilometres of travel in the Canadian Prairie Region in 2006. Turnpikes travelled slightly more than half (52 percent) of these kilometres, Rockies accounted for 45 percent, and triples accounted for about three percent. The figure demonstrates the inter-provincial nature of long truck travel in the region and the importance of network connections between major urban centres (i.e., Winnipeg, Manitoba; Regina and Saskatoon, Saskatchewan; Calgary, Edmonton, Lethbridge, and Fort McMurray, Alberta). There is little evidence of long truck travel between the region and its neighbouring jurisdictions, principally owing to differences in long truck regulations or the prohibition of long trucks in these jurisdictions. The undivided highway network for Rockies serving smaller population centres and northern areas exhibits relatively low long truck traffic volumes (often less than 10 Rockies per day).

As shown in Figure 17a, the 29 million kilometres of Rocky travel in 2006 was distributed across the full extent of the region's 10,300-km long truck network, with no particular concentration of travel between any origin-destination pair. The one exception to this was the Rocky travel on Highway 63 between Edmonton and Fort McMurray, Alberta (about 40 Rockies per day).

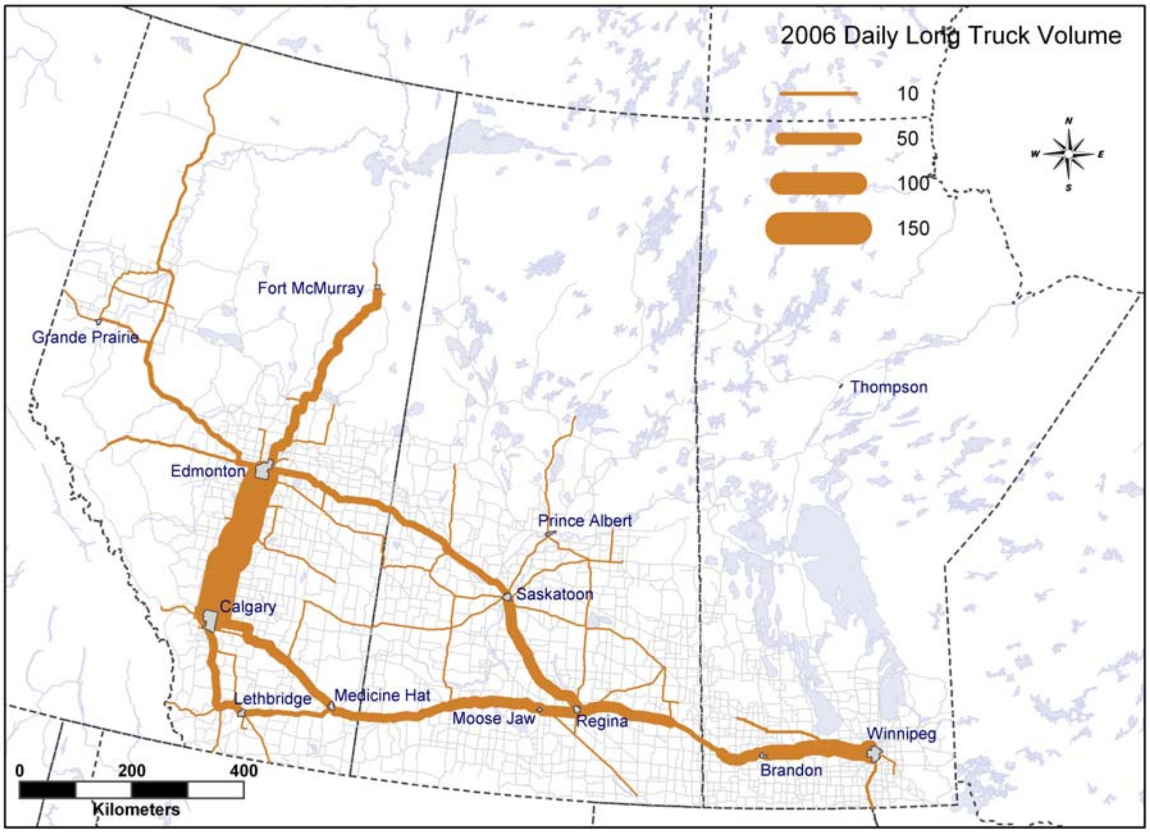


Figure 16: Daily long truck volume in the Canadian Prairie Region in 2006.

By contrast, the 35 million kilometres of Turnpike travel in 2006 shown in Figure 17b occurred on the region's 3800-km network of divided highways. The highest concentration of Turnpike travel (about 140 Turnpikes per day) occurred on segments of Highway 2 between Edmonton and Calgary, Alberta. The gap in Turnpike travel evident on the Trans Canada Highway between Winnipeg, Manitoba and Regina, Saskatchewan reflects the undivided nature of this section in 2007. Turnpikes travelling on this highway were required to split and operate as two tractor semitrailers on the undivided highway section. This section of highway opened for Turnpike travel in 2008.

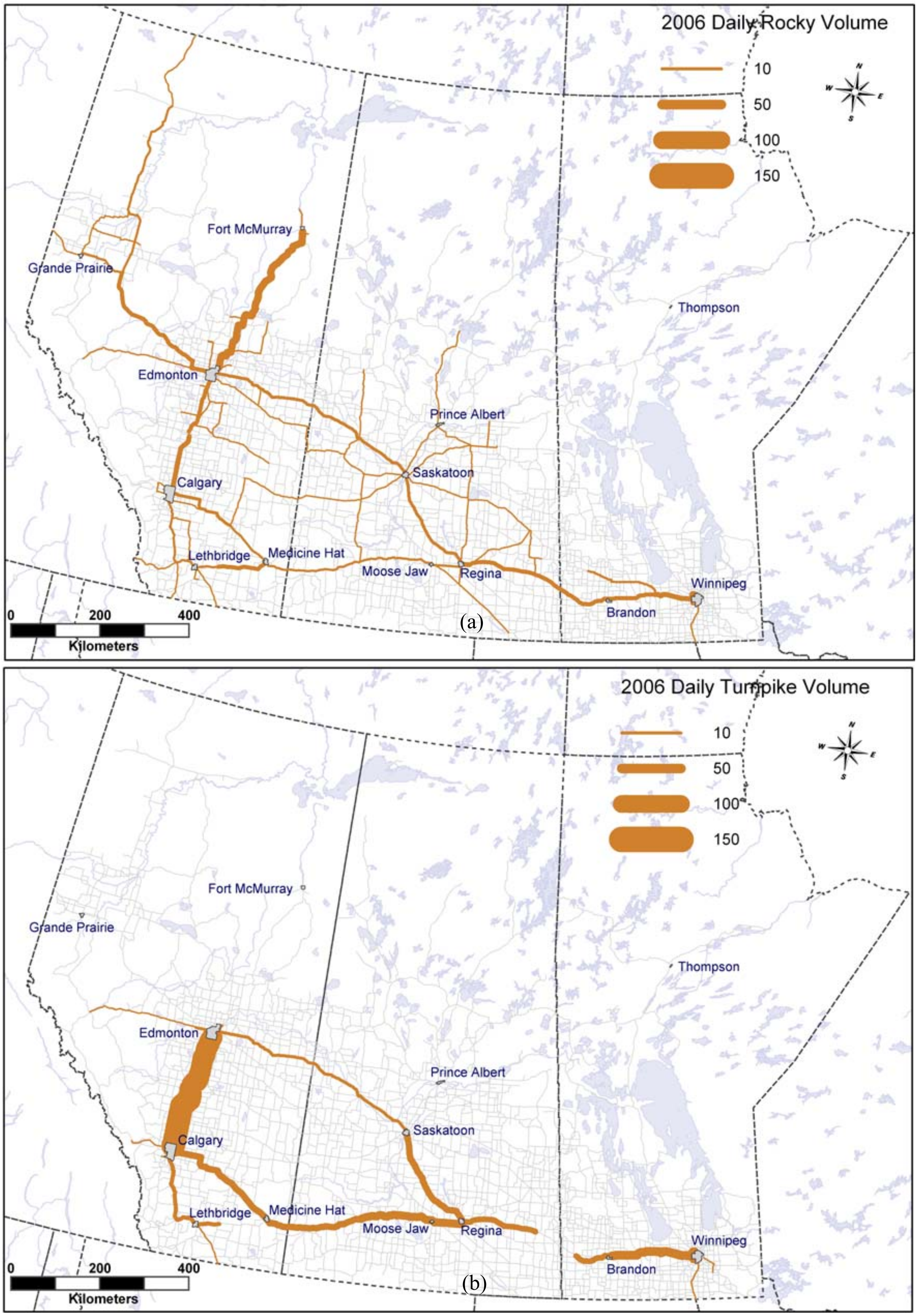


Figure 17: Daily volume of (a) Rockies and (b) Turnpikes in the Canadian Prairie Region in 2006.

Table 5 provides details about the distribution of long truck travel by truck type and jurisdiction in 2006. This distribution is characterized as follows:

- Long trucks travelled a total of eight million kilometres in Manitoba, which represents 12 percent of the regional total. Manitoba is over-represented in terms of the percentage of regional long truck travel on its network (12 percent) relative to its share of regional network centreline-kilometres (nine percent). Rockies accounted for 36 percent of long truck travel in Manitoba, Turnpikes accounted for 60 percent, and triples accounted for three percent.

- Long trucks travelled a total of 19 million kilometres in Saskatchewan, which represents nearly 30 percent of the regional total. Saskatchewan is under-represented in terms of the percentage of regional long truck travel on its network (30 percent) relative to its share of regional network centreline-kilometres (40 percent). Rockies accounted for 40 percent of long truck travel in Saskatchewan, Turnpikes accounted for 60 percent, and triples accounted for less than one percent.

- Long trucks travelled a total of 39 million kilometres in Alberta, which represents nearly 60 percent of the regional total. Alberta is over-represented in terms of the percentage of regional long truck travel on its network (60 percent) relative to its share of regional network centreline-kilometres (51 percent). Rockies and Turnpikes each accounted for 48 percent of long truck travel in Alberta, and triples accounted for four percent.

Table 5: Vehicle-Kilometres of Travel by Long Truck Type and Jurisdiction in 2006

Jurisdiction	Distance travelled (millions of VKT)			Total [a]
	Rockies	Turnpikes	Triples	
Manitoba	3	5	< 1	8
Saskatchewan	8	12	< 1	19
Alberta	19	19	2	39
Total [a]	29	35	2	67

Note: [a] Totals may not exactly equal the sum of individual cells due to rounding.

Temporal variations of long truck volume

Temporal variations of long truck volumes are illustrated at two locations in the region in 2007: (1) WIM M65 in Manitoba, located on the Trans Canada Highway west of Winnipeg; and (2) WIM A3 in Alberta, located near Red Deer on Highway 2 between Calgary and Edmonton. Figure 18 shows daily, weekly, and seasonal variations of long truck volume in 2007 at these locations. Similar analyses of temporal variations are possible at any WIM station with a complete dataset for a given year.

Long truck volume at these locations exhibited the following temporal characteristics in 2007:

- At both M65 and A3, seven of 10 long trucks passed these stations (in both directions) during the combined evening (18:00 to 23:59) and nighttime (00:00 to 05:59) period (71 percent at M65 and 69 percent at A3). The combined morning (06:00 to 11:59) and afternoon (12:00 to 17:59) period accounted for the remaining 30 percent of long truck volume at these stations.

- Nearly 90 percent of long truck volume occurred during weekdays (89 percent at M65 and 85 percent at A3), and the remaining 10 percent occurred on weekends.

Tuesday, Wednesday, and Thursday were over-represented in terms of daily long truck volume throughout the week at both stations.

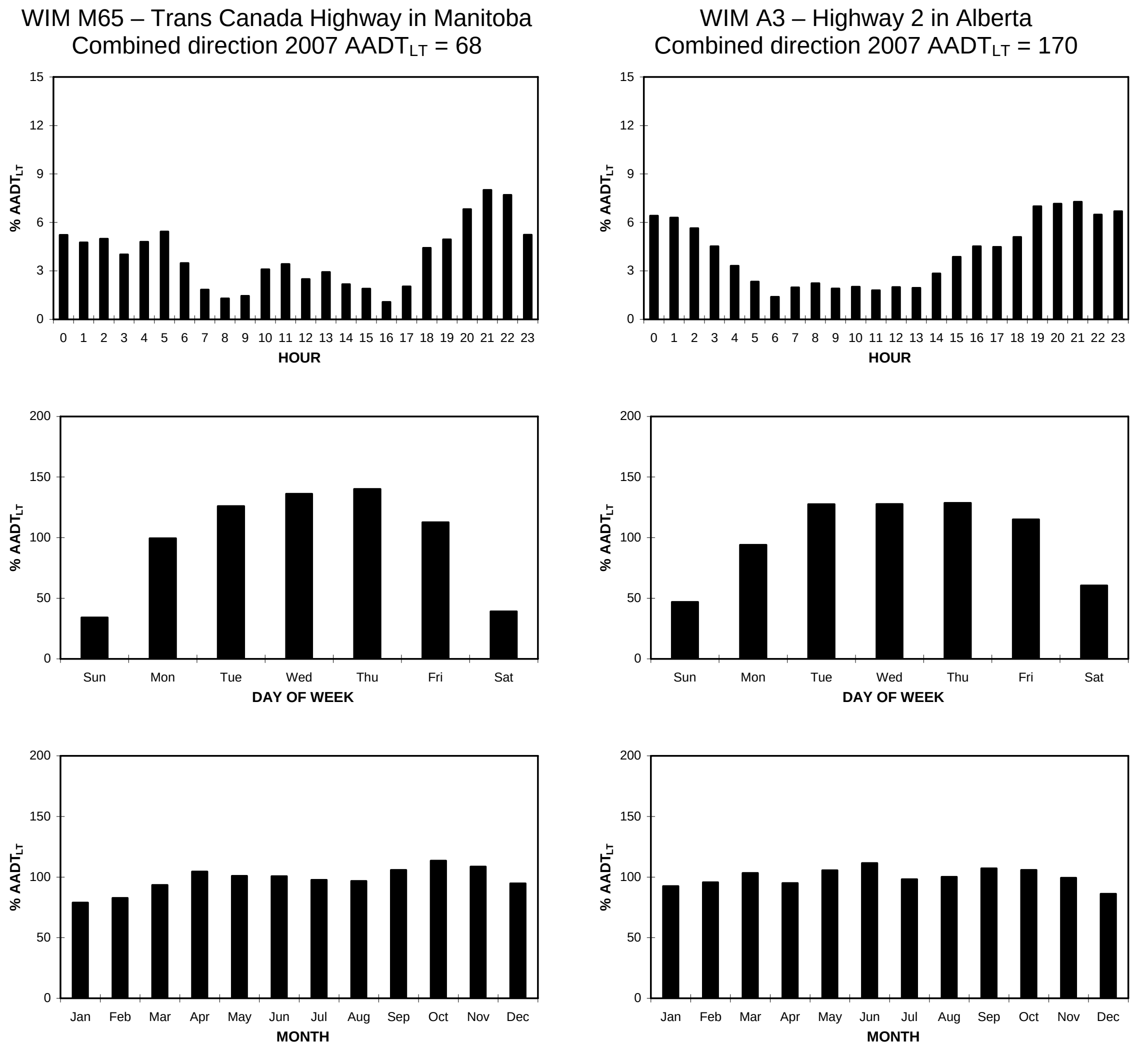


Figure 18: Temporal variations of long truck volume at M65 and A3 in 2007.

Note: AADT$_{LT}$ is the annual average daily long truck volume.

- Minor seasonal variations in long truck volume were evident. Long truck travel was lowest in winter (December, January, February), accounting for 22 percent of total volume at M65 and 23 percent at A3. About one-quarter of long truck volume occurred in each of spring (March, April, May) and summer (June, July, August) at both locations. Fall (September, October, November) accounted for 28 percent of long truck volume at M65 and 26 percent at A3.

Spatial variations of long truck volume

Spatial variations in long truck volume indicate that, on a regional level, long truck travel is disproportionately distributed by highway centreline-kilometre. The model shows that 2800 km of highway (just over one-quarter of the total region's long truck network length) accounted for 51 million VKT in 2006 (over three-quarters of the region's long truck VKT)[19]. Spatial concentration also occurred on a provincial level as illustrated in the following points:

- In Manitoba, PTH 1 (between Winnipeg and the Saskatchewan boundary) represents about one-third of the province's long truck network centreline-kilometres and accounted for 80 percent of its long truck VKT in 2006. This stretch of PTH 1, PTH 100, and PTH 101 together represent less than half of Manitoba's long truck network centreline-kilometres but accounted for nearly 90 percent of the province's long truck VKT.

- In Saskatchewan, Highways 1, 11 (between Regina and Saskatoon), and 16 (between Saskatoon and the Alberta boundary) represent less than 30 percent of the province's long truck network centreline-kilometres and accounted for over 80

[19] The following highways are used in this calculation: (1) in Manitoba, PTH 1 (between Winnipeg and the Saskatchewan boundary), PTH 100, and PTH 101; (2) in Saskatchewan, Highway 1, Highway 11 (between Regina and Saskatoon), and Highway 16 (between Saskatoon and the Alberta boundary); and (3) in Alberta, Highway 1, Highway 2 (between Calgary and Edmonton), Highway 16 (between Edmonton and the Saskatchewan boundary), and Highway 63.

percent of its long truck VKT in 2006. Over half of Saskatchewan's long truck VKT occurred on Highway 1, but it represents less than 20 percent of its long truck network centreline-kilometres.

- In Alberta, Highways 1, 2, 3, 16, and 63 represent 45 percent of the province's long truck network centreline-kilometres and accounted for about 80 percent of its long truck VKT in 2006. About 40 percent of Alberta's long truck VKT occurred on Highway 2 between Calgary and Edmonton, but this stretch of highway represents less than five percent of the province's long truck network centreline-kilometres.

5.1.2. Weight

Weight characteristics of long truck exposure are presented in terms of annual rolling gross weight and its payload and tare weight components. Details about gross vehicle and axle load spectra for long trucks are described in Section 6.3. Five WIMs are used in the analysis[20]: A3, A4, and A6 in Alberta; and M62 and M65 in Manitoba (see Figure 7 in Section 4.1 for the locations of these WIMs). RGW is reported only on segments for which these stations are used to estimate long truck exposure directly and on adjacent segments estimated by transferring these direct estimates. These segments comprise about 900 km of the long truck network. Figure 19 shows the annual long truck rolling gross and payload weights on these segments in 2007. For the selected highway

[20] WIMs A3, A4, and A6 have axle weight sensors in all four travel lanes. WIM M65 has axle weight sensors in the westbound and eastbound drive lanes; long truck travel in the passing lanes is negligible. WIM M62 has axle weight sensors in the westbound drive lane. Rolling gross and payload weights at M62 are calculated by doubling the westbound weights, which assumes that long truck volumes and their weight characteristics are evenly distributed by direction.

segments, rolling payload weight (represented by the width of the light green line) is overlaid onto the RGW (represented by the total width of the dark red line, including the portion covered by the light green line). The tare weight proportion of the RGW is represented by the widths of the dark red lines visible on either side of the rolling payload weight. The widths of these lines are plotted at the same scale.

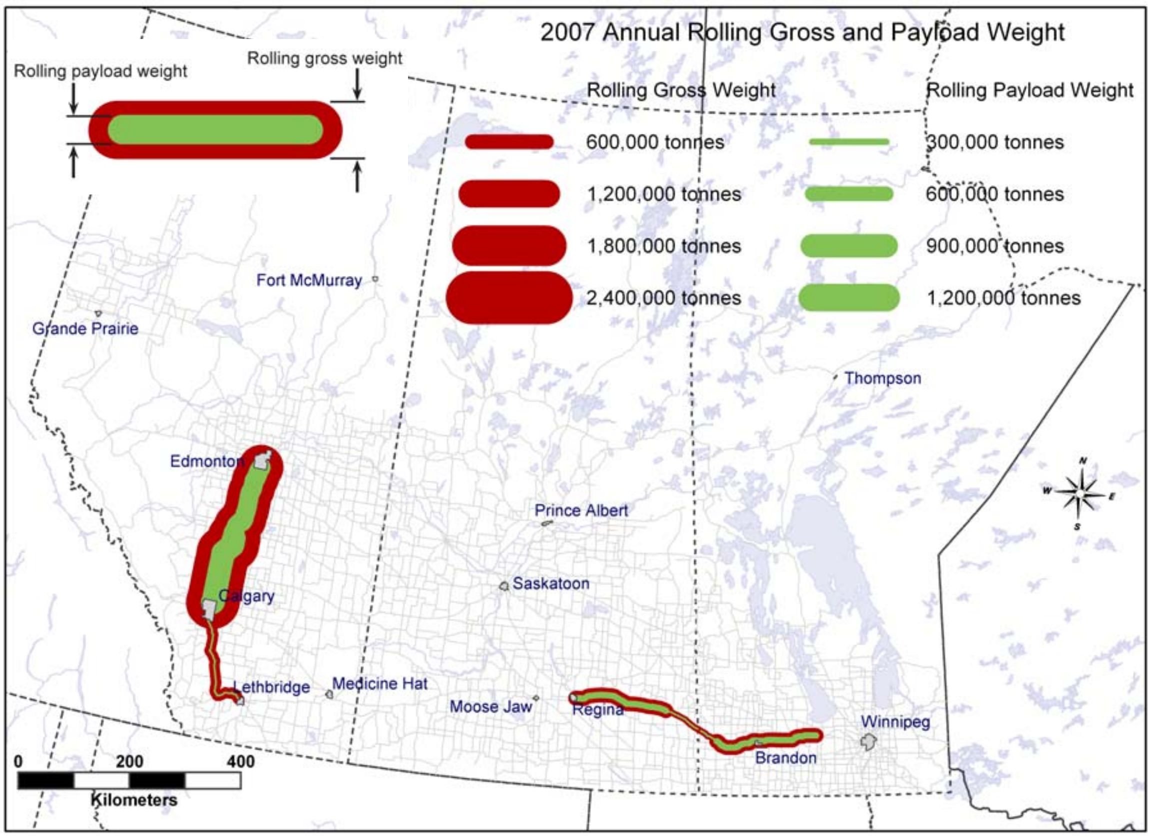


Figure 19: Long truck rolling gross and payload weight on selected Canadian Prairie Region highways in 2007.

Note: The rolling payload weight (represented by the width of the light green line) is overlaid onto the rolling gross weight (represented by the total width of the dark red line, including the portion covered by the light green line). The tare weight proportion of the rolling gross weight is represented by the widths of the dark red lines visible on either side of the rolling payload weight. The widths of these lines are plotted at the same scale (i.e., 1.2 million tonnes of rolling gross weight is plotted at the same width as 1.2 million tonnes of rolling payload weight).

The proportion of RGW attributed to payload weight (for long trucks as a group) at the five WIM stations ranged between about one-third and half (36 percent at WIM M65, 40 percent at WIM A6, 41 percent at WIM A4, 46 percent at WIM A3, and 49 percent at WIM M62). In other words, from a transportation infrastructure design and evaluation perspective, more than half of the total load attributed to long trucks at these locations was tare weight.

