USING EXPOSURE-BASED EVIDENCE TO ASSESS REGULATORY COMPLIANCE OF PRODUCTIVITY-PERMITTED LONG TRUCKS

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Abstract

This paper uses exposure-based evidence to assess regulatory compliance of productivity-permitted long trucks (Rocky Mountain doubles, Turnpike doubles, and triples). Compliance is considered a latent (unobservable) variable and is expressed as a function of exposure and the regulatory environment. This generic expression is applied to long truck operations in the Canadian Prairie Region by using exposure indicators to assess long truck compliance with network restrictions, weight limits, and safety-related operational conditions. The analysis finds that 99 percent of observed long trucks comply with the undivided highway network restriction and prescribed weight limits. Using exposure-based collision rates as a surrogate for assessing safety compliance, published evidence demonstrates that long trucks have a lower collision rate than other articulated trucks. Better exposure data mining and fusion techniques and the application of advanced monitoring technologies have potential to improve our capability to estimate exposure and thus enhance our understanding of compliance.

Keywords: Exposure, Long Trucks, Compliance, Safety, Truck Weight, Network

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1. Introduction

This paper uses exposure-based evidence to assess regulatory compliance of productivity-permitted long trucks. Productivity-permitted long trucks are multiple trailer configurations, consisting primarily of van trailers, which operate beyond basic vehicle length limitations but within basic weight restrictions. In the Canadian Prairie Region, there are three predominant long truck configurations: Rocky Mountain doubles (Rockies); Turnpike doubles (Turnpikes); and triple trailer combinations (triples). These vehicles operate under special permits granted to increase the technical productivity of hauling relatively low-density freight. Long trucks are subject to regulations concerning highway networks, size and weight, and safety-related operational conditions. The application of exposure indicators—in terms of volume and weight characteristics—provides evidence of long truck compliance with respect to these regulations.

Specifically, the objectives of the paper are to:

- develop a methodological framework for assessing long truck compliance using exposure-based evidence;

- describe regulations governing long truck operations in the Canadian Prairie Region; and

- provide exposure-based evidence of long truck regulatory compliance in the Canadian Prairie Region with network restrictions, weight limits, and safety-related operational conditions.

Our analysis focuses on the Canadian Prairie Region experience with long truck operations, but provides insights and lessons which have general application. This experience began in Alberta in the late 1960s. Over the next four decades, Saskatchewan and Manitoba also permitted long trucks on intra-jurisdictional highway networks. Recent network expansions, a favourable regulatory environment, and rising demand for hauling cubic freight have generated more inter-jurisdictional opportunities for long trucks than were available a decade ago. Today, long trucks operate on rural, principally uncongested highways designed for high speed travel. The long truck network, which measures over 10,000 centreline-kilometres, consists of both divided and undivided routes, and provides connections to all major urban centres in the region. In 2006, long trucks travelled approximately 67 million kilometres on this network. Empirical and anecdotal evidence indicates that long truck volumes are steadily growing on major corridors (e.g., at one location on the Trans Canada Highway in Manitoba long truck volumes nearly doubled between 2005 and 2008) (Regehr, 2009).

2. Methodological Framework

2.1 Compliance as a Latent Transportation System Impact

The transportation systems analysis approach provides the theoretical basis for understanding the relationship between truck regulations and exposure, and assessing regulatory compliance. This approach involves three interrelated elements: (1) the transportation system, T, which is expressed by a service function and consists of vehicles, networks, and the regulatory environment; (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 is expressed in terms of exposure, E, the services that E provides, and the resources consumed by E. The short-term equilibration of the transportation service and demand functions define

F as a function of *T* and *A*. Over time, characteristics of *F* stimulate changes in *A* and *T*, eventually creating a new equilibrium point for *F*.