Table 6 provides the annual rolling gross and payload weights by long truck type at the five WIM stations in 2007. Observations about long truck weight characteristics are as follows:

- In 2007, Turnpikes accounted for nearly 90 percent of the long truck rolling gross and payload weights at WIMs A3 and A4, about three-quarters of the long truck rolling gross and payload weights at WIM M65, about two-thirds at WIM M62, and about half at WIM A6.

- In 2007, Rockies accounted for about 10 percent of the long truck rolling gross and payload weights at WIMs A3 and A4, about one-quarter of the long truck rolling gross and payload weights at WIM M65, about one-third at WIM M62, and about one-quarter at WIM A6.

- In 2007, triples accounted for less than five percent of the long truck rolling gross and payload weights at WIMs A3 and A4, less than one percent of the long truck rolling gross and payload weights at WIMs M65 and M62, and about one-quarter of the rolling gross and payload weights at WIM A6.

Table 6: Rolling Gross and Payload Weight by Long Truck Type at Selected Weigh-in-Motion Stations in 2007

WIM	Rolling gross weight (thousands of tonnes)				Rolling payload weight (thousands of tonnes)			
	Rockies	Turnpikes	Triples	Total [b]	Rockies	Turnpikes	Triples	Total [b]
A3	250	2170	120	2530	100	1010	50	1160
A4	210	1790	90	2080	70	760	30	860
A6	100	210	100	410	40	90	40	170
M62 [a]	240	460	<10	700	120	220	<10	340
M65	190	600	<10	800	70	210	<10	290

Note: [a] WIM M62 has axle weight sensors in the westbound drive lane. Rolling gross and payload weights at M62 are calculated by doubling the westbound weights, which assumes that long truck volumes and their weight characteristics are evenly distributed by direction.
[b] Totals may not exactly equal the sum of individual cells due to rounding.

5.1.3. Cube

Cubic characteristics of long truck exposure are presented in terms of rolling gross cube by jurisdiction and truck type. Because the RGC indicator is directly proportional to long truck volume and is fixed for each type of long truck, its temporal and spatial variations reflect those described for long truck volume in Section 5.1.1.

The daily long truck RGC shown in Figure 20 comprised an annual total of 1.546 billion CCL-kilometres in the Canadian Prairie Region in 2006. This metric represents the total cubic capacity for payload of long trucks (measured in CCLs) multiplied by the distance they travelled on the network. Turnpikes accounted for nearly 60 percent of these CCL-kilometres, Rockies accounted for nearly 40 percent, and triples accounted for about three percent. Turnpikes were over-represented in terms of the percentage of long truck CCL-kilometres (59 percent) relative to their share of long truck travel (52 percent), as they have the highest cubic capacity (26 CCLs) of the three long truck types. Conversely, Rockies, which have a cubic capacity of 20 CCLs, were under-represented in terms of the percentage of long truck CCL-kilometres (38 percent) relative to their share of long truck travel (45 percent). About three percent of long truck CCL-kilometres and long truck travel were attributed to triples (21 CCLs).

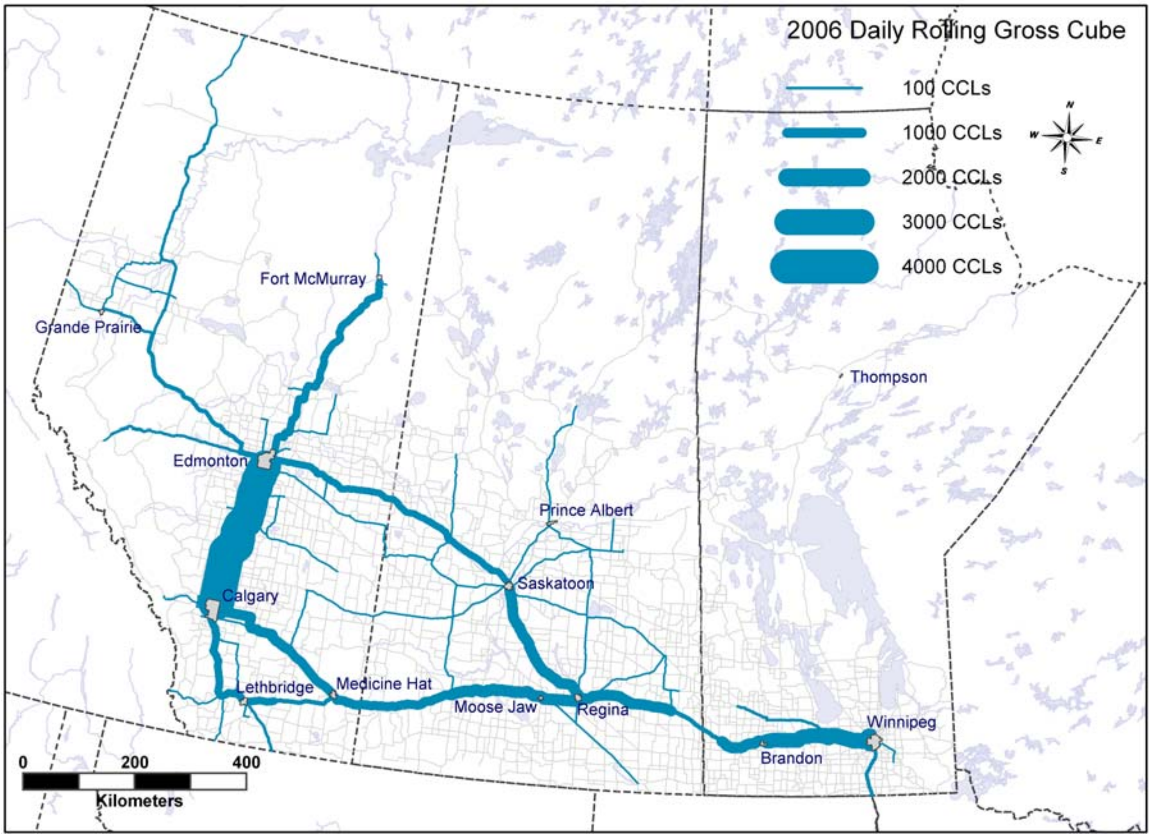


Figure 20: Daily long truck rolling gross cube in the Canadian Prairie Region in 2006.

Table 7 provides details about the distribution of long truck CCL-kilometres truck type and jurisdiction in 2006. This distribution is characterized as follows:

- Long trucks accounted for a total of 195 million CCL-kilometres in Manitoba, which represents 13 percent of the regional total. Rockies accounted for about 30 percent of these CCL-kilometres, Turnpikes accounted for two-thirds, and triples accounted for three percent.

- Long trucks accounted for a total of 456 million CCL-kilometres in Saskatchewan, which represents 30 percent of the regional total. Rockies accounted for one-third of these CCL-kilometres, Turnpikes accounted for two-thirds, and triples accounted for less than one percent.

- Long trucks accounted for a total of 896 million CCL-kilometres in Alberta, which represents 58 percent of the regional total. Rockies accounted for 42 percent of these CCL-kilometres, Turnpikes accounted for 55 percent of these CCL-kilometres, and triples accounted for four percent.

Table 7: Rolling Gross Cube-Kilometres by Long Truck Type and Jurisdiction in 2006

Jurisdiction	**Rolling gross cube-kilometres (millions of CCL-kilometres)**			**Total** [a]
	Rockies	Turnpikes	Triples	
Manitoba	60	129	6	195
Saskatchewan	154	300	2	456
Alberta	374	489	32	896
Total [a]	588	918	40	1546

Note: [a] Totals may not exactly equal the sum of individual cells due to rounding.

5.2. MODEL VALIDATION

5.2.1. Validation Framework

The long truck exposure model is validated by analyzing the engineering reasonableness of its response to actual conditions in the long truck transportation system. The model validation tests aspects of the Type 1 relationship between the transportation system, *T*, and the flow system, *F*, particularly the exposure component of *F* (see Figure 1 in Section 1.3). Model validation normally compares model results with truck traffic data that is independent from the model design and development (Barton-Aschmann Associates, Inc. and Cambridge Systematics, Inc. 1997; NCHRP 2008). However, as the long truck exposure model provides the only publicly-available long truck exposure indicators, there are no other complete, independent data sources with which its results can be compared[21]. Nevertheless, it is possible to validate the model by comparing the model results to expected results given the following actual conditions in *T*:

- the completion of a divided highway connection;
- types of long trucks operating on undivided highways;
- discontinuities within the Canadian Prairie Region long truck undivided highway network;
- the influence of long truck regulations in neighbouring jurisdictions that differ from those within the Canadian Prairie Region; and
- the establishment of staging areas in the long truck highway network.

The research considers the model to be valid for these conditions if it meets one of two validation criteria. First, the model is considered valid if its results confirm the expected *direction of change* in long truck volume by vehicle type given specific transportation system conditions. For example, Turnpike volumes would be expected to increase on a route following the completion of a divided highway connection along the route. Second, the model is considered valid if its results confirm the expected *binary quantity* of long truck volume (i.e., zero long trucks or some long trucks) by vehicle type for certain

[21] Officials from Saskatchewan estimated that long trucks travelled about 23 million kilometres in Saskatchewan in 2007. This estimate is based on carrier-reported data, and is subject to limitations associated with the reporting process. Nevertheless, it compares favourably with the 19 million kilometres of long truck travel estimated by the exposure model developed in the research for 2006.

transportation system conditions. For example, zero Turnpikes would be expected on the undivided highway network, because regulations prohibit their operation on these highways.

5.2.2. Completion of a Divided Highway Connection

Perhaps the most important development in the long truck transportation system in the last five years is the completion of the divided highway network connecting all major urban centres in the Canadian Prairie Region. Two principal divided highway connections were completed in the fall of 2007: (1) the Trans Canada Highway between Winnipeg, Manitoba and Regina, Saskatchewan; and (2) Highway 16 between Saskatoon, Saskatchewan and Edmonton, Alberta.

The validation test examines long truck exposure before and after—in a pragmatic rather than causal sense—the completion of the divided Trans Canada Highway between Winnipeg and Regina. In 2007, prior to the completion of the divided highway, the model results indicate an average daily volume of 68 long trucks (49 Turnpikes per day, 18 Rockies per day, one triple per day). Three results are expected in 2008: (1) the total volume of long trucks would increase; (2) the volume of Turnpikes would increase as carriers take advantage of the ability to operate them non-stop between Winnipeg and Regina, and beyond; and (3) the volume of Rockies would decrease as carriers shift to the more productive Turnpikes.

Figure 21 shows the average daily long truck volume by truck type at WIM M65 between 2005 and 2008, inclusive. The figure shows an annual increase in total long truck volumes in each of the years in this time period. The changes expected between 2007 and 2008—an increase in total long truck volume, an increase in Turnpike volume, and a decrease in Rocky volume—are all confirmed. In 2008 relative to 2007, the average daily long truck volume increased by about one-third (from 68 to 90 trucks per day), the average daily Turnpike volume increased by nearly two-thirds (from 49 to 80 Turnpikes per day), and the average volume of Rockies decreased by 50 percent (from 18 to nine Rockies per day). While these changes cannot be solely attributed to the completion of the divided highway connection, the *direction of the changes* confirm expected results and validate the model.

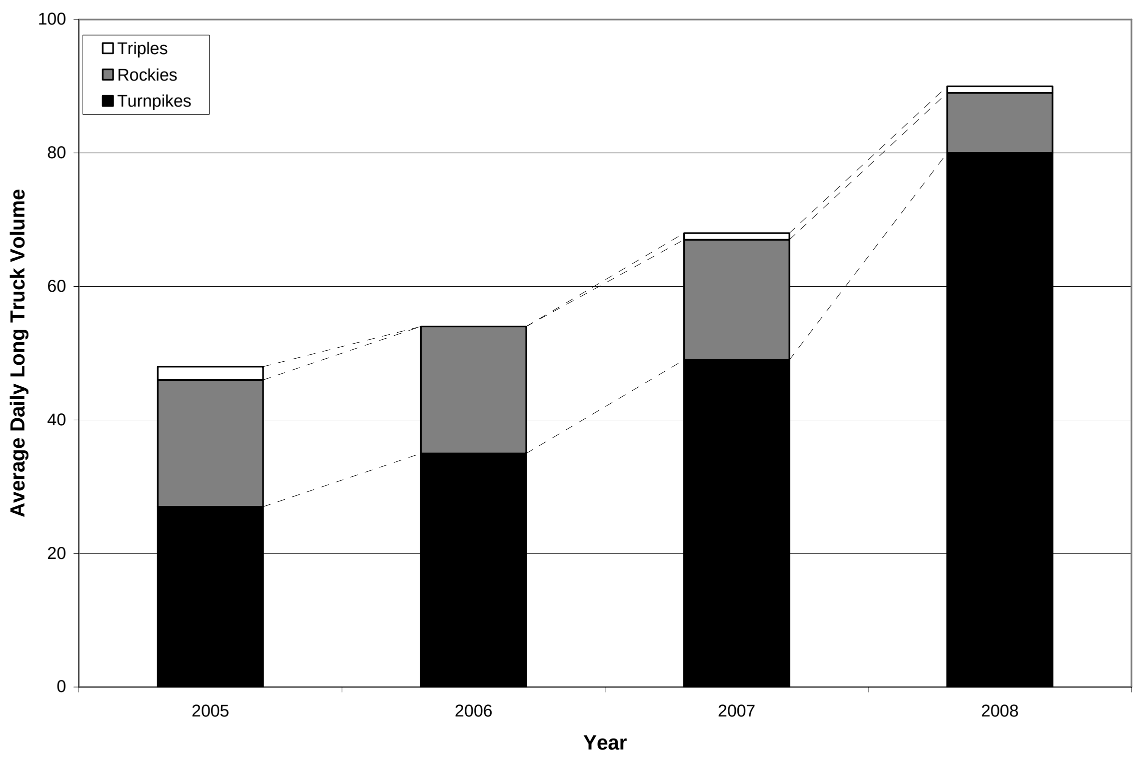


Figure 21: Average daily long truck volume by truck type at M65, 2005-2008.

5.2.3. Types of Long Trucks Operating on Undivided Highways

Regulations governing long trucks in the Canadian Prairie Region specify that, barring a few minor exceptions, Turnpikes and triples are not permitted on undivided highways. Validation tests are conducted at all nine WIM stations located on undivided highways in the long truck network (see Figure 7 in Section 4.1 for the locations of these stations). Notwithstanding occurrences of non-compliance, it is expected that the model results would reflect this regulation and no Turnpikes or triples would be observed on undivided highways.

Table 8 shows the total number of Turnpikes and triples isolated by the classification algorithm at these nine WIM locations and the average daily long truck volume model results. Average volumes are calculated by dividing the number of Turnpikes or triples isolated by the algorithm by the number of days that the WIM operates. Effectively no Turnpikes or triples are observed at these locations, and the average daily volume of Turnpikes and triples estimated by the model is zero. These results confirm expectations and validate the model in terms of the *binary quantity* criterion.

5.2.4. Undivided Highway Network Discontinuities

The most prominent discontinuity in the region's long truck undivided highway network occurs on the Yellowhead Highway (Highway 16) in Manitoba. The network discontinuity occurs because the paved shoulder width does not meet the specified criterion between Shoal Lake, Manitoba and the Saskatchewan border (approximately 90 km).

Table 8: Turnpikes and Triples Observed at Weigh-in-Motion Stations on Undivided Highways

WIM	Location	Days observed [a]	Turnpikes		Triples	
			Number isolated	Daily average	Number isolated	Daily average
Saskatchewan						
S57	Hwy. 16, near Plunkett	93	0	0	0	0
S62	Hwy. 1, near Fleming	270	10	0	2	0
S67	Hwy. 11, near Duck Lake	260	0	0	9	0
S107	Hwy. 7, near Alsask	57	6	0	0	0
S110	Hwy. 16, near Langenburg	247	1	0	2	0
S112	Hwy. 39, near Lang	274	0	0	13	0
S114	Hwy. 14, near Farley	31	0	0	0	0
Alberta						
A5	Hwy. 2A, near Leduc	365	42	0	2	0
Northwest Territories						
N2	Hwy. 3, near Fort Providence	121	0	0	0	0

Note: [a] The number of days observed is the total number of days for which acceptable data is available in the calendar year of data analysis (see Table A.1 in Appendix A).

The validation test examines the model results on the west side of the discontinuity. WIM S110, located just west of the Saskatchewan-Manitoba boundary, is on the Rocky network; however, it is expected that no Rockies would pass this site because of the network discontinuity. The model results confirm these expectations and validate the model in terms of the *binary quantity* criterion, as only 10 Rockies are isolated by the algorithm in the 247 days in which data are available in 2005 (i.e., an average volume of zero Rockies per day or about one per month).

5.2.5. Influence of Regulations in Neighbouring Jurisdictions

Even though the long truck regulatory environment is relatively uniform in the Canadian Prairie Region, in certain cases it is superseded by different regulatory schemes in jurisdictions outside the region (Regehr, Montufar, and Clayton 2009). These cases occur on highways that principally serve truck traffic on major connections between the region and outside jurisdictions. Examples of this type of situation are:

- on PTH 75 in Manitoba, which connects Winnipeg to the U.S. border and on Highway 4 in Alberta, which connects Lethbridge to the U.S. border (long trucks going into/out of the U.S. are governed by U.S. size and weight limits which are generally more restrictive than Canadian regulations);
- on PTH 1 in Manitoba, which connects Winnipeg and Ontario (long trucks are not permitted in Ontario); and
- on Highways 1, 3, 16, and 43, which connect Albertan cities to British Columbia (British Columbia does not allow long trucks on highways connecting to the Alberta network, except for a 40-km portion of Highway 43 where Rockies are permitted).

The model is validated by analyzing data from WIM devices located on two of these connections: (1) the PTH 75 connection between Winnipeg and the U.S.; and (2) the PTH 1 connection between Winnipeg and Ontario. Long truck traffic on PTH 75 has been affected by several regulatory changes in North Dakota since 2005 and operational adjustments made by carriers in response to these changes (see Section 5.2.6 for more details). However, in 2005, the U.S. size and weight regulations were such that only triples were permitted to effectively operate across the international boundary. It is expected, therefore, that only triples would be observed at WIM M63 in 2005. The model confirms this expectation as it estimates a daily volume of zero Rockies, zero

Turnpikes, and four triples. These results validate the model in terms of the *binary quantity* criterion.

On the PTH 1 connection between Winnipeg and Ontario, it is expected that no long trucks would be observed at WIM M61 since Ontario prohibits long truck travel. The model confirms this expectation as it estimates a daily volume of zero Rockies, zero Turnpikes, and zero triples on this route in 2007. This validates the model in terms of the *binary quantity* criterion.

5.2.6. Development of Staging Areas

Certain long truck carriers have developed staging areas at strategic points in the network to make full use of productivity advantages offered by long trucks. A principal example of this is the development of a staging area on PTH 75 near Emerson, Manitoba, north of the Canada-U.S. boundary in the fall of 2007. Figure 22 shows a photograph, as of February 2008, of a Turnpike double assembling from two 16.2-m trailers for northbound travel on PTH 75 in Manitoba. This operational strategy enables the carrier to improve its productivity by either assembling Turnpikes in Canada from trucks operating with single trailers in the U.S., or disassembling Turnpikes into two five-axle tractor semitrailers bound for U.S. destinations.

Figure 22: Staging area for Turnpikes near Emerson, Manitoba.

Photo credit: M. Steindel 2008.

The development of this staging area occurred in response to a change in the way North Dakota enforced truck and trailer length limits for Turnpikes. Prior to the fall of 2007 and beginning in early 2006, Canadian Turnpikes had been allowed to operate on Interstate 29 from Emerson to Fargo, North Dakota at typical Canadian truck and trailer lengths. Current interpretation and enforcement of these limits prohibits this operation (Weiss 2008). Although the maximum allowable GVW limit for Canadian Turnpikes also exceeds the North Dakota GVW limit for trucks with two trailing units (U.S. DOT 2004), this did not affect Turnpike operations since they typically operated at weights below the U.S. limits (Weiss 2008).

The validation test compares the volume of Turnpikes on PTH 75 (as measured by WIM M63) in 2005, prior to the permit of Canadian Turnpike operations to Fargo, North Dakota and the subsequent development of the staging area, to the volume of Turnpikes in 2007, after the staging area was developed. It is expected that the model results would reveal an increase in the volume of Turnpikes operating on this highway. In 2005, the model estimates a volume of zero Turnpikes per day. In 2007, the volume of Turnpikes increased to four vehicles per day. Thus the model results confirm expected results and validate the model in terms of the *direction of change* criterion.

5.2.7. Summary of Model Validation

The long truck exposure model is validated by analyzing (in terms of exposure indicators, *E*) the engineering reasonableness of its response to five transportation system conditions (i.e., conditions of *T*) using either the *direction of change* or *binary quantity* validation criterion. Table 9 summarizes the model validation for the five conditions.

Table 9: Summary of Model Validation for Five Validation Conditions

Validation test	Expected result	Model result	Validation criterion	Model validated?
Condition: Completion of a divided highway connection				
Comparison of 2007 and 2008 volumes at M65	Increase in total long truck volume	One-third increase in long trucks	Direction of change	Yes
	Increase in Turnpike volume	Nearly two-thirds increase in Turnpikes	Direction of change	Yes
	Decrease in Rocky volume	50 percent decrease in Rockies	Direction of change	Yes
Condition: Types of long trucks operating on undivided highways				
Long truck volumes at A5, S57, S62, S67, S107, S109, S110, S112, S114, M62, N2	Zero Turnpikes and triples	Effectively zero Turnpikes and triples	Binary quantity	Yes
Condition: Discontinuities in the undivided highway network				
Long truck volumes at S110	Zero Rockies	Effectively zero Rockies	Binary quantity	Yes
Condition: Influence of regulatory schemes in neighbouring jurisdictions				
Effect of external long truck regulations in the U.S. and Ontario	Only triples on PTH 75 in 2005	Only triples on PTH 75 in 2005	Binary quantity	Yes
	Zero long trucks on PTH 1 from Winnipeg to Ontario	Zero long trucks on PTH 1 from Winnipeg to Ontario	Binary quantity	Yes
Condition: Development of staging area				
Comparison of 2005 and 2007 Turnpike volumes at M63	Increase in Turnpike volume	Increase from 0 to 4 Turnpikes per day	Direction of change	Yes

6. APPLICATION OF THE LONG TRUCK EXPOSURE MODEL

This chapter applies the exposure model to demonstrate its capability to provide indicators of exposure required for: (1) the analysis of options for establishing exposure-based charges for long truck permits; (2) the determination of the safety performance of long trucks relative to other types of articulated trucks; and (3) pavement and bridge design and evaluation through the development of load spectra for long trucks.

For each application, background information outlines the issues facing decision-makers within each application context and the need for exposure indicators to support their decisions. Establishing charges for long truck permits requires indicators of all three principal exposure dimensions—volume, weight, and cube. The particular analysis presented uses these indicators to develop exposure-based indicators of revenue (i.e., a measurable performance indicator as shown in Table 4 in Section 3.2). The safety performance analysis relies on volume indicators, and determines collision rates by long truck type (i.e., a measurable performance indicator). Weight indicators are the principal input for developing long truck load spectra. Development of performance indicators for pavement and bridge design and evaluation is beyond the scope of the research.

6.1. EXPOSURE-BASED CHARGES FOR LONG TRUCK PERMITS

6.1.1. Background

As a corollary of the principally intra-jurisdictional nature of long truck operations until the mid-1990s, each of the three provinces in the Canadian Prairie Region developed long truck permit charging practices independently. However, with expanding opportunities for inter-jurisdictional long truck operations (Nix 1995), standardizing charging methods across jurisdictions becomes more important to shippers, the trucking industry, and government (TRB 2002). Chapter 5 provides evidence of increases in regional long truck volumes, and the inter-jurisdictional nature of long truck trips.

Simultaneously, the revenue generating capability of trucking relative to its share of travel on public highways is declining (TRB 2006), and public agencies are seeking new ways to ensure revenue adequacy and maintain funding for transportation infrastructure. Productivity advantages of long trucks relative to other types of articulated trucks contribute to this decline. The establishment of permit fees for long trucks is one mechanism public agencies use to obtain revenue. The Transportation Research Board's *Special Report 267* recommends the standardization of long truck permitting practices at a regional scale (TRB 2002). There are also opportunities for accessing private funds—through a variety of concession arrangements—to shift the infrastructure funding burden away from the public purse. Privatized truck-only facilities, on which larger and heavier trucks would be permitted to operate subject to a toll or fee, have stimulated investigation in the U.S. (Poole, Jr. and Samuel 2004; Forkenbrock and March 2005).

Despite the current reality, there is no standard method or rationale used in the Canadian Prairie Region for establishing charges for long truck permits. Because of the complex and evolving nature of these issues, the research approaches the subject of charging for long truck permits from a systems analysis perspective. Specifically, the research: (1) analyzes rationales for establishing permit charges for long truck operations on public highways; and (2) presents exposure-based options for harmonizing permit charging methods, analyzes their carrier cost and public revenue implications, and illustrates the sensitivity of costs and revenues to freight density and annual utilization.

6.1.2. Rationales for establishing charges for long truck permits

Two rationales are used to establish charges for long trucks on public highways: cost recovery, and revenue adequacy (Regehr, Montufar, and Clayton, forthcoming).

Cost recovery rationale

In the context of public transportation infrastructure in the U.S., the determination of user charges has traditionally been oriented towards assigning cost responsibilities to different vehicle classes, and ensuring that users pay for the transportation facilities and services that government provides (TRB 1996; U.S. DOT 1997). These charges have then generally been used to fund transportation initiatives through dedicated trust funds (TRB 2006). In Canada, the convention has been to fund public highways through general tax revenues, without specific emphasis on charging users based on their cost responsibility (Nix and Jones 1995). Recent efforts by Transport Canada to determine the full costs of highway transportation, however, signify a potential shift in this emphasis (Applied Research Associates, Inc. 2007).

Permit fees are one component of charges assessed to carriers operating long trucks. In most Canadian and U.S. jurisdictions, these fees are set to recover the costs of administering the permit program (Fekpe, Gopalakrishna, and Woodrooffe 2006).

Certain Canadian provinces charge carriers a fixed annual (or blanket) permit fee, which is independent of the number of tractors or trailers used in long truck combinations by the carrier, and the distance travelled by long truck configurations. For example, the provinces of Alberta and Manitoba charge carriers $300 and $160, respectively, for annual, blanket permits. In Alberta, this amounts to about $40,000 of annual revenue, which is used to cover administrative and engineering costs for conducting safety reviews of highways being used or considered for use by long trucks (Moroz 2008).

Because it is not linked to the extent of system use, the fixed-fee approach does not fully recover costs, as recommended by the Transportation Research Board's *Special Report 267* (2002). This report indicates that user fees "should at least" be set to recover administration and infrastructure costs, with allowance to charge for additional external costs as deemed acceptable (TRB 2002, 10). Several major studies illustrate the need for cost-based charges to be indexed to indicators of exposure (by vehicle class) to ensure full cost recovery. The U.S. Department of Transportation's *1997 Federal Highway Cost Allocation Study* (1997) allocates costs to 20 different vehicle classes (including certain types of long trucks) using estimates of vehicle-miles of travel, equivalent single axle loads (ESALs), and passenger car equivalents (PCEs). Canada's recent investigation of the full costs of transportation allocates road costs to three vehicle classes (cars, trucks, and buses) using these same cost allocators (Applied Research Associates, Inc. 2007). Australia's National Transport Commission similarly allocates costs according to distance travelled, axle weights, and PCEs, but does so for 34 different vehicle classes (including specific types of road trains) (National Transport Commission 2005).

Administrative costs notwithstanding, it is difficult to justify the use of the traditional cost-based rationale for establishing incremental charges for long trucks, which, by regulatory definition in Canada, operate within basic weight limits and provide demonstrated benefits relative to other types of trucks. The following points illustrate this difficulty:

- Because Canadian long trucks deal mainly with cube-out rather than weigh-out freight, there is no incremental basis on which to accrue pavement or bridge costs to their operations. Costs related to infrastructure provision, maintenance, and operation are limited to the costs of adjusting highway geometry to accommodate the performance characteristics of longer vehicles. While some literature indicates these costs to be substantial (U.S. DOT 2000), experiences in Canada suggest that in most cases geometric standards on the designated network are sufficient for long trucks operated by skilled drivers and subject to stringent regulatory oversight (Woodrooffe 2001).

- Societal costs related to safety are a function of the frequency, rate, and severity of collisions. Recent Canadian studies show that long trucks have lower collision rates than other articulated trucks, and that when collisions involving long trucks do occur, the severity outcome is not worse than collisions involving other articulated trucks (Woodrooffe 2001; L-P Tardif & Associates 2006; Regehr, Montufar, and Rempel 2009). Thus, evidence indicates that long trucks provide safety benefits relative to other articulated trucks.

- Long trucks offer environmental benefits relative to other commercial vehicles, and therefore there is no basis on which to charge for incremental environmental costs (Tunnel and Brewster 2005; L-P Tardif & Associates 2006; ATRI 2008).

- Nearly all primary highways in the Canadian Prairie Region are uncongested at nearly all times of the day (i.e., there is no increase in average process time per unit because of demand for service on these highways). In addition, permit conditions restrict long truck operations at times and places subject to congestion (e.g., during rush hours or long weekends near urban centres). Consequently, there is seldom justification to charge long trucks for the costs of congestion.

Revenue adequacy rationale

Because of the challenge of establishing a cost-based rationale for setting permit fees for long trucks, at least one jurisdiction has addressed the issue from the perspective of revenue adequacy—independent of incurred costs. The requirement for obtaining adequate revenues from permit fees is also recommended by the Transportation Research Board (2002). In the mid-1990s, Saskatchewan instituted revenue sharing agreements between the government and carriers that operate long trucks. According to provincial officials, the agreements required benefits (i.e., cost savings) realized by permitted carriers to be shared evenly with the government. Cost savings for long trucks were determined based on their incremental productivity advantage (measured in cargo carrying length) and were a function of the total distance travelled on a specified highway network. Revenues from the agreements were directed at transportation infrastructure improvements recommended by a public-private board of directors (Cooke 2008).

As of the fall of 2008, the program under which these agreements occurred was discontinued. This occurred principally because of the lack of a standardized permit charging practice across the Canadian Prairie Region (i.e., Saskatchewan used a revenue-based approach and Manitoba and Alberta used a fixed-fee approach) and the resulting complexity imposed on the trucking industry. Saskatchewan now uses a fixed-fee approach in which long truck carriers are charged a $2000 annual administration fee in addition to a $300 annual permit fee (Morrison 2009).

6.1.3. Options for exposure-based charging for long truck permits

The research presents four options for establishing exposure-based charges for long truck permits:

- *Option 1 – revenue-based charging*: This option stems from the revenue adequacy rationale. It recognizes the challenge in establishing a cost-based rationale for charging for cube in uncongested conditions and the simultaneous need for government revenue. Three specific cases within this option are analyzed in the subsequent sections: benefit-sharing, revenue neutrality, and full benefit taxation. These cases represent different means of establishing long truck permit charges based on revenues generated by long trucks operating on public highways.

- *Option 2 – cost recovery*: This option follows efforts to charge highway users based on costs incurred by the public agency or by society. As discussed earlier, it is not well-suited for charging vehicles that cube-out rather than weigh-out because there is no apparent incremental cost responsibility for cube-out trucks operating in uncongested conditions. Despite wide-spread adoption of this rationale, there is much debate about whether charges should be set to recover administrative costs, public agency costs, or all social costs (including externalities), and how to establish charges that meet transportation efficiency and equity objectives (TRB 1996). For trucking in the Canadian Prairie Region, this option likely implies increasing charges for conventional classes of trucks to a higher level than those for long trucks.

- *Option 3 – incentive provision*: In this option, which follows neither the revenue adequacy nor cost recovery rationales, external benefits resulting from the operation of long trucks (e.g., related to safety or energy use) are considered worthy of establishing government incentives to encourage carriers to shift to the operation of long trucks. In other words, the government pays carriers incentives to operate long trucks because of the external benefits gained by society at large. This entails negative provincial revenues (if viewed from the traditional transportation agency perspective), and would decrease carrier costs relative to current conditions.

- *Option 4 – privatization*: This option relieves the public sector of the burden of paying for highway infrastructure, but may create an environment in which trucks (including higher productivity vehicles such as Turnpikes) are charged such that the operating authority of a private facility recovers its costs, and makes a profit. Depending on the arrangement, public revenues may be obtained from concession payments. Carrier costs would be a function of the toll structure, which may vary by vehicle type, times of day, and other factors.

Analytical framework and scope

Because of the potential suitability of the revenue-based charging option for establishing permit charges for cubic oriented trucking, the research analyzes three cases within this option—benefit-sharing, revenue neutrality, and full benefit taxation. The research compares each of these cases to a base case to reveal their differences in terms of carrier costs and public revenues attributed to the annual utilization of one Turnpike. Numerical values are provided in terms of: (1) total carrier costs and public revenues; (2) unit costs and revenues per payload cube distance; and (3) unit costs and revenues per payload weight distance. An analysis of carrier costs and public revenues for the remaining three options is beyond the scope of the research.

The analysis is extended by testing the sensitivity of the base case values to freight density and annual utilization, and by illustrating the revenue implications resulting from the total distance travelled by Turnpikes in a given jurisdiction for the benefit-sharing case. In this context, the research considers utilization, which is measured in vehicle distance travelled, as an indicator of exposure in the volume dimension. The summation of all vehicle utilization (for a specific vehicle class, time period, and jurisdiction) is equivalent to the vehicle-distance travelled indicator, which is determined by applying point-based traffic volumes to a highway segment.

Base case definition, parameters, and analysis assumptions

The base case is defined by current operating conditions (as of 2008) in Manitoba for the annual utilization of: (1) one 3-S2, registered at 39,500 kg GVW; (2) two 3-S2s, each registered at 39,500 kg GVW; and (3) one Turnpike double, registered at 62,500 kg GVW. Public revenues and carrier costs associated with these three situations define the base case with which the three revenue-based long truck permit charging cases are compared. The analysis includes revenues from vehicle licensing (which is a function of registered GVW), fuel taxes, and special permit fees. Public revenues and carrier costs associated with 3-S2 operations are constant for all cases, as only the charging mechanism for long trucks is changed in this analysis. Certain base case parameters and assumptions would vary for different jurisdictions, but the essence of the analysis remains the same.

Details about the parameter values and assumptions used in the analysis follow:

- Carrier costs for long-haul operation of 3-S2s are taken from the most recently available truck cost model from Transport Canada (Logistics Solution Builders, Inc. 2005). The model indicates that a 3-S2 with a van body travelling 240,000 km/year in east-west, long-haul movements costs the carrier (in Canadian dollars adjusted for inflation to 2008) $1.61/km. This assumes that the carrier operates with a five percent profit margin (a 95 percent operating ratio). Carrier costs for Turnpike operations are not directly available from recent literature; however, industry experts indicate that carriers that use Turnpikes to replace two 3-S2s reduce their operating costs by approximately one-third. Analyses by Nix (1995) and Jack Faucett Associates—as reported by the Battelle Team (1995)—confirm this heuristic. Therefore, the research assumes that it costs $2.14/km to operate a Turnpike.

- Tractor and trailer licensing fees for a 3-S2 and Turnpike in Manitoba are $2,258 and $4,072, respectively (International Registration Plan, Inc.). These fees contribute to provincial revenue and are included as one of the components in the truck cost model.

- Both the 3-S2s and the Turnpike operate at their cubic and weight capacity.

- Fuel consumption rates for 3-S2s and Turnpikes at their weight capacity are 2.3 km/L and 1.6 km/L, respectively (ATRI 2008).

- The provincial fuel tax rate in Manitoba is $0.115/L. This is representative of the midpoint fuel taxation rate applicable in the Canadian Prairie Region (Department of Finance Canada).

- The annual permit fee for a carrier using long trucks in Manitoba is $160, independent of utilization or the number of long trucks registered. This cost is negligible relative to total costs even if the entire fee is assigned to the operation of one truck for one year, and therefore it is assumed to be included in the operating cost of $2.14/km. The fee is a component of total public revenue.

Figure 23 summarizes the carrier costs and public revenues (in 2008 Canadian dollars) for the three situations which define the base case operating conditions. The operation of one 3-S2 for 240,000 km/year at $1.61/km costs the carrier $385,400. Provincial revenues derived from this operation total $14,300. Nearly 85 percent of this revenue accrues from fuel tax, and the remainder results from the tractor registration fee. If the carrier operates two 3-S2s, both its costs and provincial revenues double. However, if the carrier chooses to operate a Turnpike instead of two 3-S2s, it incurs an annual cost of $513,800, and the province receives $21,500 in revenue, which consists of revenues from fuel tax, the tractor registration fee, and the special permit fee.

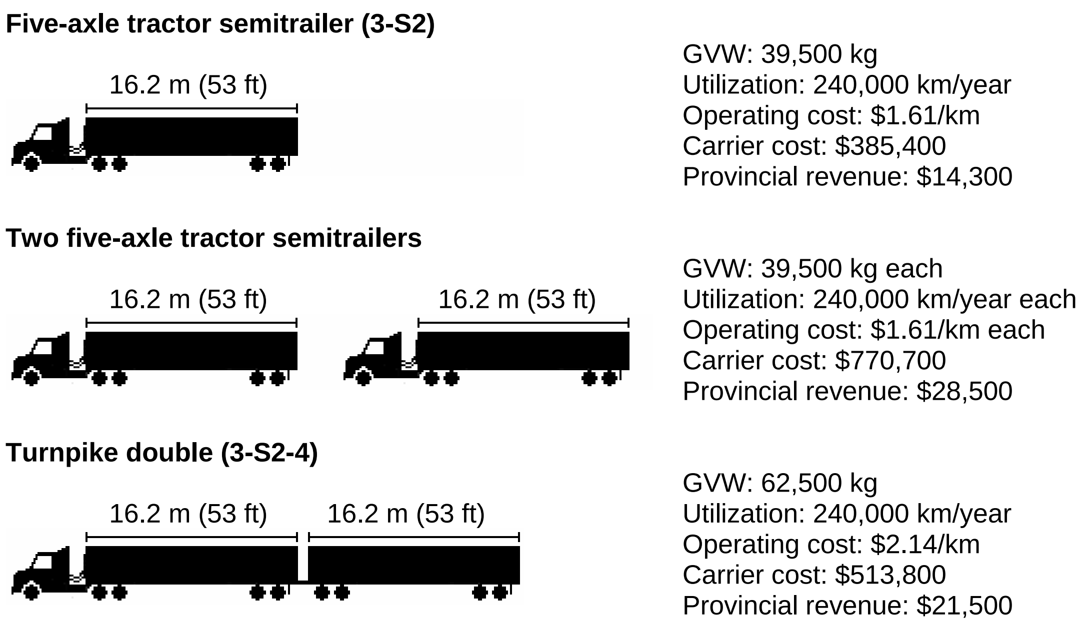


Figure 23: Summary of base case operating conditions in Manitoba as of 2008.

Analysis results

Table 10 provides carrier costs and public revenues for each of the three cases within the revenue-based charging option (benefit-sharing, revenue neutrality, and full benefit taxation). The following points summarize the analysis results:

- *Case A – benefit-sharing*: This case, which is analogous to the method previously used by Saskatchewan, evenly shares the incremental productivity benefits offered by Turnpikes relative to 3-S2s. The public revenue of $128,500 is calculated by taking the difference between the carrier cost of operating two 3-S2s ($770,700) and the cost (less the $160 permit fee) of operating one Turnpike ($513,600), and dividing by two (i.e., fifty-fifty benefit-sharing). The carrier cost of $642,300 is equal to this difference plus the base case cost of $513,800. This results in a six-fold increase in annual public revenues and a 25 percent increase in annual carrier costs relative to the base case. This case represents the approximate midpoint between the base case and full benefit taxation (Case C), and could be varied between these bounds by adjusting the sharing arrangement.

Table 10: Public Revenue and Carrier Costs for a Turnpike at Design Density and 240,000 km Annual Utilization for Cases within the Revenue-Based Charging Option

	Base Case	Case A: Benefit-sharing	Case B: Revenue neutrality	Case C: Full benefit taxation
Annual total ($/year)				
Public revenue	21,500	128,500	28,500	256,900
Carrier costs	513,800	642,300	521,000	770,700
Per cubic payload-km (cents/CCL-km) [a]				
Public revenue	0.3	2.1	0.5	4.1
Carrier costs	8.2	10.3	8.3	12.4
Per weight payload-km (cents/tonne-km)				
Public revenue	0.2	1.3	0.3	2.7
Carrier costs	5.4	6.7	5.5	8.1

Notes: [a] One CCL (cargo-carrying length) equals 1.2-m (4-ft) of cargo-carrying length.

- *Case B – revenue neutrality*: This case ensures that government revenues from registration and fuel taxes are not reduced because of carriers shifting from 3-S2s to Turnpikes. The annual revenue of $28,500 is equal to the amount received from the operation of two 3-S2s, and represents a 30 percent increase in public revenues relative to the base case. For the carrier, the incurred operating cost of $521,000 is less than a two percent increase from the base case.

- *Case C – full benefit taxation*: This case represents the situation in which all cost savings derived from the operation of Turnpikes are returned to the public agency. Consequently, the carrier costs are equal to those that it would incur if they operated two 3-S2s instead of one Turnpike. This results in a 12-fold increase in public revenues, and a 50 percent increase in carrier costs compared to the base case. As none of the savings are realized by the carrier (or shipper), there would be no financial incentive for carriers to operate Turnpikes. This case represents the upper bound that public highway agencies could charge using the revenue adequacy rationale.

Sensitivity analysis and implications of results

This particular sensitivity analysis tests the effect of freight density and annual utilization—both of which are exposure-related parameters—on the base case carrier costs per payload CCL-kilometre and payload tonne-kilometre. Figure 24(a) and Figure 24(b) show the base case costs per payload CCL-kilometre and payload tonne-kilometre, respectively, as a function of freight density for 3-S2s and Turnpikes with annual utilizations of 240,000 km. The figures illustrate three salient points. First, the curves show the cost advantage (in terms of cost per CCL-kilometre or cost per tonne-kilometre) of Turnpikes relative to 3-S2s for hauling low-density freight. The cost advantage diminishes as density increases, and reaches a minimum after both vehicles reach weigh-out conditions. Second, costs per CCL-kilometre increase with freight density. The rate of increase is higher for freight densities above the design densities of the vehicles (260 kg/m^3 for 3-S2s and 210 kg/m^3 for Turnpikes). The vehicles weigh-out at these densities and further increases in density reduce the cubic volume occupied by the payload. This effect may prompt carriers to use vehicles that are designed to haul higher density freight. At densities below design density, costs are less sensitive to changes in density because the vehicles operate under cube-out conditions. Once the vehicle reaches the cube-out condition, further decreases in freight density lead to marginal decreases in costs owing to lower operating GVW and improved fuel economy. Third, costs per tonne-kilometre decrease with freight density, and reach a minimum at the design density. For densities above design density, there is no change in the cost per tonne-kilometre because the vehicle operates under a weigh-out condition. None of these points change given plausible adjustments in the base case parameters or assumptions.

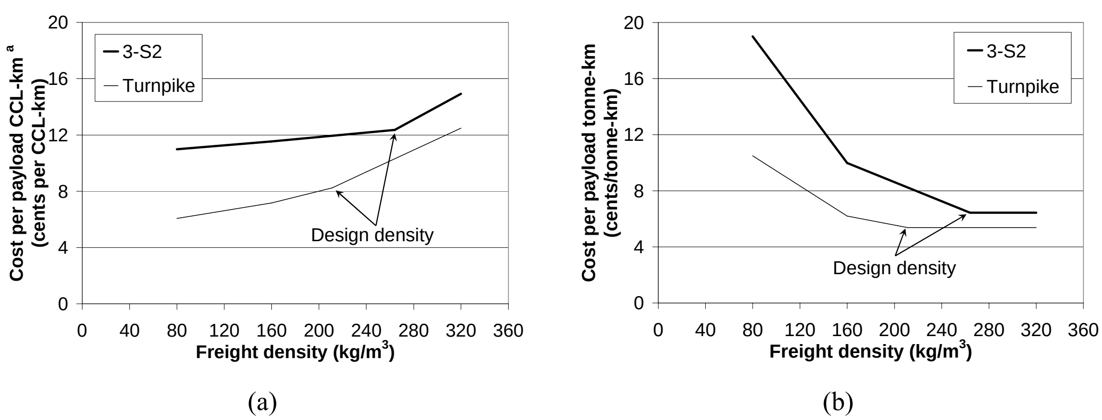


Figure 24: Sensitivity of base case costs to freight density for a five-axle tractor semitrailer and Turnpike with 240,000 km annual utilization in terms of (a) costs per payload cube-kilometre and (b) costs per payload tonne-kilometre.

Note: [a] One CCL (cargo-carrying length) equals 1.2-m (4-ft) of cargo-carrying length.

The base case costs per payload CCL-kilometre and payload tonne-kilometre also vary with annual utilization, decreasing as utilization increases. Cost variations for Turnpikes are examined for annual utilization rates between the base case level of 240,000 km and 320,000 km. This is a typical range for Turnpikes operating in the Canadian Prairie Region. For an annual utilization of about 280,000 km, there is a six percent cost savings for Turnpikes hauling freight at design density relative to the base case. These savings diminish as utilization rises; only a further one percent savings occurs for a utilization of about 320,000 km. Similar sensitivities are evident for 3-S2s, although they are more expensive to operate per payload CCL-kilometre and per payload tonne-kilometre.

Permit charging policies that are insensitive to differences in freight density (i.e., the cube-out or weigh-out condition of a vehicle) have implications on total costs and revenues for the benefit-sharing, revenue neutrality, and full benefit taxation cases. The following serves as a useful illustration. In the benefit-sharing case (Case A), the total public revenue is \$128,500, which consists of fuel tax revenues (about \$17,300), registration fees (about \$4100), and a permit fee component (about \$107,100) derived from the shared benefit of operating Turnpikes relative to two 3-S2s. If the permit fee is assessed on a payload distance basis rather than as a fixed fee (over and above the base case fuel tax and registration charges), the rates required to reach \$128,500 of revenue would be about one cent per tonne-kilometre and about two cents per CCL-kilometre for a Turnpike at design density travelling 240,000 km per year. If this weight-based charge is implemented in a manner that is insensitive to payload density, operations that are charged the same tonnage rate but haul freight with a density less than design density result in a public revenue shortfall. Similarly, if the cube-based charge is implemented in a manner that is insensitive to payload density, operations that are charged this same cubic rate but haul freight with a density higher than design density result in a potential loss in public revenue. This situation is avoided if cube-out operations are charged cube-based rates, and weigh-out operations are charged weight-based rates.

The following scenario illustrates these effects at a jurisdictional scale. As shown in Section 5.1, Turnpikes accounted for 4.97 million kilometres of travel in Manitoba in 2006. If about 95 percent of this travel was cube-out and five percent was weigh-out, and the cube-out and weigh-out travel were subject to charging rates of about two cents per payload CCL-kilometre and one cent per payload tonne-kilometre, respectively, the travel would generate $2.22 million in annual revenue[22]. If only cube-based charges were assessed, the total revenue generated by Turnpike travel in Manitoba would be $2.18 million[23]. This assumes that the weigh-out freight has a density of 320 kg/m^3 (20 lb/ft^3) and occupies 17 CCLs of space. Similarly, if only weight-based charges were assessed and the cube-out freight has a density of 160 kg/m^3 (10 lb/ft^3), the total revenue generated by Turnpike travel in Manitoba would be $1.70 million[24]. Thus, in this scenario, provincial revenue is highest if charges are assessed differentially for cube-out and weigh-out operations.

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[22] Calculated as: (4.97 million km × 0.95 × 26 CCLs × \$0.0172/CCL-km) + (4.97 million km × 0.05 × 39.8 t × \$0.0112/tonne-km) = \$2.22 million

[23] Calculated as: (4.97 million km × 0.95 × 26 CCLs × \$0.0172/CCL-km) + (4.97 million km × 0.05 × 17 CCLs × \$0.0172/CCL-km) = \$2.18 million

[24] Calculated as: (4.97 million km × 0.95 × 30.1 t × \$0.0112/tonne-km) + (4.97 million km × 0.05 × 39.8 t × \$0.0112/tonne-km) = \$1.70 million

6.1.4. Implementation principles

Three principles that will help guide the process of implementing exposure-based permit charges are outlined. First, any perspective on establishing permit charges requires enhanced and refined indicators of truck traffic exposure. Conventional sources of truck traffic exposure data, however, often do not provide appropriate indicators of long truck exposure. This makes it difficult to establish system-wide exposure estimates for these vehicles. The results of the exposure model presented in Chapter 5 address this difficulty for the Canadian Prairie Region. Advances in truck traffic measurement programs and the improved utilization of existing WIM datasets assist in modelling long truck volume and weight characteristics. However, there is a need to develop corresponding indicators of cube—for example, the 1.2-m (4-ft) cargo-carrying length indicator, or some other metric such as the twenty-foot equivalent unit (TEU) used in the container industry. Nix (1995) directly addresses this shortcoming, and indicates that because of their suitability for hauling low-density freight, “tonnage figures are not the best indicators” for understanding market impacts of long trucks. As cubic measurements are difficult to ascertain from standard traffic measurement equipment, exposure data require supplementation with field observations and industry expertise.

Second, the flexibility of charging schemes for truck traffic should reflect differences between cube-out and weigh-out trucking. According to Sonstegaard (1987, 342), “there is a long tradition of adjusting [freight] rates to weight density, or charging by [cube] instead of weight when density drops below a certain level.” Many trucking companies involved in hauling cubic freight charge shippers by the truckload as a function of distance—essentially a cubic metric—rather than by the weight of the shipment. Extending this logic to the establishment of permit fees suggests that charging methods should also be differentially sensitive to cube-out and weigh-out trucking.

Finally, the range of perspectives used to establish charges for long truck operations—or more broadly, the debate about whether they should be charged anything at all—arises from uncertainties in previous research about this and related subjects. Uncertainty exists because system components are constantly changing—roads, vehicles, technologies, operating strategies, shipper demands, government priorities, and public expectations. Despite these uncertainties, however, pragmatic questions remain: should we charge for long multiple trailer truck permits, and if so how and how much? As long as uncertainty persists, there will be an unavoidable element of risk when implementing any of the options presented—or some hybrid thereof. But, as stated by the Transportation Research Board (2002, 3) in a study on the regulation of truck size and weight, "…inevitable uncertainty is not an argument for inaction, since maintaining the status quo would guarantee the loss of important opportunities for reducing the costs of transportation".

6.2. LONG TRUCK SAFETY PERFORMANCE

6.2.1. Background

Previous research about long truck safety relies on two independent lines of evidence: the analysis of safety performance as measured by collision frequency and rates, and the assessment of vehicle handling characteristics. The research is interested in the former.

Studies measuring the safety performance of long trucks show disparate results. Some indicate that long trucks exhibit lower collision rates than other types of trucks (Trialpha Consulting Ltd. 2000; Woodrooffe 2001; L-P Tardif & Associates 2006). Others conclude that long trucks pose a detriment to road safety. These studies cite: (1) the behavioural impacts that long trucks have on other motorists in the traffic stream (Barnett 1995); and (2) poorer fatal crash performance under certain conditions such as darkness, adverse road conditions, higher volumes, and higher speeds (Forkenbrock and Hanley 2003). Craft found that long trucks are no "more or less safe" than other combination trucks (2000, 59). Similarly, Braver et al. concluded that "no overall increase in crash risk was observed among tractors pulling two trailers relative to tractors pulling one trailer", although this result includes regular length double configurations (1997, 90).

In many studies, comparison of collision rates between long trucks and other truck classes is hindered by a lack of reliable and relevant data regarding long truck exposure and the number of collisions involving long trucks (GAO 1992; Nix 1995; U.S. DOT 2000; Forkenbrock and Hanley 2003; U.S. DOT 2004). According to the U.S. DOT (2004, ES-3), there is "considerable uncertainty about the amount of long truck traffic" reported by states in which long truck operations are permitted, because their truck traffic measurement and estimation programs "are not designed to provide statistically reliable estimates of total [long truck] travel." Alternatively, carrier-reported long truck travel statistics, which have been used by some Canadian-based studies (e.g., Nix 1995; Trialpha Consulting Limited 2000; L-P Tardif & Associates 2006), are subject to incomplete sampling of long truck carriers, and errors or uncertainties associated with the reporting process. Several U.S.-based analyses of long truck safety performance rely on collision data obtained through the federal Fatality Analysis Reporting System (FARS) and corresponding details of these collisions provided by the Trucks Involved in Fatal Accidents (TIFA) dataset. This approach, however, does not enable isolation of long truck collisions from other multiple trailer truck collisions (Nix 1995; Forkenbrock and Hanley 2003). More extensive understanding of Canadian experiences with long truck operations and their safety performance is needed (Forkenbrock and Hanley 2003). This need is demonstrated by a National Cooperative Highway Research Program initiative launched in 2006 to document Canadian experiences with truck size and weight issues for the purpose of informing U.S. policy.

6.2.2. Analysis scope and definitions

The research analyzes the safety performance of articulated trucks using collision and vehicle exposure data from the Canadian province of Alberta, for the period between 1999 and 2005, inclusive. The exposure model developed by the research provides the exposure indicators—in terms of vehicle-kilometres of travel by truck type—required for this analysis. The scope of the analysis is defined by: (1) the highway network; (2) the types of articulated trucks used to compare safety performance; and (3) the types of rates used for these comparisons.

Alberta long truck network

The Alberta long truck network is defined in terms of two long truck groups: (1) Turnpikes and triples, and (2) Rockies. Turnpikes and triples are only permitted on multi-lane highways with four or more driving lanes, except for a few short two-lane highway sections. Rockies are permitted on the Turnpike and triple network in addition to a specified network of two-lane undivided highways. Long truck routes through major urban areas are excluded from the analysis.

The Alberta long truck network has expanded several times between 1999 and 2005, with the most significant change occurring in late 2003. To accommodate these changes, two networks are established for analysis. 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 consists of approximately 4500 centreline-kilometres, 40 percent of which permits Turnpikes and triples. The 2004 to 2005 network consists of 5300 centreline-kilometres, 38 percent of which permits Turnpikes and triples.

Articulated truck types

The analysis compares the safety performance of five articulated truck types:

- tractor semitrailer combinations;
- legal-length tractor double trailers (tractor double trailer combinations with a total length less than 25 m);
- Rocky Mountain doubles;
- Turnpike doubles; and
- triple trailer combinations.

Rates used to compare safety performance

Safety performance is defined in terms of collision frequency and collision rate. In using this definition of safety performance, the scope of the analysis is limited to the understanding of truck safety through an analysis of collision involvement, rather than the assessment of collision causation or vehicle handling characteristics.

Rate—a measurable indicator of performance—is a function of traffic exposure. Two types of rate calculations are used: collision rate by vehicle type (i.e., the number of collisions by vehicle type divided by the total exposure of the same vehicle type), and vehicles-in-collisions rate by vehicle type (i.e., the number of vehicles of a given type involved in collisions divided by the total exposure of 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.

6.2.3. Collision data and verification

The collision analysis is based on data from the Alberta Collision Information System (ACIS). The ACIS is a comprehensive collision database maintained by Alberta Infrastructure and Transportation (now Alberta Transportation) using information from collision reports completed by police officers. All reported collisions involving articulated trucks on the rural Alberta long truck network between 1999 and 2005, inclusive, are extracted from the database.

The ACIS database contains information on types of vehicles involved in collisions, but does not differentiate between specific types of double trailer configurations (i.e., legal-length tractor double trailers, Rockies, and Turnpikes). To address this data gap, each long truck operator that was involved in a double trailer collision was contacted to verify the type of double configuration involved in the collision. Collisions involving triples were also verified through communication with trucking companies.

6.2.4. Safety performance of long trucks and other articulated trucks

Collision rates for each articulated truck type over the seven-year period are shown in Table 11. Turnpikes had the lowest collision rate of all truck types at 16 collisions per 100 million VKT. Long trucks as a group had a collision rate of 25 collisions per 100 million VKT and all articulated trucks (including long trucks) had a collision rate of 41 collisions per 100 million VKT. Details about the safety performance of these articulated trucks are provided in terms of collision severity and temporal characteristics of collisions.

Collision severity

Table 12 shows the number of articulated trucks in reported collisions and the vehicles-in-collisions rate on the long truck network by collision severity. Long trucks accounted for about two percent of all articulated trucks in each of fatal, injury, and property damage only (PDO) collisions. In terms of rates, long trucks as a group had about the same vehicles-in-collisions rate as other articulated trucks in fatal collisions. Both

Turnpikes and Rockies had lower vehicles-in-collisions rates than other articulated trucks for injury and PDO collisions.

Table 11: Collision Rate by Truck Type on the Alberta Long Truck Network, 1999-2005

Truck type	Number of collisions [b]	Distance travelled [b] (100 million km)	Collision rate (collisions per 100 million VKT)
Tractor semitrailer	2369	56.50	42
Legal-length double	955	21.59	44
Rocky Mountain double	36	1.12	32
Turnpike double	21	1.31	16
Triple trailer	8	0.13	62
All long trucks [a]	65	2.56	25
All legal-length articulated trucks [a]	3262	78.09	42
All articulated trucks [a]	3322	80.64	41

Note: [a] The total number of collisions is not the sum of all collisions because there are cases where two different truck types are involved in the same collision. Distance totals may not exactly add due to rounding.
[b] These columns provide the total number of collisions and the total distance travelled by truck type for the seven-year time period from 1999 to 2005, inclusive.

Source: Originally published in the *Canadian Journal of Civil Engineering* by Regehr, Montufar, and Rempel 2009.

Table 12: Vehicles-in-Collisions Rate per 100 Million Vehicle-Kilometres of Travel by Severity for the Alberta Long Truck Network, 1999-2005

Truck type	Fatal		Injury		PDO		Total [a]	
	Trucks	Rate	Trucks	Rate	Trucks	Rate	Trucks	Rate
Tractor semitrailer	87	2	715	13	1689	30	2491	44
Legal-length double	50	2	324	15	609	28	983	46
Rocky Mountain double	1	1	7	6	28	25	36	32
Turnpike double	2	2	5	4	14	11	21	16
Triple trailer	0	0	4	31	4	31	8	62
Total	140	2	1055	13	2344	29	3539	44

Note: [a] Rates are calculated by taking the total trucks in collisions by type divided by the total exposure by truck type, and not by adding the fatal, injury, and PDO columns.

Source: Originally published in the *Canadian Journal of Civil Engineering* by Regehr, Montufar, and Rempel 2009.

Long trucks were involved in 36 single-vehicle collisions and 29 multiple-vehicle collisions between 1999 and 2005, inclusive:

- 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.

Temporal characteristics of collisions

An analysis of collisions by season revealed that winter (December, January, and February) accounted for the highest proportion of articulated trucks involved in collisions (33 percent), followed by fall (September, October, and November) at 25 percent. Summer (June, July, August) accounted for the lowest proportion of articulated trucks involved in collisions (20 percent), and spring (March, April, and May) accounted for 22 percent. Winter and spring were over-represented in terms of the proportion of articulated trucks involved in collisions relative to their corresponding traffic volume operating on the network during these seasons. This was also true for long trucks. For example, winter accounted for nearly one-third of long trucks in collisions, but less than one-quarter of long truck traffic. In summer and fall, the proportion of all articulated trucks—and long trucks only—involved in collisions was less than the corresponding proportion of traffic in these seasons.

Long truck collisions exhibited the following seasonal characteristics:

- Nearly one-third (11 of 36) of Rockies were involved in collisions in each of winter and fall. Spring accounted for 28 percent (10 of 36) of Rockies in collisions, and summer accounted for 11 percent (four of 36).

- Turnpikes were involved in six collisions in winter and seven in fall. Spring and summer accounted for the smallest proportion of collisions involving Turnpikes (four of 21 in each season).

- Of the eight triples involved in collisions, winter accounted for three, fall and spring accounted for two each, and summer accounted for one.

A time of day analysis revealed that about 60 percent of tractor semitrailer and legal-length tractor double trailer collisions occurred in the morning (06:00 to 11:59) and afternoon (12:00 to 17:59). By contrast, over 80 percent of long truck collisions occurred in the evening (18:00 to 23:59) and night (00:00 to 05:59). This finding about the frequency of long truck collisions reflects the reality that long truck exposure is relatively concentrated during the evening and night, compared to legal-length articulated truck traffic which is generally characterized by higher levels of activity during the morning and afternoon. Long truck collisions exhibited the following hourly characteristics:

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

- Two-thirds (14 of 21) of Turnpikes were involved in collisions at night. Evening and morning hours accounted for three Turnpikes involved in collisions each. The remaining collision occurred in the afternoon.

- Of the eight triples involved in collisions, evening hours accounted for five and night hours accounted for three.

6.2.5. Sensitivity of results

The collision and vehicles-in-collisions rates presented in the research are developed from all reported collisions and an estimation of all articulated truck exposure over the seven-year period. Calculations are, therefore, based on the population of collisions and exposure, not on samples of this population. As with any exposure-based rate calculation, there is some level of uncertainty involved in the calculation of the rates, principally resulting from the estimation of exposure for each vehicle type. Uncertainty arises because there is no single, comprehensive data source available for articulated truck—and long truck—exposure on the Alberta long truck network. A sensitivity analysis was conducted to test the effect of variations in the exposure estimates by truck type on the collision rate calculations.

Results of the sensitivity analysis are shown in Table 13. This table shows the variations of collision rates given a 10 percent increase and 10 percent decrease in the exposure estimates of each truck type. The sensitivity analysis reveals the following:

- The collision rate for all long trucks with a 10 percent decrease in VKT is lower than the collision rate for all legal-length 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 legal-length articulated trucks increases by 70 percent and the collision rate for all long trucks remains constant; or (2) the VKT for all long trucks decreases by 39 percent and the collision rate for all legal-length articulated trucks remains constant.

- The collision rate for Turnpikes with a 10 percent decrease in VKT is lower than the collision rate for all legal-length 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 legal-length articulated trucks increases by 169 percent and the collision rate for Turnpikes remains constant; or (2) the VKT for Turnpikes decreases by 62 percent and the collision rate for all legal-length articulated trucks remains constant.

Table 13: Sensitivity of Collision Rates to Changes in Vehicle-Kilometres of Travel by Truck Type

Truck type	**Collision rate (collisions per 100 million VKT)**		
	10% decrease in VKT	Calculated rate	10% increase in VKT
Tractor semitrailer	47	42	38
Legal-length double	49	44	40
Rocky Mountain double	36	32	29
Turnpike double	18	16	15
Triple trailer combination	70	62	57
All long trucks	28	25	23
All legal-length articulated trucks	46	42	38
All articulated trucks	46	41	37

Source: Originally published in the *Canadian Journal of Civil Engineering* by Regehr, Montufar, and Rempel 2009.

6.3. LONG TRUCK LOAD SPECTRA FOR PAVEMENTS AND BRIDGES

6.3.1. Background

Measurement, understanding, and prediction of vehicle-infrastructure interactions support decisions about truck regulation, freight productivity, and road wear (Sweatman, Addis, and Mitchell 1995). Ongoing developments in the design and evaluation of pavements and bridges require more refined estimates of truck loading characteristics, which are one aspect of these interactions. Truck traffic databases generated by WIM devices fulfill the truck weight data requirements for mechanistic-empirical pavement design (Lu and Harvey 2006; AASHTO 2008) and the design and evaluation of highway bridges (Miao and Chan 2002; NCHRP 2003) by providing dynamically measured axle weights for each vehicle passage. A dynamically-measured axle weight differs from the weight of that axle measured under static conditions. The accuracy of dynamic axle weight measurements by WIMs depends on appropriate installation and maintenance of WIM hardware, calibration of axle weight sensors, and data processing procedures (Dahlin 1992; Gillman 1992; Papagiannakis, Senn, and Huang 1996; Raz et al. 2004).

The rationale behind mechanistic-empirical pavement design is to combine “a sound basis of good science and engineering” with empirical methods that have a “long record of experience and familiarity” (Haas et al. 2007, 3). The mechanistic component of this approach calculates pavement stresses, strains, and displacements as a function of material properties, layer thicknesses, and vehicle loading conditions—expressed in terms of probability distribution functions of axle weights or axle load spectra. The empirical component relates the stresses, strains, and displacements to pavement damage (Swan et al. 2008). Axle load spectra (defined by Equation 4 in Section 3.3.2) replace the empirically-based load equivalency factors used to determine equivalent single axle loads (ESALs).

The mechanistic-empirical approach requires the following truck traffic exposure data inputs: truck volume, directional and lane distributions, operational speed, temporal volume adjustment factors, truck class distribution, axle loads and distributions, and axle configurations (Li et al. 2007; AASHTO 2008). Because of the extensive truck traffic data requirements of the new design approach and the cost and complexity associated with collecting these data, default values are presented in the *Mechanistic-Empirical Pavement Design Guide* (AASHTO 2008). Recent research efforts have begun to confront this issue, for example, by deriving axle load spectra from gross vehicle weight and truck volume data (which are more readily available than axle weight data) (Haider and Harichandran 2007) and by establishing region-specific truck traffic data inputs (Swan et al. 2008).

Although the nomenclature differs, the concept of representing (live) vehicle and axle loads as distributions or spectra is evident in the use of probabilistic procedures to determine bridge reliability and safety (Nowak and Szerszen 1998; Ghosn 2000). Elements of truck exposure that affect the deterioration of highway bridge structures are: GVW, axle weight, axle configuration (which is related to vehicle length), and truck volume (as it relates to the presence of multiple vehicles on the bridge and bridge fatigue) (Khaleel and Itani 1993; Laman and Nowak 1995; NCHRP 2003). These characteristics are also intrinsic to specifications of U.S. Federal Bridge Formula B, the Ontario Bridge Formula, and other formulae used to control truck size and weight for bridges (Nowak and Szerszen 1998; Ghosn 2000; NCHRP 2006; NCHRP 2007).

In Canada, long trucks operate under the same GVW and axle limits as other trucks, and therefore do not (obviously) contribute incrementally to pavement or bridge deterioration beyond the effects expected from trucks operating under basic weight restrictions. In the U.S., however, there is particular concern associated with the effect of U.S. LCVs (which include Rockies, Turnpikes, and triples with similar size and weight characteristics as Canadian long trucks) on pavements and bridges because they operate at higher GVWs than trucks subject to basic size and weight laws. Major studies have been directed at this issue (e.g., Maring 1986; TRB 1990; GAO 1994; U.S. DOT 2000; U.S. DOT 2004), and their results indicate that U.S. LCVs generally do not increase pavement wear because more axles are used to carry the load, but they may exceed the safe load capacity of certain bridges.

6.3.2. Source data

ALS are developed from a full year of weight data collected in 2007 at WIM M65, located on the Trans Canada Highway near MacGregor, Manitoba, approximately 110 km west of Winnipeg. Piezoelectric axle weight sensors are installed in the westbound and eastbound drive lanes. AVCs are used to classify vehicles in the passing lanes, but no weight data are available for these lanes. Manitoba Infrastructure and Transportation has calibrated the WIM device regularly over the past several years for axle weights, axle spacing, vehicle length, and speed (Lobban 2009). According to manufacturer specifications, properly installed and calibrated piezoelectric sensors provide GVW measurements that are within 15 percent of actual (static) truck weights 19 times out of 20 (International Road Dynamics, Inc. 2001).

6.3.3. Dynamic load spectra for long trucks

Representative gross vehicle load spectra

Figure 25 shows directional representative gross vehicle load spectra, expressed as cumulative distributions, for Rockies and Turnpikes at WIM M65 in 2007. The number of triples observed at this location is too small for meaningful analysis. Observations about the dynamic gross vehicle load spectra for Rockies and Turnpikes follow:

- The spectra reveal that both Rockies and Turnpikes operate at GVWs across the available GVW range (bounded at the minimum by their tare weights and at the maximum by the GVW limits). Neither the Rocky nor Turnpike spectra exhibit peaks distinguishing empty from loaded vehicles.

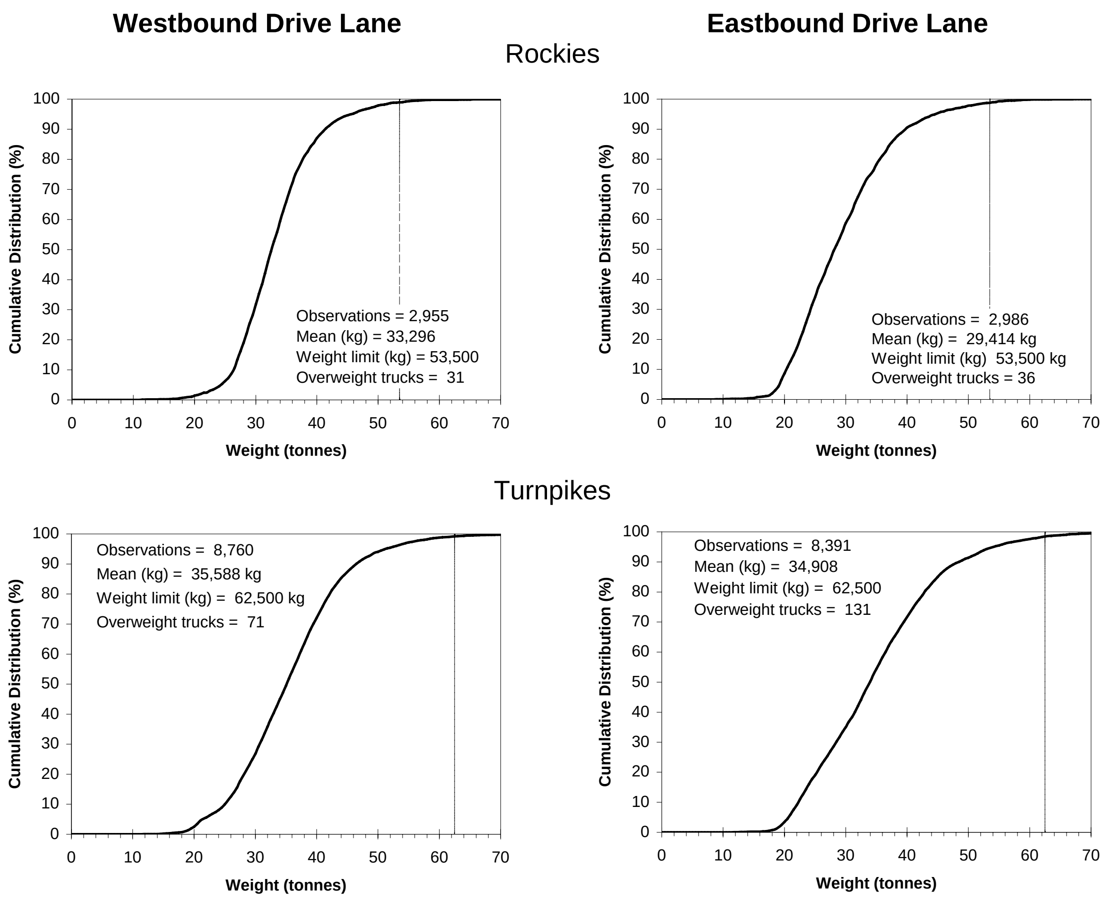

Figure 25: Dynamic representative gross vehicle load spectra for Rockies and Turnpikes by direction at M65 in 2007.

- On average, westbound Rockies are heavier than eastbound Rockies (mean of 33,300 kg compared to 29,400 kg). There is no substantial difference between the mean GVW of westbound and eastbound Turnpikes at this location (means of 35,600 kg and 34,900 kg for westbound and eastbound Turnpikes, respectively).

- Despite having a GVW limit of 53,500 kg[25], nearly nine of 10 Rockies (in either direction) operate at GVWs less than the 39,500-kg GVW limit for 3-S2s. Similarly, about seven of 10 Turnpikes (in either direction) operate at GVWs less than the GVW limit for 3-S2s, despite being subject to a 62,500-kg limit.

- Based on the dynamic weight measurements, about one percent (67 of 5941) of Rockies in both directions exceed the GVW limit of 53,500 kg. Similarly, less than one percent (71 of 8760) of westbound Turnpikes and about 1.5 percent (131 of 8391) of eastbound Turnpikes exceed the GVW limit of 62,500 kg.

Representative axle load spectra

Figure 26 and Figure 27 show representative axle load spectra by direction for Rockies and Turnpikes at WIM M65 in 2007. The spectra are expressed here as cumulative distributions and in tabular form in Appendix D. The spectra comprise the dynamically measured loads of the Rocky and Turnpike configurations uniquely isolated by the classification algorithm (see Figure 9 in Section 4.2.1). A total of 5,941 Rockies and 17,151 Turnpikes were observed at this location in 2007.

The spectra in Figure 26 reveal the following about the weight characteristics of Rockies:

- There are essentially no directional differences in mean axle loads for steering axles (4200 kg for westbound and eastbound Rockies) and tridems (10,700 kg and 10,800 kg for westbound and eastbound Rockies, respectively). Mean loads for

[25] The GVW limit in Manitoba for Rockies with B connections is 62,500 kg. However, most Rockies are subject to a GVW limit of 53,500 kg since they operate with A converter dollies.

westbound single axles and tandems are higher than eastbound loads for these groups (4500 kg compared to 3800 kg for single axles and 9400 kg compared to 8200 kg for tandems).

- There are no substantial directional differences between the median weights of westbound and eastbound steering axles (about 4000 kg) and tridems (10,500 kg and 10,000 kg for westbound and eastbound tridems, respectively). The median weights for westbound single axles (4500 kg) and tandems (9000 kg) are higher than eastbound median weights for these axle groups (3500 kg for single axles and 7500 kg for tandems).

- Of the four axle groups, steering axles exhibit the highest percentage of overweight (dynamic) observations—2.4 percent (72 of 2955) for westbound steering axles and 6.7 percent (199 of 2986) for eastbound steering axles. The percentage of overweight (dynamic) observations for all other axle groups (in either direction) does not exceed one percent.

The spectra in Figure 27 reveal the following about the weight characteristics of Turnpikes:

- There are essentially no directional differences in mean axle loads for steering axles (about 4400 kg), tandems (about 7900 kg), and tridems (about 11,700 kg). The mean of westbound single axle loads (4700 kg) is higher than the mean of eastbound single axle loads (3600 kg).

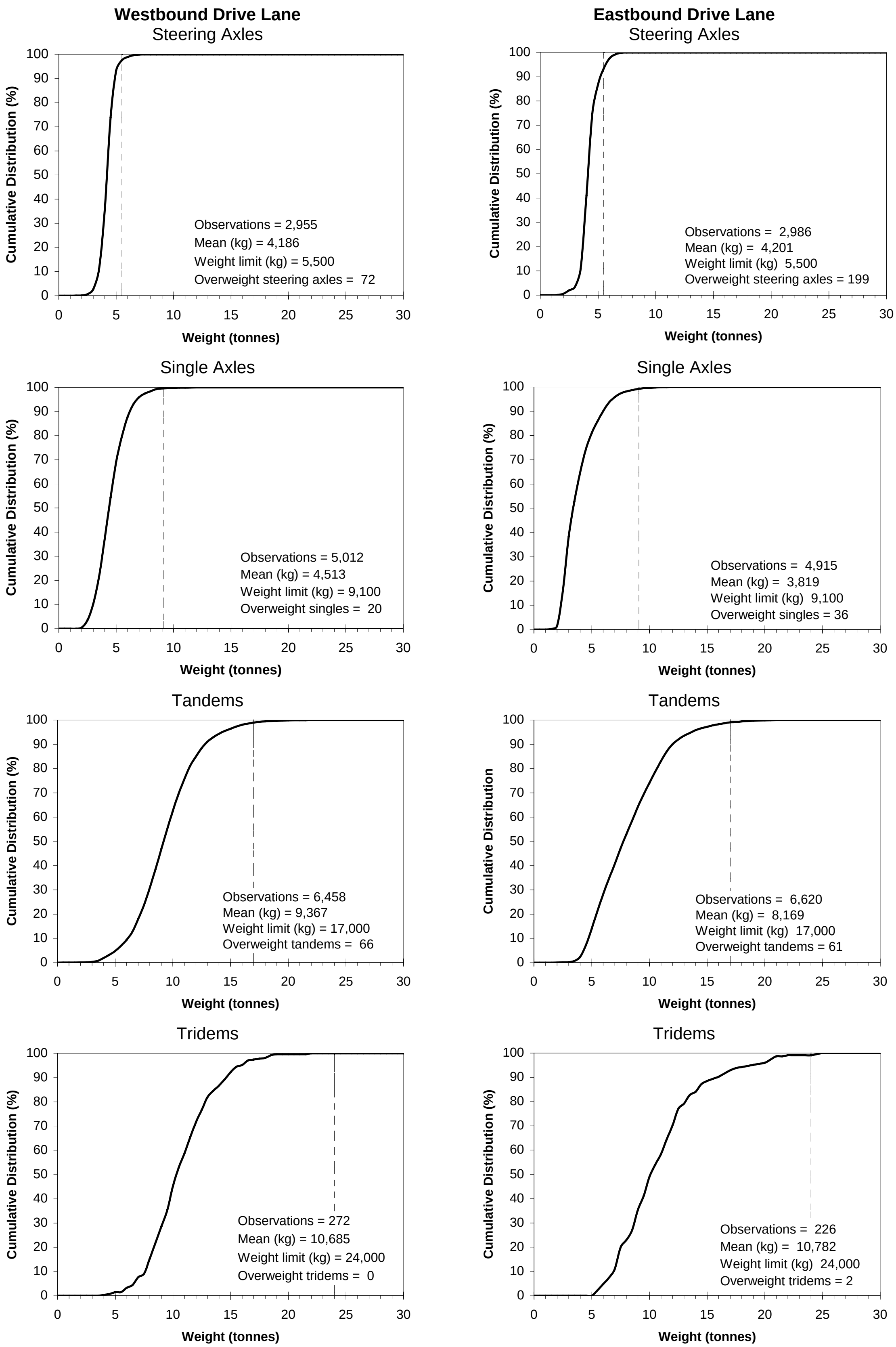

Figure 26: Dynamic representative axle load spectra for Rockies at M65 in 2007.

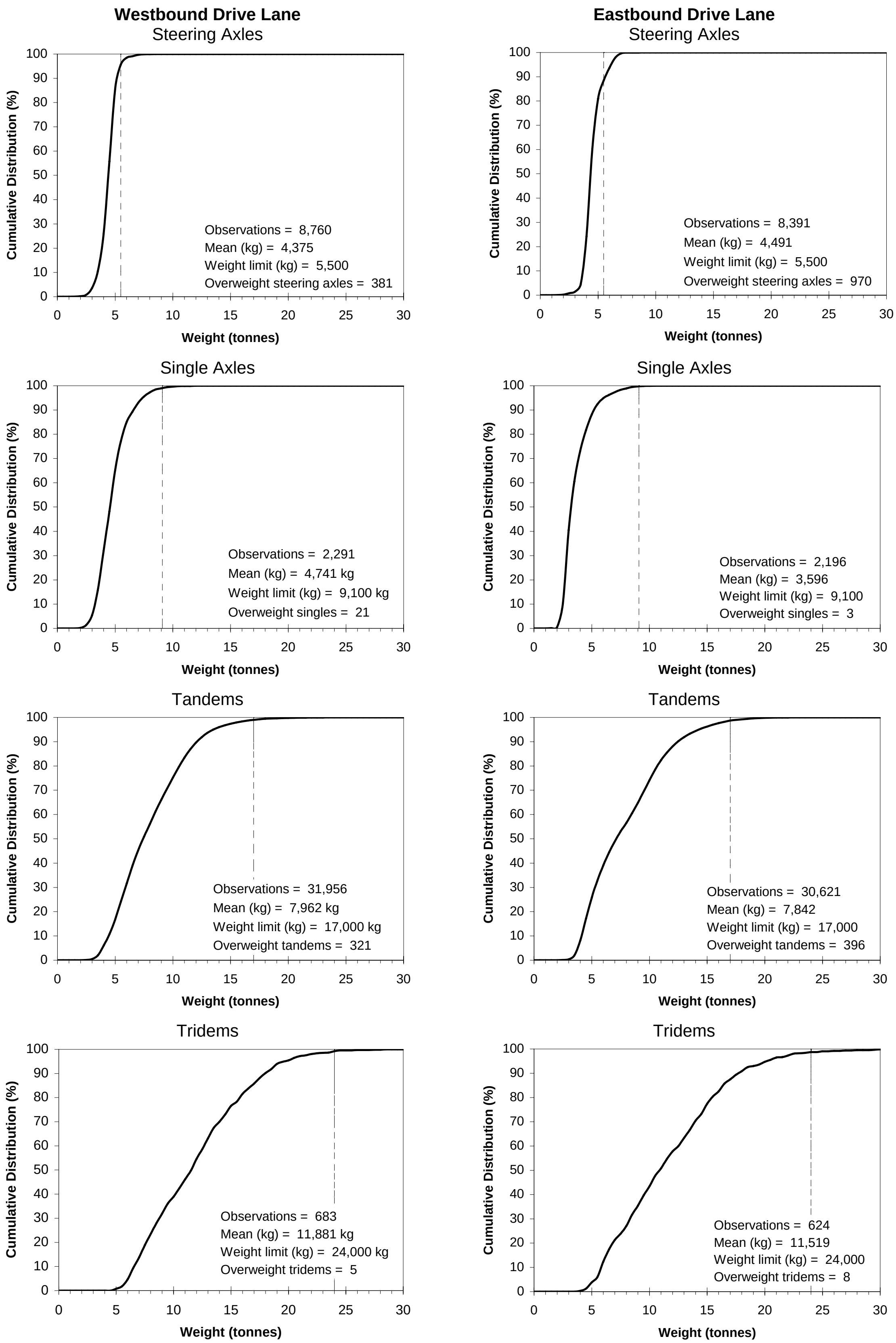

Figure 27: Dynamic representative axle load spectra for Turnpikes at M65 in 2007.

- There are no substantial directional differences between the median weights of westbound and eastbound steering axles (about 4500 kg). The median weights for westbound single axles (4500 kg), tandems (7500 kg), and tridems (11,500 kg) are higher than eastbound median weights for these axle groups (3100 kg for single axles, 7000 kg for tandems, and 11,000 kg for tridems).

- Of the four axle groups, steering axles exhibit the highest percentage of overweight (dynamic) observations—4.3 percent (381 of 8760) for westbound steering axles and 11.6 percent (970 of 8391) for eastbound steering axles. The percentage of overweight (dynamic) observations for all other axle groups (in either direction) does not exceed 1.5 percent.

6.3.4. Gross vehicle load spectra for predominant articulated trucks

The long truck gross vehicle and axle load spectra presented in Section 6.3.3 are necessary for highway infrastructure design and evaluation; however, additional insights are gained by comparing long truck loading characteristics to those of other types of articulated trucks. Figure 28 shows the dynamic gross vehicle load spectra for Turnpikes, Rockies, eight-axle B-trains, 3-S3s, and 3-S2s at WIM M65 in 2007 for eastbound and westbound trucks combined. The spectra are plotted with reference to the (static) GVW limits for these vehicles in Manitoba, which are: 62,500 kg for Turnpikes and eight-axle B-trains; 53,500 kg for Rockies; 46,500 kg for 3-S3s; and 39,500 kg for 3-S2s. Comparison of these spectra reveals the following insights:

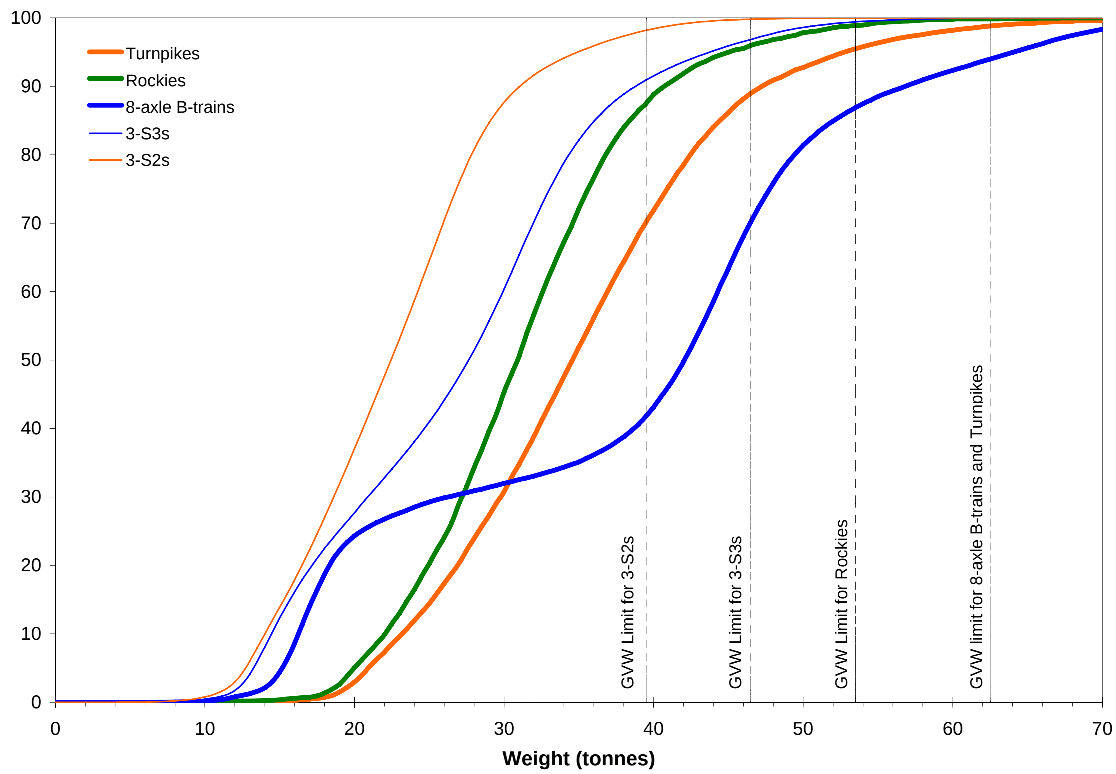

Figure 28: Comparison of dynamic gross vehicle load spectra for predominant articulated trucks at M65 in 2007.

- Turnpikes, Rockies, and 3-S2s operate at GVWs across the available GVW range (bounded at the minimum by their tare weights and at the maximum by the GVW limits). A very low proportion of these vehicles exceed their GVW limit when analyzing dynamic weights (about one percent of Turnpikes and Rockies, and less than two percent of 3-S2s). None exhibits peaks distinguishing empty from loaded vehicles. These observations are consistent with typical cube-out operations.

- The gross vehicle load spectra of eight-axle B-trains and 3-S3s exhibit peaks (particularly evident for eight-axle B-trains), which roughly correspond to loaded and empty vehicles. Approximately six percent of B-trains and three percent of 3-

S3s are recorded (dynamically) as being overweight. These observations are consistent with typical weigh-out operations.

- The 3-S3 load and Rocky load spectra are nearly identical above a weight level of about 40,000 kg. In other words, the same proportion (about 10 percent) of 3-S3s and Rockies are heavier than this weight level, despite the fact that 3-S3s are governed by a lower GVW limit than Rockies.

- The eight-axle B-train load spectrum crosses the Turnpike load spectrum at a weight level of about 30,000 kg. The same proportion (about 70 percent) of eight-axle B-trains and Turnpikes—both of which are subject the same GVW limit—are heavier than this weight level. However, about half of eight-axle B-trains exceed a weight level of about 40,000 kg, whereas one-quarter of Turnpikes exceed this level. Further, whatever the GVW, Turnpike loads are spread over more axles (typically nine or 10) and more wheels (typically 34 or 38) than loads carried by eight-axle B-trains (30 wheels). In other words, a Turnpike has less intense axle and wheel loads at the same GVW as an eight-axle B-train.

In summary, regulations which permit long truck operations in the Canadian Prairie Region and govern their weights have created gross vehicle load spectra that are distinct from other predominant articulated trucks. This distinction demonstrates the need to measure and understand the weight characteristics of different types of long trucks for the design and evaluation of transportation infrastructure. The characteristics of long truck load spectra are consistent with cube-out trucking and therefore also with the reason for granting them special permit: to increase the technical productivity of hauling low-density, general freight.

7. CONCLUSIONS

The research designs, develops, validates, and applies an exposure model of productivity-permitted general freight trucking on uncongested highways. Using the transportation systems analysis approach, the research provides and applies exposure indicators that support analysis and decision-making concerning the establishment of charges for long truck permits, long truck safety performance, and the loading characteristics of long trucks.

This chapter synthesizes the findings of the research in three categories: (1) truck exposure as a unifying explanatory variable for predicting transportation system impacts; (2) aspects of productivity-permitted general freight trucking in the Canadian Prairie Region; and (3) issues clarified by applying the long truck exposure model. The chapter also makes recommendations for future research.

7.1. TRUCK EXPOSURE AS A UNIFYING EXPLANATORY VARIABLE

The definition and application of the term exposure used in the research extends its conventional use, which arises principally from the context of road safety. The research defines exposure—and specifically truck exposure—as the number and nature of truck traffic events at a point or along a segment in a specified time. The essence of truck exposure, therefore, which is normally limited to volume indicators, explicitly includes the characterization of the weight and cubic dimensions of trucking, as well as its temporal, spatial, and vehicle-specific attributes. Because of this definitional extension, the application of the truck exposure concept becomes relevant and necessary for a wider range of transportation engineering and planning contexts.

The research considers truck exposure as the unifying explanatory variable for predicting transportation system impacts. This idea is the foundation of the exposure model design and development. Exposure, expressed as a component of the flow system, *F*, is also the fundamental link between the transportation system, *T*, the activity system, *A*, and their impacts. Relevant exposure and transportation system indicators are critical for civil engineering analysis, design, evaluation, and decision-making.

The exposure model of productivity-permitted general freight trucking is developed from raw exposure data that are routinely available from truck traffic measurement and estimation programs. These data require appropriate mining and screening techniques and the application of industry intelligence to develop relevant insights about long truck traffic. The research creates a unique, system-wide long truck exposure knowledge base by:

- analyzing and normalizing available data sources (i.e., weigh-in-motion data, sample classification count data from automatic vehicle classifiers and manual surveys, and industry intelligence);
- mining existing WIM and AVC datasets by developing and applying a new long truck classification algorithm, and calibrating the algorithm for conditions in the Canadian Prairie Region;

- applying network segmentation principles to the long truck network in the region;
- establishing a data hierarchy to facilitate data integration and improve decision-making transparency; and
- assigning exposure estimates to highway network segments.

7.2. PRODUCTIVITY-PERMITTED GENERAL FREIGHT TRUCKING IN THE CANADIAN PRAIRIE REGION

Long trucks are permitted in the Canadian Prairie Region because they offer technical productivity advantages relative to conventional truck configurations for hauling general freight with effective densities up to about 240 kg/m^3 (15 lb/ft^3). Rockies, Turnpikes, and triples constitute the Canadian Prairie Region long truck fleet. Recent network expansion in the region has created a 10,000 centreline-kilometre network of uncongested highways that offer continuous intra-jurisdictional, intercity operational possibilities for these vehicles. Based on data collected between 2003 and 2008, the exposure model predicts a total annual travel (representative of 2006 conditions) of 67 million kilometres by long trucks. Turnpikes accounted for more than half (52 percent) of these kilometres, Rockies accounted for 45 percent, and triples accounted for about three percent. The model reveals strong temporal and geographic concentration of long truck travel on the highway network. For example, at certain locations over two-thirds of long truck travel occurred at night and nearly 90 percent occurred on weekdays. Over three-quarters of the long truck travel in the region occurred on about one-quarter of the network's centreline-kilometres.

Long truck exposure characteristics demonstrate the suitability of these trucks for hauling cube-out freight. At one WIM station in Manitoba in 2007, the majority of Turnpikes (70 percent) and Rockies (90 percent) operated at GVWs below the 39,500-kg GVW limit for five-axle tractor semitrailers, despite being subject to higher GVW limits (62,500 kg and 53,500 kg for Turnpikes and Rockies, respectively). Depending on the location, between half and two-thirds of long truck rolling gross weight is attributed to vehicle tare weight. In 2006, long trucks accounted for over 1.5 billion cargo-carrying length-kilometres of rolling gross cube in the Canadian Prairie Region, which is equivalent to the utilization of one 16.2-m (53-ft) van tractor semitrailer for nearly 120 million kilometres.

Analysis of long truck traffic between 2005 and 2008 at one location on the Trans Canada Highway in Manitoba reveals two trends concerning long truck operations, both of which are supported by industry intelligence. First, long truck volumes at this location have nearly doubled over the past four years, from 48 long trucks per day in 2005 to 90 long trucks per day in 2008. Although the research does not establish direct cause-and-effect relationships, this growth may be commensurate with increasing demand for hauling low-density freight, highway investments that have provided critical network connectivity between major urban centres in the region, and a favourable regulatory environment in each of the region's three jurisdictions. Second, as the divided highway network expands, carriers have shifted towards greater use of Turnpike doubles (about nine of 10 long trucks at this location) relative to Rocky Mountain doubles (about one of 10 long trucks at this location) on these routes. Rockies continue to offer productivity advantages on two-lane undivided highways, particularly in Alberta and Saskatchewan where these networks are relatively dense. Triples represent a very small proportion of long truck volume at this location (about one percent).

The exposure model results are validated by analyzing the engineering reasonableness of the model's response (in terms of exposure indicators) to actual transportation system conditions—particularly related to network, regulatory, and vehicle factors. The model is considered valid since the observed exposure responses (based on either the *direction of change* or *binary quantity* criterion) confirm expected results for each of the conditions tested.

7.3. ISSUES CLARIFIED BY APPLYING THE LONG TRUCK EXPOSURE MODEL

The long truck exposure model is applied to three transportation contexts: road use charging, road safety, and pavement and bridge design and evaluation. The application of the model in these three contexts clarifies issues that should be considered by decision-makers concerning long truck operations.

First, transportation agencies establish long truck permit fees as one mechanism for charging for road use and ultimately funding transportation infrastructure. Recent trends have reduced the capability of charging mechanisms to generate adequate revenues, prompting agencies to seek new opportunities for funding transportation infrastructure. These opportunities include modifying the conventional cost-recovery rationale, establishing charges on the basis of a revenue adequacy rationale, or privatizing highway facilities. The cubic productivity, safety, infrastructure, and environmental benefits of long trucks in the Canadian Prairie Region make it difficult to justify a cost-based rationale for charging for long truck operating permits, and may give reason for providing (relative) incentives for carriers that choose more productive transportation options. Barring the provision of incentives and assuming highways remain a public sector responsibility, decision-makers should consider a revenue-based rationale for establishing charges for long truck permits.

The research compares three revenue-based cases with the current base case conditions in Manitoba for establishing long truck permit charges: benefit-sharing, revenue neutrality, and full benefit taxation. Analysis of the carrier costs and public revenues for these three cases reveals increases in Turnpike double operating costs ranging between about two percent for revenue neutrality to 50 percent for full benefit taxation relative to the base case. Corresponding public revenue increases for these three cases range between 30 percent for revenue neutrality to a 12-fold increase for full benefit taxation. The sensitivity of these results to freight density (an indicator of weight and cube) and annual utilization (an indicator of volume) highlights the cost and revenue implications of charges that are not indexed to these measures of exposure.

Second, the research finds that the exposure-based collision rate for Turnpikes (16 collisions per 100 million vehicle-kilometres travelled) is half of the collision rate for Rockies, about one-third of the rate for legal-length articulated trucks, and one-quarter of the rate for triples. This relative safety performance ranking does not change given a plus or minus 10 percent change in either the long truck or legal-length articulated truck travel. For the analysis period, long trucks as a group had about the same vehicles-in-collisions rate as other articulated trucks in fatal collisions. Both Turnpikes and Rockies had lower vehicles-in-collisions rates than other articulated trucks for injury and property damage only collisions. These results are based on a seven-year analysis of collisions and exposure data in Alberta, and are normalized for a common highway network. The research thus provides evidence for decision-makers that long trucks offer safety advantages relative to other types of articulated trucks in addition to demonstrated productivity increases.

Third, the analysis of long truck loading characteristics provides the detailed exposure indicators required for new pavement and bridge design and evaluation procedures and demonstrates the cubic orientation of long truck operations. Generally, average axle and gross vehicle weights for long trucks are less than prescribed maximum weight limits and (dynamic) overweight observations are rare. When comparing the gross vehicle load spectra of five predominant articulated trucks in the Canadian Prairie Region (Turnpikes, Rockies, eight-axle B-trains, 3-S3s, and 3-S2s), it is evident that the long truck spectra are distinct and require unique specification for the design and evaluation of transportation infrastructure. Gross vehicle load characteristics of Rockies and 3-S3s are nearly identical for the heaviest 10 percent of the observations, despite 3-S3s being subject to a lower GVW limit than Rockies. Similarly, Turnpikes are more lightly loaded than eight-axle B-trains even though they are subject to the same GVW limit.

7.4. RECOMMENDATIONS FOR FUTURE RESEARCH

The research identifies the need for future research to:

- enhance the capability of truck traffic measurement and estimation programs to measure, estimate, and model long truck exposure by expanding the network of weigh-in-motion installations, integrating real-time exposure data available through the implementation of GPS or on-board tracking devices, developing and calibrating data mining techniques, and validating the model results;

- expand the application of the long truck exposure model—and the definition of system impacts and appropriate performance, exposure, and transportation system indicators—to other transportation contexts, principally: energy, fuel, and emissions; modal shifts and competition; truck enforcement and regulation; road geometry and traffic operations; and highway network planning;

- design, develop, and implement technologies and systems to control truck exposure by redirecting exposure situations which are known to have unacceptable impacts to times and places which function in more acceptable ways;

- develop transportation engineering and planning tools for forecasting long truck exposure by establishing explanatory relationships between specific elements of the transportation system (e.g., network and regulatory factors) and long truck exposure; and

- identify the potential for establishing an upper bound to the proportion of long truck penetration (by volume) into the articulated truck fleet by analyzing commodity characteristics and related body type distributions.

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APPENDIX A: DETAILS ABOUT EXPOSURE DATA SOURCES

This appendix provides information about the exposure data sources used to develop the long truck exposure knowledge base. Details about WIM, AVC, and manual classification count locations and times are given in Tables A.1, A.2, and A.3, respectively.

Table A.1: Weigh-in-Motion Stations on the Canadian Prairie Region Long Truck Network Used for Analysis

Station	Highway	Name	Calendar year of data analysis			
			2005	2006	2007	2008
Alberta						
A3	2	Red Deer	✓		✓	
A4	2	Leduc VIS	✓		✓	
A5	2A	Leduc	✓		✓	
A6	3	Fort McLeod	✓		✓	
A7	16	Edson	✓		✓	
Saskatchewan						
S2	1	Grand Coulee			✓	
S57	16	Plunkett	✓			
S60	11	Grasswood	✓			
S62	1	Fleming	✓			
S66	16	Radisson	✓			
S67	11	Duck Lake	✓			
S104	11	Lumsden	✓			
S106	16	Lashburn	✓			
S107	7	Alsask		✓		
S110	16	Langenburg	✓			
S111	1	Maple Creek		✓		
S112	39	Lang	✓			
S114	14	Farley	✓			
Manitoba						
M61	1	Brokenhead	✓		✓	
M62	1	Oak Lake	✓	✓	✓	
M63	75	Glenlea	✓		✓	
M64	100	Symington	✓		✓	
M65	1	MacGregor	✓	✓	✓	✓
Northwest Territories						
N2	3	Fort Providence				✓

Table A.2: Automatic Vehicle Classifiers on the Canadian Prairie Region Long Truck Network Used for Analysis

Station	Highway	Name	Dates of sample
Alberta			
A63 [a]	63	Site 63:06 km 35	November 5 – November 29, 2005
Manitoba			
M19	1	Deacon's Corner	October 21 – November 2, 2007
M20	101	North Perimeter	October 21 – November 2, 2007
M25	1	Kirkella	October 15 – October 23, 2007
M46	16	Portage la Prairie	October 15 – October 26, 2007
M55	1	Headingley	October 21 – November 2, 2007

Note: [a] Only total vehicle length data are available from A63.

Table A.3: Sample Classification Intersection Count Locations

Count location	Date	Day of week	Time of day
Alberta			
Hwy. 2 & Hwy. 5 N. of Cardston N. Jct.	Feb. 6, 2007	Tuesday	0700-1900
Hwy. 28 & Hwy. 63 & Hwy. 829 W. of Radway	Feb. 7, 2007	Wednesday	0700-1900
Hwy. 9 & Hwy. 36 E. of Hanna E. Jct.	Feb. 7, 2007	Wednesday	0700-1900
Hwy. 3 & Hwy. 999 Rge Rd 190, Chin Access	Feb. 8, 2007	Thursday	0700-1900
Hwy. 2 & Hwy. 35 N. of Grimshaw	Feb. 8, 2007	Thursday	0700-1900
Hwy. 12 & Hwy. 21 S.E. of Alix W. Jct.	Feb. 8, 2007	Thursday	0700-1900
Hwy. 8 & Hwy. 22 N.E. of Bragg Creek	Feb. 9, 2007	Friday	0700-1900
Hwy. 13 & Hwy. 21 W. of Camrose	Feb. 9, 2007	Friday	0700-1900
Hwy. 14 & Hwy. 36 S.W. of Viking	Feb. 9, 2007	Friday	0700-1900
Hwy. 2 & Hwy. 49 E. of Rycroft	Feb. 12, 2007	Monday	0700-1900
Hwy. 23 & Hwy. 24 & Hwy. 542 N. of Vulcan	Feb. 12, 2007	Monday	0700-1900
Hwy. 2 & Hwy. 49 S.W. of Donnelly	Feb. 12, 2007	Monday	0700-1900
Hwy. 43 & Hwy. 49 at Valleyview	Feb. 12, 2007	Monday	0700-1900
Hwy. 1 & Hwy. 901 E. of Gleichen	Feb. 13, 2007	Tuesday	0700-1900
Hwy. 16 & Hwy. 631 N.W. of Royal Park	Feb. 13, 2007	Tuesday	0700-1900
Hwy. 16 & Hwy. 893 S. of Islay	Feb. 14, 2007	Wednesday	0700-1900
Hwy. 3 & Hwy. 887 N.E. of Seven Persons	Feb. 14, 2007	Wednesday	0700-1600
Manitoba			
Hwy. 1 W. of Headingley	Jul. 10, 2008	Thursday	1530-1630
	Jul. 30, 2008	Wednesday	1145-1630
	Aug. 13, 2008	Wednesday	0300-0700
Hwy. 101 & Inkster Boulevard	Jul. 30, 2007	Monday	1415-1530
	Aug. 10, 2007	Friday	0830-1600
	Aug. 14, 2007	Monday	0900-1600
	Aug. 20, 2007	Monday	0830-1600
Hwy. 100 & Pembina Highway	Apr. 3, 2008	Thursday	0930-1400

APPENDIX B: FHWA 13-CATEGORY CLASSIFICATION SCHEME

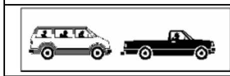
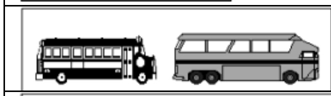
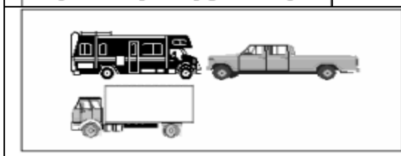
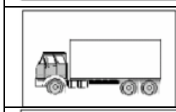
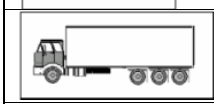
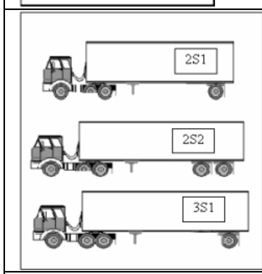
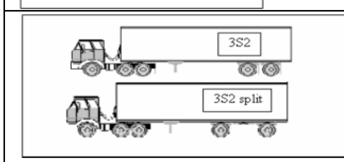
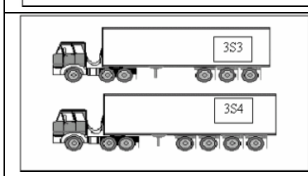
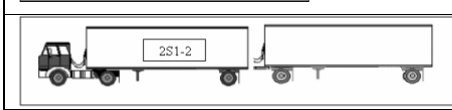
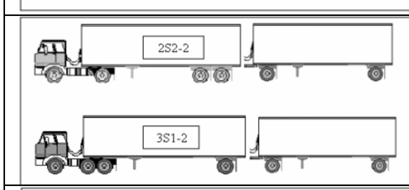
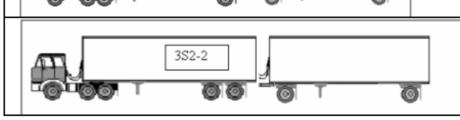
	FHWA Class 1 – Motorcycles
	FHWA Class 2 – Passenger Cars (With 1- or 2-Axle Trailers)
	FHWA Class 3 – 2 Axles, 4-Tire Single Units, Pickup or Van (With 1- or 2-Axle Trailers)
	FHWA Class 4 – Buses
	FHWA Class 5 – 2D - 2 Axles, 6-Tire Single Units (Includes Handicapped-Equipped Bus and Mini School Bus)
	FHWA Class 6 – 3 Axles, Single Unit
	FHWA Class 7 – 4 or More Axles, Single Unit
	FHWA Class 8 – 3 to 4 Axles, Single Trailer
	FHWA Class 9 – 5 Axles, Single Trailer
	FHWA Class 10 – 6 or More Axles, Single Trailer
	FHWA Class 11 – 5 or Less Axles, Multiple Trailers
	FHWA Class 12 – 6 Axles, Multiple Trailers
	FHWA Class 13 – 7 or More Axles, Multiple Trailers

Figure B.1: Federal Highway Administration 13-category classification scheme.

APPENDIX C: LONG TRUCK NETWORK SEGMENTS DATASET

Table C.1: Manitoba Long Truck Network Segments

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume Rocky	Turnpike	Triple	Total	Average daily RGW (000's of tonnes) Rocky	Turnpike	Triple	Total	Average daily RGC (CCLs) Rocky	Turnpike	Triple	Total	Comment
1	5.72	702	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007
1	11.57	702	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007
1	16.28	702	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007
1	1.49	702	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007
1	6.79	702	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007
1	2.96	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	2.05	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	16.26	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	5.20	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	8.80	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	4.92	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	7.00	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	6.25	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	3.50	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	8.44	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	4.75	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	3.55	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	6.25	704	WIM	D	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	1.64	706	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	4.00	708	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	4.17	708	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	8.91	710	WIM	T	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	8.31	712	WIM	T	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	1.29	712	WIM	T	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	15.09	712	WIM	T	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	18.09	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	1.69	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	12.04	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	6.00	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	7.60	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	9.90	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	11.47	714	WIM	D	18	49	1	68	186	605	7	797	360	1274	21	1655	M65 2007
1	6.60	716	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	8.77	718	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	4.43	718	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	0.92	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	6.00	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	8.75	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	18.83	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	8.67	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	7.43	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	2.44	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	4.11	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	2.71	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	0.30	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	0.30	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	5.65	720	WIM	B	24	49	1	74					480	1274	21	1775	M65 2007 + M46 2007
1	5.44	722	IND	D	0	0	0	0					0	0	0	0	Industry
1	2.56	724	AVC	D	0	1	0	1					0	26	0	26	M19 2007

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.1: Manitoba Long Truck Network Segments (cont…)

					Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				
Road	Length (km)	Long Truck Segment	Source	Method	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Comment
1	7.80	724	AVC	D	0	1	0	1					0	26	0	26	M19 2007
1	2.10	724	AVC	D	0	1	0	1					0	26	0	26	M19 2007
1	3.90	724	AVC	D	0	1	0	1					0	26	0	26	M19 2007
1	4.00	724	AVC	D	0	1	0	1					0	26	0	26	M19 2007
1	7.01	724	AVC	D	0	1	0	1					0	26	0	26	M19 2007
1	8.20	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	6.60	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	13.22	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	13.32	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	13.50	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	2.20	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	6.00	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	13.93	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	20.64	726	WIM	D	0	0	0	0					0	0	0	0	M61 2007
1	1.98	728	WIM	T	0	0	0	0					0	0	0	0	M61 2007
1	11.13	728	WIM	T	0	0	0	0					0	0	0	0	M61 2007
1	2.41	728	WIM	T	0	0	0	0					0	0	0	0	M61 2007
1	1.56	728	WIM	T	0	0	0	0					0	0	0	0	M61 2007
1	0.15	728	WIM	T	0	0	0	0					0	0	0	0	M61 2007
3	8.39	702	IND	D	0	0	0	0					0	0	0	0	Industry
5	3.73	702	IND	D	0	2	0	2					0	52	0	52	Industry
5	1.44	704	AVC	D	6	0	0	6					120	0	0	120	M46 2007
7	1.59	702	WIM	B	17	27	4	48					340	702	84	1126	Flow balance - Perimeter
12	5.10	702	WIM	B	0	1	0	1					0	26	0	26	M19 2007 - M61 2007
12	3.30	702	WIM	B	0	1	0	1					0	26	0	26	M19 2007 - M61 2007
12	7.20	702	WIM	B	0	1	0	1					0	26	0	26	M19 2007 - M61 2007
12	1.40	702	WIM	B	0	1	0	1					0	26	0	26	M19 2007 - M61 2007
12	2.84	702	WIM	B	0	1	0	1					0	26	0	26	M19 2007 - M61 2007
16	14.10	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	4.10	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	10.70	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	1.70	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	13.32	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	9.47	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	11.50	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	8.10	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	6.52	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	15.21	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	0.30	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	11.70	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	9.51	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	12.50	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	8.86	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	7.50	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	2.30	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	1.70	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16	16.73	702	AVC	D	6	0	0	6					120	0	0	120	M46 2007
16 A	2.46	702	AVC	T	6	0	0	6					120	0	0	120	M46 2007
16 A	0.10	702	AVC	T	6	0	0	6					120	0	0	120	M46 2007

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.1: Manitoba Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
16 A	0.94	702	AVC	T	6	0	0	6					120	0	0	120	M46 2007
16 A	5.59	702	AVC	T	6	0	0	6					120	0	0	120	M46 2007
29	0.50	702	WIM	T	2	4	4	10					40	104	84	228	M63 2007
75	1.30	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	6.90	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	7.10	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	6.85	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	4.00	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	5.90	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	4.10	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	4.28	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	0.41	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	3.40	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	9.92	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	14.20	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	13.49	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	4.60	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	2.51	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
75	4.17	702	WIM	D	2	4	4	10					40	104	84	228	M63 2007
100	1.84	702	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	2.80	702	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	4.20	702	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	3.08	702	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	1.21	704	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	5.40	704	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	3.60	704	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	1.98	704	WIM	B	8	16	4	28					160	416	84	660	Flow balance - Perimeter
100	3.38	706	WIM	B	6	12	0	18					120	312	0	432	Flow balance - Perimeter
100	4.00	706	WIM	B	6	12	0	18					120	312	0	432	Flow balance - Perimeter
100	1.63	706	WIM	B	6	12	0	18					120	312	0	432	Flow balance - Perimeter
100	6.84	708	WIM	D	0	0	0	0					0	0	0	0	M64 2007
101	2.00	702	WIM	B	24	39	5	68					480	1014	105	1599	Flow balance - Perimeter
101	6.50	702	WIM	B	24	39	5	68					480	1014	105	1599	Flow balance - Perimeter
101	3.62	704	WIM	B	17	27	4	48					340	702	84	1126	Flow balance - Perimeter
101	5.87	706	WIM	B	17	27	4	48					340	702	84	1126	Flow balance - Perimeter
101	4.90	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	3.95	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	2.85	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	0.86	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	3.33	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	2.00	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	4.00	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	3.81	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	4.69	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
101	1.18	708	AVC	D	0	0	0	0					0	0	0	0	M20 2007
110	1.87	704	WIM	B	0	19	1	20					0	494	21	515	M65 2007 - M62 2007
221	3.50	702	WIM	B	7	12	1	20					140	312	21	473	Flow balance - Perimeter
221	3.23	702	WIM	B	7	12	1	20					140	312	21	473	Flow balance - Perimeter
457	3.40	702	WIM	B	0	19	1	20					0	494	21	515	M65 2007 - M62 2007
468	3.24	702	WIM	B	0	19	1	20					0	494	21	515	M65 2007 - M62 2007

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
1	25.00	802	WIM	D	6	32	0	38					120	832	0	952	S111 2006
1	24.41	802	WIM	D	6	32	0	38					120	832	0	952	S111 2006
1	26.78	802	WIM	D	6	32	0	38					120	832	0	952	S111 2006
1	12.68	802	WIM	D	6	32	0	38					120	832	0	952	S111 2006
1	5.52	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	12.21	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	0.96	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	39.73	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	2.34	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	16.12	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	5.05	804	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	0.14	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	24.55	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	13.72	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	15.30	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	26.11	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	24.83	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	2.63	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	10.09	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	4.93	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	0.75	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	18.82	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	8.81	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	14.63	806	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	6.57	808	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	1.59	810	WIM	D	8	41	0	49					160	1066	0	1226	S2 2007
1	0.13	810	WIM	D	8	41	0	49					160	1066	0	1226	S2 2007
1	24.50	810	WIM	D	8	41	0	49					160	1066	0	1226	S2 2007
1	13.06	810	WIM	D	8	41	0	49					160	1066	0	1226	S2 2007
1	16.61	810	WIM	D	8	41	0	49					160	1066	0	1226	S2 2007
1	2.56	812	WIM	T	8	41	0	49					160	1066	0	1226	S2 2007
1	9.04	814	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	5.50	814	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	7.21	814	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	1.70	815	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	2.28	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	14.96	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	13.01	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	1.62	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	9.16	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	0.66	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	11.52	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	6.89	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	0.00	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	13.70	816	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	20.45	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	3.90	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	1.27	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	21.39	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	1.50	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
1	1.32	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	6.54	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	0.41	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	13.03	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	3.26	818	WIM	T	18	30	0	48	240	460	2	703	360	780	0	1140	M62 2007
1	0.51	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	0.76	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	5.53	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	13.11	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	24.25	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	10.20	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	9.63	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
1	2.64	820	WIM	T	18	0	0	18	240	0	0	240	360	0	0	360	M62 2007 (RMDs only)
2	4.10	802	WIM	D	4	0	0	4					80	0	0	80	S67 2005
2	0.78	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	5.04	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	15.23	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	15.38	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	23.55	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	11.18	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	1.53	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	0.34	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	11.74	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	1.46	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	65.65	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	20.38	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	19.29	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	12.06	804	IND	D	1	0	0	1					20	0	0	20	Industry
2	19.68	804	IND	D	1	0	0	1					20	0	0	20	Industry
3	13.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	23.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	3.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	15.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	9.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	11.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	15.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	1.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	2.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	2.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	2.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	1.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	18.00	804	M&E	A	3	0	0	3					60	0	0	60	Similar to Hwy. 14
3	19.00	804	M&E	A	3	0	0	3					60	0	0	60	Similar to Hwy. 14
3	16.00	806	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	6.00	806	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	3.00	806	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
3	1.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	0.00	802	IND	D	2	0	0	2					40	0	0	40	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
4	5.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	3.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	3.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	22.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	15.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	0.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	34.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	7.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	13.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	6.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	13.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	0.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	30.00	802	IND	D	2	0	0	2					40	0	0	40	Industry
4	29.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
4	16.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
4	3.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
4	9.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
4	2.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
4	1.81	806	WIM	D	15	0	0	15					300	0	0	300	S106 2005
4	1.00	806	WIM	D	15	0	0	15					300	0	0	300	S106 2005
4	2.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	6.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	13.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	37.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	7.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	2.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	84.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	4.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
4	0.00	808	IND	D	2	0	0	2					40	0	0	40	Industry
6	0.85	800	WIM	D	3	0	0	3					60	0	0	60	S112 2005
6	2.83	800	WIM	D	3	0	0	3					60	0	0	60	S112 2005
6	15.43	802	WIM	B	2	0	0	2					40	0	0	40	50/50 split from S112
6	6.50	802	WIM	B	2	0	0	2					40	0	0	40	50/50 split from S112
6	14.68	802	WIM	B	2	0	0	2					40	0	0	40	50/50 split from S112
6	1.44	802	WIM	B	2	0	0	2					40	0	0	40	50/50 split from S112
6	38.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	3.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	5.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	3.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	28.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	15.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	7.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	7.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	37.00	804	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 4
6	6.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	2.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	23.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	15.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
6	21.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	10.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	28.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	7.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
6	9.00	806	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
7	21.36	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	17.49	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	6.46	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	1.14	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	14.70	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	11.49	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	1.66	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	17.85	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	0.00	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	23.01	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	29.39	802	WIM	D	5	0	0	5					100	0	0	100	S107 2006
7	9.11	804	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	35.89	804	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	28.80	804	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	0.75	804	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	13.43	806	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	2.43	806	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	3.27	806	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	0.00	806	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	0.00	806	WIM	T	5	0	0	5					100	0	0	100	S107 2006
7	16.02	806	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	20.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
9	18.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
9	14.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
9	4.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
9	21.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
9	32.00	804	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
9	1.64	806	WIM	T	3	0	0	3					60	0	0	60	S57 2005
10	10.36	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	2.05	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	9.93	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	23.63	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	11.94	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	1.13	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	16.30	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	3.40	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	25.43	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	0.88	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	1.80	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	35.85	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	8.19	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	4.75	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	2.05	802	IND	D	2	0	0	2					40	0	0	40	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
10	0.66	802	IND	D	2	0	0	2					40	0	0	40	Industry
10	2.27	804	WIM	T	3	0	0	3					60	0	0	60	S57 2005
11	28.71	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	21.98	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	16.96	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	0.00	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	0.39	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	14.94	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	2.00	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	8.18	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	5.41	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	20.08	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	19.09	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	11.50	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	26.95	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	4.06	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	11.17	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	32.78	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	0.13	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	0.00	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	14.59	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	3.67	804	PW	D	14	34	1	49					280	884	21	1185	S60 2005/S104 2005
11	9.27	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
11	3.95	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
11	17.47	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
11	25.60	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
11	23.18	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
11	44.26	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
11	0.00	810	PW	D	4	0	0	4					80	0	0	80	S67 2005
12	2.58	802	PW	T	4	0	0	4					80	0	0	80	S67 2005
14	2.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	14.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	6.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	16.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	7.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	16.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	22.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	8.00	802	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	10.00	804	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	35.00	804	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	1.00	804	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	21.00	804	PW	T	2	0	0	2					40	0	0	40	S114 2005
14	30.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
14	19.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
14	1.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
14	0.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
14	5.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
14	8.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
14	8.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
14	16.00	806	PW	D	2	0	0	2					40	0	0	40	S114 2005
16	1.85	802	WIM/IND	D	15	12	0	27					300	312	0	612	S106 2005/Industry
16	1.78	802	WIM/IND	D	15	12	0	27					300	312	0	612	S106 2005/Industry
16	5.52	802	WIM/IND	D	15	12	0	27					300	312	0	612	S106 2005/Industry
16	9.86	802	WIM/IND	D	15	12	0	27					300	312	0	612	S106 2005/Industry
16	13.60	802	WIM/IND	D	15	12	0	27					300	312	0	612	S106 2005/Industry
16	2.09	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	8.36	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	11.93	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	26.22	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	6.10	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	0.91	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	46.74	804	WIM/IND	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	6.99	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	7.21	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	0.37	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	20.42	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	22.96	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	23.99	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	14.02	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	0.21	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	1.19	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	2.00	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	0.21	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	20.88	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	11.85	806	WIM/IND	D	15	13	0	28					300	338	0	638	S106 2005/Industry
16	4.00	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	5.47	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	1.30	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	4.97	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	20.13	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	10.36	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	9.38	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	9.79	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	11.72	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	22.17	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	8.46	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	6.89	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	7.23	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	18.89	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	3.16	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	6.14	808	WIM	D	3	0	0	3					60	0	0	60	S57 2005
16	5.27	810	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	14.65	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	10.96	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	23.29	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	24.16	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
16	24.93	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	26.85	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	15.54	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	19.46	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	0.80	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	3.21	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	0.35	812	WIM	T	3	0	0	3					60	0	0	60	S57 2005
16	11.85	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	2.33	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	1.18	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	25.17	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	1.00	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	7.79	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	8.42	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	7.13	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	14.89	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
16	3.76	814	WIM	D	0	0	0	0					0	0	0	0	S110 2005
17	16.00	802	WIM	T	2	0	0	2					40	0	0	40	S114 2005
17	9.00	802	WIM	T	2	0	0	2					40	0	0	40	S114 2005
22	15.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
29	27.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
29	23.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 4
35	16.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
35	8.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
35	5.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
35	1.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
35	9.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
35	9.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
35	8.00	802	M&E	A	1	0	0	1					20	0	0	20	Similar to Hwy. 14
39	38.78	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	0.28	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	1.21	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	0.62	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	24.07	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	2.63	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	29.18	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	14.62	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	41.20	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	0.43	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	0.33	804	WIM	D	3	0	0	3					60	0	0	60	S112 2005
39	12.00	806	WIM	B	1	0	0	1					20	0	0	20	50/50 split from S112
39	23.00	806	WIM	B	1	0	0	1					20	0	0	20	50/50 split from S112
39	6.00	806	WIM	B	1	0	0	1					20	0	0	20	50/50 split from S112
39	26.00	806	WIM	B	1	0	0	1					20	0	0	20	50/50 split from S112
39	0.00	806	WIM	B	1	0	0	1					20	0	0	20	50/50 split from S112
41	30.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	30.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	27.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.2: Saskatchewan Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
41	10.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	1.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	16.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	10.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	11.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	4.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	22.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
41	2.00	802	M&E	A	2	0	0	2					40	0	0	40	Similar to Hwy. 14
46	11.00	802	M&E	A	4	0	0	4					80	0	0	80	Similar to Hwy. 10
46	11.00	802	M&E	A	4	0	0	4					80	0	0	80	Similar to Hwy. 10
102	13.51	802	IND	D	1	0	0	1					20	0	0	20	Industry
364	0.00	802	M&E	A	4	0	0	4					80	0	0	80	Similar to Hwy. 10

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume: Rocky	Turnpike	Triple	Total	Average daily RGW (000's of tonnes): Rocky	Turnpike	Triple	Total	Average daily RGC (CCLs): Rocky	Turnpike	Triple	Total	Comment
1	3.73	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	4.73	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	23.16	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	1.02	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	3.17	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	22.29	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	3.17	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	17.25	902	IND	D	0	2	0	2					0	52	0	52	Industry
1	11.45	904	WIM	D	0	2	0	2					0	52	0	52	Industry
1	2.48	904	WIM	D	0	2	0	2					0	52	0	52	Industry
1	8.11	906	WIM	B	6	16	0	22					110	416	0	526	50/50 split from S111 2006
1	3.86	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	6.56	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	9.80	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	10.83	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	8.73	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	11.98	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	17.94	908	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	14.23	910	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	16.00	910	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	1.62	910	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	17.14	910	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	3.71	910	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	33.81	910	WIM	B	11	32	0	43					220	832	0	1052	S111 2006 + S107 2006
1	8.38	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	3.18	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	9.42	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	8.32	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	25.73	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	19.63	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	26.71	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	5.72	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	1.87	912	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	6.74	914	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	16.12	914	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1	24.70	914	WIM	T	6	32	0	38					120	832	0	952	S111 2006
1 A	0.12	902	IND	D	2	0	0	2					40	0	0	40	Industry
1 A	12.24	902	IND	D	2	0	0	2					40	0	0	40	Industry
1 A	5.88	902	IND	D	2	0	0	2					40	0	0	40	Industry
1 A	8.35	904	WIM	B	6	16	0	22					110	416	0	526	50/50 split from S111 2006
2	21.29	902	IND	D	2	0	0	2					40	0	0	40	Industry
2	3.73	902	IND	D	2	0	0	2					40	0	0	40	Industry
2	0.86	902	IND	D	2	0	0	2					40	0	0	40	Industry
2	15.77	904	IND	D	2	0	0	2					40	0	0	40	Industry
2	3.35	904	IND	D	2	0	0	2					40	0	0	40	Industry
2	11.01	904	IND	D	2	0	0	2					40	0	0	40	Industry
2	0.26	904	IND	D	2	0	0	2					40	0	0	40	Industry
2	19.01	904	IND	D	2	0	0	2					40	0	0	40	Industry
2	9.14	904	IND	D	2	0	0	2					40	0	0	40	Industry
2	2.21	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
2	18.06	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	15.52	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	1.78	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	3.12	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	13.02	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	9.65	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	12.96	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	1.36	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	7.26	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	9.16	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	9.78	906	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	15.41	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	4.19	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	9.09	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	2.20	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	2.16	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	5.40	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	2.32	908	WIM	T	9	16	8	33	101	213	100	415	180	416	168	764	A6 2007
2	6.82	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	9.73	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	9.74	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	4.83	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	5.26	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	9.72	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	11.34	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	14.51	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	16.05	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	9.34	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	2.53	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	18.17	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	3.07	910	WIM	D	21	140	9	170	245	2168	119	2532	420	3640	189	4249	A3 2007
2	6.98	912	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	10.52	912	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	8.82	914	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	5.47	914	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	2.53	916	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	10.88	916	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	18.71	918	WIM	D	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	12.94	918	WIM	D	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	15.25	918	WIM	D	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	18.52	918	WIM	D	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	1.40	920	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	2.13	922	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	3.08	922	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	3.21	922	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	7.02	922	WIM	T	19	125	9	153	206	1785	93	2084	380	3250	189	3819	A4 2007
2	6.01	924	IND	D	2	0	0	2					40	0	0	40	Industry
2	6.56	924	IND	D	2	0	0	2					40	0	0	40	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

Road		Length (km)	Long Truck Segment	Source	Method	Average daily volume Rocky	Turnpike	Triple	Total	Average daily RGW (000's of tonnes) Rocky	Turnpike	Triple	Total	Average daily RGC (CCLs) Rocky	Turnpike	Triple	Total	Comment
2		3.37	924	IND	D	2	0	0	2					40	0	0	40	Industry
2		16.62	926	IND	D	2	0	0	2					40	0	0	40	Industry
2		23.14	926	IND	D	2	0	0	2					40	0	0	40	Industry
2		13.16	928	IND	D	2	0	0	2					40	0	0	40	Industry
2		24.32	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		11.01	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		20.44	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		5.53	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		1.70	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		1.17	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		2.05	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		8.06	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		8.17	930	IND	D	10	0	0	10					200	0	0	200	Industry
2		4.66	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		3.33	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		18.59	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		9.40	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		4.74	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		21.09	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		0.83	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		1.10	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		10.62	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		34.10	932	IND	D	2	0	0	2					40	0	0	40	Industry
2		16.68	934	IND	D	2	0	0	2					40	0	0	40	Industry
2		1.60	934	IND	D	2	0	0	2					40	0	0	40	Industry
2		15.01	934	IND	D	2	0	0	2					40	0	0	40	Industry
2		12.32	934	IND	D	2	0	0	2					40	0	0	40	Industry
2		1.61	934	IND	D	2	0	0	2					40	0	0	40	Industry
2		2.86	934	IND	D	2	0	0	2					40	0	0	40	Industry
2		12.23	936	IND	D	2	0	0	2					40	0	0	40	Industry
2	A	3.39	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	10.30	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	0.91	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	2.64	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	16.49	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	2.82	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	12.55	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	0.82	902	WIM	T	2	0	0	2					40	0	0	40	A5 2007
2	A	12.44	904	WIM	D	2	0	0	2					40	0	0	40	A5 2007
2	A	5.71	904	WIM	D	2	0	0	2					40	0	0	40	A5 2007
2	A	11.41	904	WIM	D	2	0	0	2					40	0	0	40	A5 2007
3		15.54	902	IND	D	2	0	0	2					40	0	0	40	Industry
3		3.30	902	IND	D	2	0	0	2					40	0	0	40	Industry
3		4.25	902	IND	D	2	0	0	2					40	0	0	40	Industry
3		2.92	902	IND	D	2	0	0	2					40	0	0	40	Industry
3		1.79	902	IND	D	2	0	0	2					40	0	0	40	Industry
3		4.97	902	IND	D	2	0	0	2					40	0	0	40	Industry
3		2.58	902	IND	D	2	0	0	2					40	0	0	40	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
3	4.49	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	2.10	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	1.19	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	8.88	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	10.07	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	3.05	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	12.03	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	28.77	902	IND	D	2	0	0	2					40	0	0	40	Industry
3	4.36	904	WIM	T	9	16	8	33					180	416	168	764	A6 2007
3	21.86	906	WIM	D	9	16	8	33					180	416	168	764	A6 2007
3	6.40	906	WIM	D	9	16	8	33					180	416	168	764	A6 2007
3	13.74	906	WIM	D	9	16	8	33					180	416	168	764	A6 2007
3	1.14	908	WIM	T	9	16	8	33					180	416	168	764	A6 2007
3	2.99	908	WIM	T	9	16	8	33					180	416	168	764	A6 2007
3	11.69	910	IND	D	7	17	6	30					140	442	126	708	Industry
3	10.17	910	IND	D	7	17	6	30					140	442	126	708	Industry
3	23.12	910	IND	D	7	17	6	30					140	442	126	708	Industry
3	0.81	910	IND	D	7	17	6	30					140	442	126	708	Industry
3	2.87	910	IND	D	7	17	6	30					140	442	126	708	Industry
3	31.48	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	4.90	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	13.34	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	5.31	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	2.10	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	17.79	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	4.29	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	4.05	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	7.52	912	IND	D	20	0	0	20					400	0	0	400	Industry
3	16.34	912	IND	D	20	0	0	20					400	0	0	400	Industry
4	15.88	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	3.61	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	5.05	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	13.42	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	7.90	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	19.70	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	7.67	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	1.14	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	12.38	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	1.71	902	IND	D	1	3	1	5					20	78	21	119	Industry
4	9.68	902	IND	D	1	3	1	5					20	78	21	119	Industry
5	4.15	902	IND	D	0	0	0	0					0	0	0	0	Industry
5	18.73	902	IND	D	0	0	0	0					0	0	0	0	Industry
5	17.94	902	IND	D	0	0	0	0					0	0	0	0	Industry
5	7.86	902	IND	D	0	0	0	0					0	0	0	0	Industry
5	16.28	904	IND	D	2	0	0	2					40	0	0	40	Industry
5	3.41	904	IND	D	2	0	0	2					40	0	0	40	Industry
5	0.95	904	IND	D	2	0	0	2					40	0	0	40	Industry
8	16.55	902	IND	D	2	0	0	2					40	0	0	40	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
9	14.93	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	29.05	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	0.81	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	6.99	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	23.52	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	23.67	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	18.14	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	1.70	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
9	13.17	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
11 A	3.32	902	IND	D	0	2	0	2					0	52	0	52	Industry
12	1.74	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	3.27	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	12.21	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	14.69	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	0.38	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	12.88	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	5.68	902	IND	D	2	0	0	2					40	0	0	40	Industry
12	1.64	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	7.70	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	8.39	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	10.24	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	1.49	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	2.29	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	8.36	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	3.34	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	12.18	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	13.13	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	1.83	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	22.60	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	30.30	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	1.80	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	23.63	904	IND	D	2	0	0	2					40	0	0	40	Industry
12	1.61	904	IND	D	2	0	0	2					40	0	0	40	Industry
13	1.61	902	IND	D	5	0	0	5					100	0	0	100	Industry
13	8.87	902	IND	D	5	0	0	5					100	0	0	100	Industry
13	18.16	902	IND	D	5	0	0	5					100	0	0	100	Industry
13	6.05	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	0.92	902	IND	D	5	0	0	5					100	0	0	100	Industry
14	3.24	902	IND	D	5	0	0	5					100	0	0	100	Industry
14	6.74	902	IND	D	5	0	0	5					100	0	0	100	Industry
14	7.32	902	IND	D	5	0	0	5					100	0	0	100	Industry
14	17.19	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	7.39	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	7.80	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	1.02	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	2.66	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	15.24	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	1.83	904	IND	D	5	0	0	5					100	0	0	100	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
14	12.81	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	14.57	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	19.94	904	IND	D	5	0	0	5					100	0	0	100	Industry
14	16.37	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	4.03	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	0.76	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	9.39	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	12.32	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	15.14	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	13.02	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	3.23	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	14.78	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	6.45	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	3.37	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	6.57	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	21.29	906	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	2.45	908	WIM	T	2	0	0	2					40	0	0	40	S114 2005
14	0.65	908	WIM	T	2	0	0	2					40	0	0	40	S114 2005
15	2.84	902	IND	D	0	2	0	2					0	52	0	52	Industry
15	2.10	902	IND	D	0	2	0	2					0	52	0	52	Industry
15	4.00	904	IND	D	2	0	0	2					40	0	0	40	Industry
15	1.69	904	IND	D	2	0	0	2					40	0	0	40	Industry
15	5.23	906	IND	D	2	0	0	2					40	0	0	40	Industry
15	3.18	906	IND	D	2	0	0	2					40	0	0	40	Industry
16	19.40	902	IND	D	5	0	0	5					100	0	0	100	Industry
16	1.97	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	9.66	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	22.03	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	49.55	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	8.14	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	3.52	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	30.63	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	25.32	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	11.01	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	19.04	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	10.59	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	8.56	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	8.39	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	9.75	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	11.75	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	12.83	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	0.27	904	WIM	D	4	4	0	8					80	104	0	184	A7 2007
16	4.22	906	IND	B	24	4	0	28					480	104	0	584	A7 2007 + Industry on Hwy. 43
16	10.38	908	IND	B	20	3	0	23					400	78	0	478	Hwy. 16(906) - Hwy. 16A
16	6.08	908	IND	B	20	3	0	23					400	78	0	478	Hwy. 16(906) - Hwy. 16A
16	6.69	908	IND	B	20	3	0	23					400	78	0	478	Hwy. 16(906) - Hwy. 16A
16	3.05	908	IND	B	20	3	0	23					400	78	0	478	Hwy. 16(906) - Hwy. 16A
16	3.28	908	IND	B	20	3	0	23					400	78	0	478	Hwy. 16(906) - Hwy. 16A

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
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Road		Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
						Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
16		7.35	910	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		6.49	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		4.94	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		15.52	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		12.34	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		21.21	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		10.98	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		3.91	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		8.80	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		1.88	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		16.26	912	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		20.51	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		13.00	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		13.55	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		21.37	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		19.88	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		16.43	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16		18.84	914	WIM	T	15	12	0	27					300	312	0	612	S106 2005/Industry
16	A	6.77	902	IND	D	4	1	0	5					80	26	0	106	Industry
16	A	4.78	902	IND	D	4	1	0	5					80	26	0	106	Industry
16	A	3.87	902	IND	D	4	1	0	5					80	26	0	106	Industry
16	A	8.36	902	IND	D	4	1	0	5					80	26	0	106	Industry
16	A	3.24	904	IND	D	4	1	0	5					80	26	0	106	Industry
17		14.96	902	WIM	T	2	0	0	2					40	0	0	40	S114 2005
17		16.20	902	WIM	T	2	0	0	2					40	0	0	40	S114 2005
18		8.65	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		4.02	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		6.48	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		17.00	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		7.03	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		16.59	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		3.47	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		22.85	902	IND	D	2	0	0	2					40	0	0	40	Industry
21		11.66	904	IND	D	0	2	0	2					0	52	0	52	Industry
22		6.84	902	IND	D	2	0	0	2					40	0	0	40	Industry
22		12.83	904	IND	D	2	0	0	2					40	0	0	40	Industry
22	X	6.48	902	IND	D	0	1	0	1					0	26	0	26	Industry
22	X	9.71	904	IND	D	2	0	0	2					40	0	0	40	Industry
22	X	6.56	904	IND	D	2	0	0	2					40	0	0	40	Industry
22	X	9.87	904	IND	D	2	0	0	2					40	0	0	40	Industry
23		8.09	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		13.01	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		5.07	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		12.85	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		13.98	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		17.71	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		19.57	902	IND	D	2	0	0	2					40	0	0	40	Industry
23		17.66	902	IND	D	2	0	0	2					40	0	0	40	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

Road	Length (km)	Long Truck Segment	Source	Method	Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				Comment
					Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	
23	8.63	902	IND	D	2	0	0	2					40	0	0	40	Industry
23	16.62	902	IND	D	2	0	0	2					40	0	0	40	Industry
28	13.46	902	AVC	T	39	0	0	39					780	0	0	780	A63 2005
28	7.58	902	AVC	T	39	0	0	39					780	0	0	780	A63 2005
28	8.99	902	AVC	T	39	0	0	39					780	0	0	780	A63 2005
28	6.67	902	AVC	T	39	0	0	39					780	0	0	780	A63 2005
28	16.62	904	IND	D	2	0	0	2					40	0	0	40	Industry
28	11.49	904	IND	D	2	0	0	2					40	0	0	40	Industry
28	11.31	904	IND	D	2	0	0	2					40	0	0	40	Industry
28	26.40	904	IND	D	2	0	0	2					40	0	0	40	Industry
28	3.53	904	IND	D	2	0	0	2					40	0	0	40	Industry
28 A	12.75	902	AVC	T	39	0	0	39					780	0	0	780	A63 2005
28 A	1.55	902	AVC	T	39	0	0	39					780	0	0	780	A63 2005
35	9.28	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	6.51	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	19.49	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	22.95	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	19.95	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	0.84	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	1.64	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	35.39	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	16.22	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	42.78	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	1.80	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	5.15	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	32.74	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	7.80	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	51.66	902	IND	T	10	0	0	10					200	0	0	200	Industry
35	1.53	904	WIM	T	5	0	0	5					100	0	0	100	N2 2008
35	70.69	904	WIM	T	5	0	0	5					100	0	0	100	N2 2008
35	69.66	904	WIM	T	5	0	0	5					100	0	0	100	N2 2008
35	49.24	904	WIM	T	5	0	0	5					100	0	0	100	N2 2008
36	5.89	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	5.97	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	18.23	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	25.96	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	16.77	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	10.15	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	16.17	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	13.56	902	WIM	T	5	0	0	5					100	0	0	100	S107 2006
36	1.08	904	IND	D	5	0	0	5					100	0	0	100	Industry
36	36.90	904	IND	D	5	0	0	5					100	0	0	100	Industry
36	54.46	906	IND	D	2	0	0	2					40	0	0	40	Industry
36	19.86	906	IND	D	2	0	0	2					40	0	0	40	Industry
39	3.29	902	IND	D	2	0	0	2					40	0	0	40	Industry
39	8.88	902	IND	D	2	0	0	2					40	0	0	40	Industry
43	20.39	902	IND	D	5	0	0	5					100	0	0	100	Industry
43	12.23	902	IND	D	5	0	0	5					100	0	0	100	Industry

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

					Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)				
Road	Length (km)	Long Truck Segment	Source	Method	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Comment
43	2.25	902	IND	D	5	0	0	5					100	0	0	100	Industry
43	7.48	902	IND	D	5	0	0	5					100	0	0	100	Industry
43	5.99	902	IND	D	5	0	0	5					100	0	0	100	Industry
43	4.74	902	IND	D	5	0	0	5					100	0	0	100	Industry
43	12.08	902	IND	D	5	0	0	5					100	0	0	100	Industry
43	3.28	904	IND	D	5	0	0	5					100	0	0	100	Industry
43	17.89	904	IND	D	5	0	0	5					100	0	0	100	Industry
43	2.42	904	IND	D	5	0	0	5					100	0	0	100	Industry
43	25.82	906	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	15.64	906	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	9.13	906	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	2.26	906	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	10.18	906	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	36.40	908	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	5.04	910	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
43	7.27	912	IND	D	20	0	0	20					400	0	0	400	Industry
43	17.71	912	IND	D	20	0	0	20					400	0	0	400	Industry
43	13.92	914	IND	D	20	0	0	20					400	0	0	400	Industry
43	1.04	914	IND	D	20	0	0	20					400	0	0	400	Industry
43	8.51	914	IND	D	20	0	0	20					400	0	0	400	Industry
43	37.44	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	15.02	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	17.95	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	5.92	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	34.27	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	8.43	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	4.69	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	18.06	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	2.51	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	10.21	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	5.44	916	IND	D	20	0	0	20					400	0	0	400	Industry
43	4.23	918	IND	D	20	0	0	20					400	0	0	400	Industry
43	16.74	918	IND	D	20	0	0	20					400	0	0	400	Industry
43	1.91	920	IND	D	20	0	0	20					400	0	0	400	Industry
43	16.46	920	IND	D	20	0	0	20					400	0	0	400	Industry
43	5.46	920	IND	D	20	0	0	20					400	0	0	400	Industry
43	19.40	920	IND	D	20	0	0	20					400	0	0	400	Industry
43	6.12	920	IND	D	20	0	0	20					400	0	0	400	Industry
43	7.95	920	IND	D	20	0	0	20					400	0	0	400	Industry
43	9.75	920	IND	D	20	0	0	20					400	0	0	400	Industry
49	20.30	902	IND	D	2	0	0	2					40	0	0	40	Industry
49	32.12	902	IND	D	2	0	0	2					40	0	0	40	Industry
49	13.00	902	IND	D	2	0	0	2					40	0	0	40	Industry
49	22.98	902	IND	D	2	0	0	2					40	0	0	40	Industry
49	8.11	902	IND	D	2	0	0	2					40	0	0	40	Industry
49	4.85	902	IND	D	2	0	0	2					40	0	0	40	Industry
49	12.96	904	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)
49	16.13	904	IND	B	10	0	0	10					200	0	0	200	50/50 split from Hwy. 43 (south)

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

Table C.3: Alberta Long Truck Network Segments (cont…)

		Long Truck			Average daily volume				Average daily RGW (000's of tonnes)				Average daily RGC (CCLs)			
Road	Length (km)	Segment	Source	Method	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total	Rocky	Turnpike	Triple	Total
49	8.09	904	IND	B	10	0	0	10					200	0	0	200
49	36.24	904	IND	B	10	0	0	10					200	0	0	200
49	3.19	904	IND	B	10	0	0	10					200	0	0	200
52	6.52	902	IND	D	2	0	0	2					40	0	0	40
52	2.40	902	IND	D	2	0	0	2					40	0	0	40
53	8.17	902	IND	D	2	0	0	2					40	0	0	40
53	3.21	902	IND	D	2	0	0	2					40	0	0	40
53	10.68	902	IND	D	2	0	0	2					40	0	0	40
53	0.19	902	IND	D	2	0	0	2					40	0	0	40
53	14.57	902	IND	D	2	0	0	2					40	0	0	40
53	3.45	902	IND	D	2	0	0	2					40	0	0	40
55	0.75	902	IND	D	2	0	0	2					40	0	0	40
55	4.41	902	IND	D	2	0	0	2					40	0	0	40
55	26.42	902	IND	D	2	0	0	2					40	0	0	40
60	14.01	902	IND	D	0	0	0	0					0	0	0	0
60	9.72	902	IND	D	0	0	0	0					0	0	0	0
63	12.81	902	AVC	T	39	0	0	39					780	0	0	780
63	21.24	902	AVC	T	39	0	0	39					780	0	0	780
63	15.04	902	AVC	T	39	0	0	39					780	0	0	780
63	15.01	902	AVC	T	39	0	0	39					780	0	0	780
63	8.04	902	AVC	T	39	0	0	39					780	0	0	780
63	1.13	902	AVC	T	39	0	0	39					780	0	0	780
63	15.40	902	AVC	T	39	0	0	39					780	0	0	780
63	22.90	904	AVC	D	39	0	0	39					780	0	0	780
63	55.23	904	AVC	D	39	0	0	39					780	0	0	780
63	46.88	904	AVC	D	39	0	0	39					780	0	0	780
63	43.75	904	AVC	D	39	0	0	39					780	0	0	780
63	47.77	904	AVC	D	39	0	0	39					780	0	0	780
63	31.50	904	AVC	D	39	0	0	39					780	0	0	780
63	12.04	904	AVC	D	39	0	0	39					780	0	0	780
63	4.30	904	AVC	D	39	0	0	39					780	0	0	780
63	20.87	906	IND	D	2	0	0	2					40	0	0	40
69	14.31	902	IND	D	2	0	0	2					40	0	0	40
901	36.06	902	IND	D	2	0	0	2					40	0	0	40
901	4.05	902	IND	D	2	0	0	2					40	0	0	40

Notes: WIM = weigh-in-motion; AVC = automatic vehicle classifier; IND = industry intelligence; M&E = measurement and estimation programs
D = direct; T = transfer; B = flow balance; A = similar highway assignment

APPENDIX D: DYNAMIC AXLE LOAD SPECTRA

Table D.1: Axle Load Distribution Factors for Westbound Rockies at M65 in 2007

Weight Range	Singles (%)		Tandems (%)	Tridems (%)
(tonnes)	Steering Axles	Single Axles		
0.0-0.5	0.0	0.0	0.0	0.0
0.6-1.0	0.0	0.0	0.0	0.0
1.1-1.5	0.0	0.0	0.0	0.0
1.6-2.0	0.1	0.5	0.1	0.0
2.1-2.5	0.5	3.1	0.0	0.0
2.6-3.0	2.0	6.7	0.2	0.0
3.1-3.5	8.4	11.3	0.4	0.0
3.6-4.0	24.4	15.8	1.2	0.4
4.1-4.5	38.2	17.0	1.3	0.4
4.6-5.0	19.5	14.8	1.5	0.7
5.1-5.5	4.3	10.6	2.1	0.0
5.6-6.0	1.4	8.1	2.5	1.8
6.1-6.5	0.7	5.2	3.3	1.1
6.6-7.0	0.3	2.9	5.3	3.3
7.1-7.5	0.1	1.6	5.6	1.5
7.6-8.0	0.0	0.9	7.1	6.3
8.1-8.5	0.0	0.9	7.8	6.6
8.6-9.0	0.0	0.3	8.3	6.6
9.1-9.5	0.0	0.1	7.9	6.6
9.6-10.0	0.0	0.1	7.8	9.9
10.1-10.5	0.0	0.1	7.1	7.7
10.6-11.0	0.0	0.0	6.1	5.9
11.1-11.5	0.0	0.0	5.4	6.6
11.6-12.0	0.0	0.1	3.8	6.3
12.1-12.5	0.0	0.0	3.5	5.1
12.6-13.0	0.0	0.0	2.6	5.1
13.1-13.5	0.0	0.0	1.8	2.6
13.6-14.0	0.0	0.0	1.5	2.2
14.1-14.5	0.0	0.0	1.1	2.6
14.6-15.0	0.0	0.0	0.9	2.9
15.1-15.5	0.0	0.0	0.9	2.2
15.6-16.0	0.0	0.0	0.7	0.7
16.1-16.5	0.0	0.0	0.5	1.8
16.6-17.0	0.0	0.0	0.4	0.4
17.1-17.5	0.0	0.0	0.3	0.4
17.6-18.0	0.0	0.0	0.2	0.4
18.1-18.5	0.0	0.0	0.1	1.1
18.6-19.0	0.0	0.0	0.0	0.4
19.1-19.5	0.0	0.0	0.1	0.0
19.6-20.0	0.0	0.0	0.1	0.0
20.1-20.5	0.0	0.0	0.0	0.0
20.6-21.0	0.0	0.0	0.0	0.0
21.1-21.5	0.0	0.0	0.0	0.0
21.6-22.0	0.0	0.0	0.0	0.4
22.1-22.5	0.0	0.0	0.0	0.0
22.6-23.0	0.0	0.0	0.0	0.0
23.1-23.5	0.0	0.0	0.0	0.0
23.6-24.0	0.0	0.0	0.0	0.0
24.1-24.5	0.0	0.0	0.0	0.0
24.6-25.0	0.0	0.0	0.0	0.0
25.1-25.5	0.0	0.0	0.0	0.0
25.6-26.0	0.0	0.0	0.0	0.0
26.1-26.5	0.0	0.0	0.0	0.0
26.6-27.0	0.0	0.0	0.0	0.0
27.1-27.5	0.0	0.0	0.0	0.0
27.6-28.0	0.0	0.0	0.0	0.0
28.1-28.5	0.0	0.0	0.0	0.0
28.6-29.0	0.0	0.0	0.0	0.0
29.1-29.5	0.0	0.0	0.0	0.0
29.6-30.0	0.0	0.0	0.0	0.0

Table D.2: Axle Load Distribution Factors for Eastbound Rockies at M65 in 2007

Weight Range	Singles (%)		Tandems (%)	Tridems (%)
(tonnes)	Steering Axles	Single Axles		
0.0-0.5	0.0	0.0	0.0	0.0
0.6-1.0	0.0	0.0	0.0	0.0
1.1-1.5	0.1	0.2	0.0	0.0
1.6-2.0	0.5	1.2	0.0	0.0
2.1-2.5	1.4	14.5	0.1	0.0
2.6-3.0	1.4	22.3	0.1	0.0
3.1-3.5	7.5	14.5	0.5	0.0
3.6-4.0	30.2	12.0	1.7	0.0
4.1-4.5	33.5	9.7	4.9	0.0
4.6-5.0	12.2	6.6	6.7	0.0
5.1-5.5	6.5	4.6	7.1	2.2
5.6-6.0	4.2	4.4	7.0	2.7
6.1-6.5	1.6	3.5	6.5	2.7
6.6-7.0	0.7	2.3	6.1	3.5
7.1-7.5	0.1	1.4	6.3	8.8
7.6-8.0	0.0	0.9	5.8	3.1
8.1-8.5	0.0	0.5	5.7	4.0
8.6-9.0	0.0	0.5	5.8	8.4
9.1-9.5	0.0	0.3	5.0	5.8
9.6-10.0	0.0	0.1	4.7	8.0
10.1-10.5	0.0	0.1	4.7	4.9
10.6-11.0	0.0	0.2	4.4	4.4
11.1-11.5	0.0	0.0	3.9	6.2
11.6-12.0	0.0	0.1	3.0	5.8
12.1-12.5	0.0	0.0	2.0	6.6
12.6-13.0	0.0	0.0	1.5	2.2
13.1-13.5	0.0	0.0	1.1	3.5
13.6-14.0	0.0	0.0	1.2	1.3
14.1-14.5	0.0	0.0	0.8	3.1
14.6-15.0	0.0	0.0	0.6	1.3
15.1-15.5	0.0	0.0	0.6	0.9
15.6-16.0	0.0	0.0	0.4	0.9
16.1-16.5	0.0	0.0	0.4	1.3
16.6-17.0	0.0	0.0	0.4	1.3
17.1-17.5	0.0	0.0	0.1	0.9
17.6-18.0	0.0	0.0	0.2	0.4
18.1-18.5	0.0	0.0	0.2	0.4
18.6-19.0	0.0	0.0	0.1	0.4
19.1-19.5	0.0	0.0	0.1	0.4
19.6-20.0	0.0	0.0	0.1	0.4
20.1-20.5	0.0	0.0	0.1	1.3
20.6-21.0	0.0	0.0	0.0	1.3
21.1-21.5	0.0	0.0	0.0	0.0
21.6-22.0	0.0	0.0	0.0	0.4
22.1-22.5	0.0	0.0	0.0	0.0
22.6-23.0	0.0	0.0	0.0	0.0
23.1-23.5	0.0	0.0	0.0	0.0
23.6-24.0	0.0	0.0	0.0	0.0
24.1-24.5	0.0	0.0	0.0	0.4
24.6-25.0	0.0	0.0	0.0	0.4
25.1-25.5	0.0	0.0	0.0	0.0
25.6-26.0	0.0	0.0	0.0	0.0
26.1-26.5	0.0	0.0	0.0	0.0
26.6-27.0	0.0	0.0	0.0	0.0
27.1-27.5	0.0	0.0	0.0	0.0
27.6-28.0	0.0	0.0	0.0	0.0
28.1-28.5	0.0	0.0	0.0	0.0
28.6-29.0	0.0	0.0	0.0	0.0
29.1-29.5	0.0	0.0	0.0	0.0
29.6-30.0	0.0	0.0	0.0	0.0

Table D.3: Axle Load Distribution Factors for Westbound Turnpikes at M65 in 2007

Weight Range	Singles (%)		Tandems (%)	Tridems (%)
(tonnes)	Steering Axles	Single Axles		
0.0-0.5	0.0	0.0	0.0	0.0
0.6-1.0	0.0	0.0	0.0	0.0
1.1-1.5	0.0	0.0	0.0	0.0
1.6-2.0	0.2	0.2	0.0	0.0
2.1-2.5	0.6	1.2	0.1	0.0
2.6-3.0	2.8	4.1	0.4	0.0
3.1-3.5	6.8	10.2	1.5	0.0
3.6-4.0	15.3	16.2	4.1	0.0
4.1-4.5	30.0	16.3	4.7	0.0
4.6-5.0	30.1	17.1	6.1	0.7
5.1-5.5	9.8	11.6	7.3	1.0
5.6-6.0	2.8	8.1	7.4	2.9
6.1-6.5	0.6	4.3	7.4	4.8
6.6-7.0	0.6	3.7	6.4	4.2
7.1-7.5	0.2	2.5	5.5	5.1
7.6-8.0	0.1	1.7	5.2	4.5
8.1-8.5	0.0	1.2	5.2	4.5
8.6-9.0	0.0	0.5	4.9	4.0
9.1-9.5	0.0	0.5	4.6	4.2
9.6-10.0	0.0	0.2	4.5	2.8
10.1-10.5	0.0	0.2	4.2	3.5
10.6-11.0	0.0	0.0	4.0	3.7
11.1-11.5	0.0	0.0	3.4	3.7
11.6-12.0	0.0	0.1	2.8	4.8
12.1-12.5	0.0	0.0	2.2	4.1
12.6-13.0	0.0	0.0	1.8	4.4
13.1-13.5	0.0	0.0	1.3	4.4
13.6-14.0	0.0	0.0	1.0	2.5
14.1-14.5	0.0	0.0	0.7	3.1
14.6-15.0	0.0	0.0	0.6	3.5
15.1-15.5	0.0	0.0	0.5	1.8
15.6-16.0	0.0	0.0	0.4	3.2
16.1-16.5	0.0	0.0	0.4	2.2
16.6-17.0	0.0	0.0	0.3	2.0
17.1-17.5	0.0	0.0	0.2	2.3
17.6-18.0	0.0	0.0	0.2	2.0
18.1-18.5	0.0	0.0	0.1	1.6
18.6-19.0	0.0	0.0	0.1	2.2
19.1-19.5	0.0	0.0	0.1	0.9
19.6-20.0	0.0	0.0	0.1	0.6
20.1-20.5	0.0	0.0	0.1	1.0
20.6-21.0	0.0	0.0	0.0	0.7
21.1-21.5	0.0	0.0	0.0	0.3
21.6-22.0	0.0	0.0	0.0	0.6
22.1-22.5	0.0	0.0	0.0	0.3
22.6-23.0	0.0	0.0	0.0	0.1
23.1-23.5	0.0	0.0	0.0	0.1
23.6-24.0	0.0	0.0	0.0	0.6
24.1-24.5	0.0	0.0	0.0	0.3
24.6-25.0	0.0	0.0	0.0	0.0
25.1-25.5	0.0	0.0	0.0	0.0
25.6-26.0	0.0	0.0	0.0	0.1
26.1-26.5	0.0	0.0	0.0	0.0
26.6-27.0	0.0	0.0	0.0	0.0
27.1-27.5	0.0	0.0	0.0	0.1
27.6-28.0	0.0	0.0	0.0	0.0
28.1-28.5	0.0	0.0	0.0	0.1
28.6-29.0	0.0	0.0	0.0	0.0
29.1-29.5	0.0	0.0	0.0	0.0
29.6-30.0	0.0	0.0	0.0	0.0

Table D.4: Axle Load Distribution Factors for Eastbound Turnpikes at M65 in 2007

Weight Range (tonnes)	Singles (%)		Tandems (%)	Tridems (%)
	Steering Axles	Single Axles		
0.0-0.5	0.0	0.0	0.0	0.0
0.6-1.0	0.0	0.0	0.0	0.0
1.1-1.5	0.0	0.1	0.0	0.0
1.6-2.0	0.2	0.4	0.0	0.0
2.1-2.5	0.6	9.7	0.1	0.0
2.6-3.0	0.6	30.3	0.3	0.0
3.1-3.5	3.0	20.0	1.7	0.0
3.6-4.0	19.9	12.5	6.1	0.3
4.1-4.5	35.9	8.6	9.2	1.0
4.6-5.0	20.9	6.5	8.4	2.6
5.1-5.5	7.4	4.2	7.1	2.2
5.6-6.0	5.3	2.5	6.2	6.3
6.1-6.5	4.1	1.4	5.3	5.1
6.6-7.0	1.8	1.1	4.4	3.8
7.1-7.5	0.3	1.0	4.2	2.6
7.6-8.0	0.0	0.5	3.5	3.2
8.1-8.5	0.0	0.6	4.0	4.6
8.6-9.0	0.0	0.3	4.2	3.7
9.1-9.5	0.0	0.2	4.7	4.3
9.6-10.0	0.0	0.0	4.7	3.7
10.1-10.5	0.0	0.0	4.4	4.3
10.6-11.0	0.0	0.0	3.8	3.0
11.1-11.5	0.0	0.0	3.0	3.8
11.6-12.0	0.0	0.0	2.6	3.2
12.1-12.5	0.0	0.0	2.1	2.1
12.6-13.0	0.0	0.0	1.6	3.4
13.1-13.5	0.0	0.0	1.4	3.4
13.6-14.0	0.0	0.0	1.2	3.8
14.1-14.5	0.0	0.0	1.0	2.7
14.6-15.0	0.0	0.0	0.8	4.2
15.1-15.5	0.0	0.0	0.8	3.0
15.6-16.0	0.0	0.0	0.7	2.1
16.1-16.5	0.0	0.0	0.5	3.2
16.6-17.0	0.0	0.0	0.5	1.8
17.1-17.5	0.0	0.0	0.3	1.9
17.6-18.0	0.0	0.0	0.2	1.4
18.1-18.5	0.0	0.0	0.2	1.6
18.6-19.0	0.0	0.0	0.2	0.5
19.1-19.5	0.0	0.0	0.1	0.6
19.6-20.0	0.0	0.0	0.1	1.1
20.1-20.5	0.0	0.0	0.0	0.8
20.6-21.0	0.0	0.0	0.0	1.0
21.1-21.5	0.0	0.0	0.0	0.2
21.6-22.0	0.0	0.0	0.0	0.6
22.1-22.5	0.0	0.0	0.0	0.8
22.6-23.0	0.0	0.0	0.0	0.2
23.1-23.5	0.0	0.0	0.0	0.2
23.6-24.0	0.0	0.0	0.0	0.3
24.1-24.5	0.0	0.0	0.0	0.0
24.6-25.0	0.0	0.0	0.0	0.3
25.1-25.5	0.0	0.0	0.0	0.0
25.6-26.0	0.0	0.0	0.0	0.2
26.1-26.5	0.0	0.0	0.0	0.0
26.6-27.0	0.0	0.0	0.0	0.2
27.1-27.5	0.0	0.0	0.0	0.0
27.6-28.0	0.0	0.0	0.0	0.2
28.1-28.5	0.0	0.0	0.0	0.0
28.6-29.0	0.0	0.0	0.0	0.0
29.1-29.5	0.0	0.0	0.0	0.2
29.6-30.0	0.0	0.0	0.0	0.2