In this paper, we are concerned with using exposure-based evidence to assess truck compliance with the regulatory environment (i.e., a component of *T*), holding *A* constant. Therefore, as shown by the structural model in Equation 1, we express truck compliance, *C*, as a function of three explanatory variables: a set of truck traffic exposure indicators, *E*; a set of inherent transportation system indicators, *T*, that define the regulatory environment; and a set of exogenous transportation system indicators, *X*, that describe relevant political and environmental factors. We define truck traffic exposure as the number and nature of truck traffic events at a point or along a segment, in a specified time. Exposure has three principal dimensions—volume, weight, and cube (Regehr, Montufar, and Middleton 2009)—although only volume and weight indicators are used in this paper. Equation 1 is expressed generically here and applied to long trucks in subsequent sections of this paper.

$$C = f(E, T, X) \tag{1}$$

where:

C: truck compliance (latent)
E: set of truck traffic exposure indicators
T: set of inherent transportation system indicators
X: set of exogenous transportation system indicators

Compliance is considered a latent or unobservable dependent variable in Equation 1. The expression of a latent variable within a structural equation model is a statistical technique that is useful when direct measurement is not possible (Washington, Karlaftis, and Mannering 2003). Examples of the use of this technique in the field of highway management are Ben-Akiva and Ramaswamy (1993), Ben-Akiva and Gopinath (1995), Madanat, Mishalani, and Ibrahim (1995), and Jang (2003). Our intent is to provide an underlying theoretical framework for using exposure as a means of assessing compliance, rather than to predict compliance by fully characterizing the explanatory variables in Equation 1.

In the context of compliance, the latent variable concept is illustrated by realizing that it is impossible to measure compliance in a holistic sense. That is, we cannot measure the proportion of trucks that comply with all specified regulations—network-related restrictions, size and weight limits, and safety-related operational conditions—at all places and times. Yet, the goal of these regulations and the enforcement programs that support them is compliance. Without direct measurement capability, it is difficult for road agencies to monitor and evaluate the degree to which compliance is achieved. However, using exposure as the basis, it is possible to measure aspects of compliance—in effect, to measure manifestations of on-road compliance using exposure indicators. To capture the essence of this idea, we have purposefully used the term *assess* when referring to the measurement of these manifestations.

This approach expands on the conventional notion of commercial vehicle enforcement by shifting the emphasis away from capturing violations via roadside inspections to assessing compliance. Although inspection-based enforcement is attractive because its metrics (inspections, violations, and out-of-service orders) are measurable, these metrics may tend to encourage programs which are judged based on the number of violations captured rather than the compliance achieved—which is the ultimate goal. Compliance assessment, rather, relies

on publicly-available exposure-based evidence of regulatory compliance (as discussed in this paper), and/or vehicle and driver monitoring technologies deployed by carriers to enable demonstration of compliance. This shift in emphasis is already occurring in Australia through the alternative compliance scheme (NRTC, 1998), and has been advanced at the conceptual level in North America by the Transportation Research Board (2003) and Fekpe, Gopalakrishna and Woodrooffe (2006).

2.2 Using Exposure Indicators to Assess Regulatory Compliance

By measuring exposure, it is possible to assess the compliance of long trucks with aspects of the regulations that govern their operation. Three measurable exposure-based indicators are examined. First, long truck volumes (by vehicle type) measured at points on the long truck network provide an indication of compliance with network-related restrictions that prohibit certain types of long trucks on those portions of the network. Second, axle and gross vehicle loads, which are a direct measure of long truck exposure, provide an indication of compliance with weight limits. Third, exposure-based collision rates, which are a function collision frequency by vehicle type and exposure (typically vehicle distance travelled), are a measurable surrogate of compliance with safety-related operational conditions.

3. Regulations Currently Governing Long Truck Operations

3.1 Network Restrictions

Figure 1 shows the Canadian Prairie Region rural long truck network as of October 31, 2008. 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.

3.2 Size and Weight Limits

In Canada, size and weight limits for long trucks are defined by provincial regulatory agencies. Figure 2 depicts typical configurations and trailer dimensions of the predominant long trucks operating in the Canadian Prairie Region. Further details are provided by Regehr (2009). Long trucks have van (sometimes container) body types. Length and gross vehicle weight (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 8.7-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 8.7-m van pup semitrailer followed by two 8.7-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.
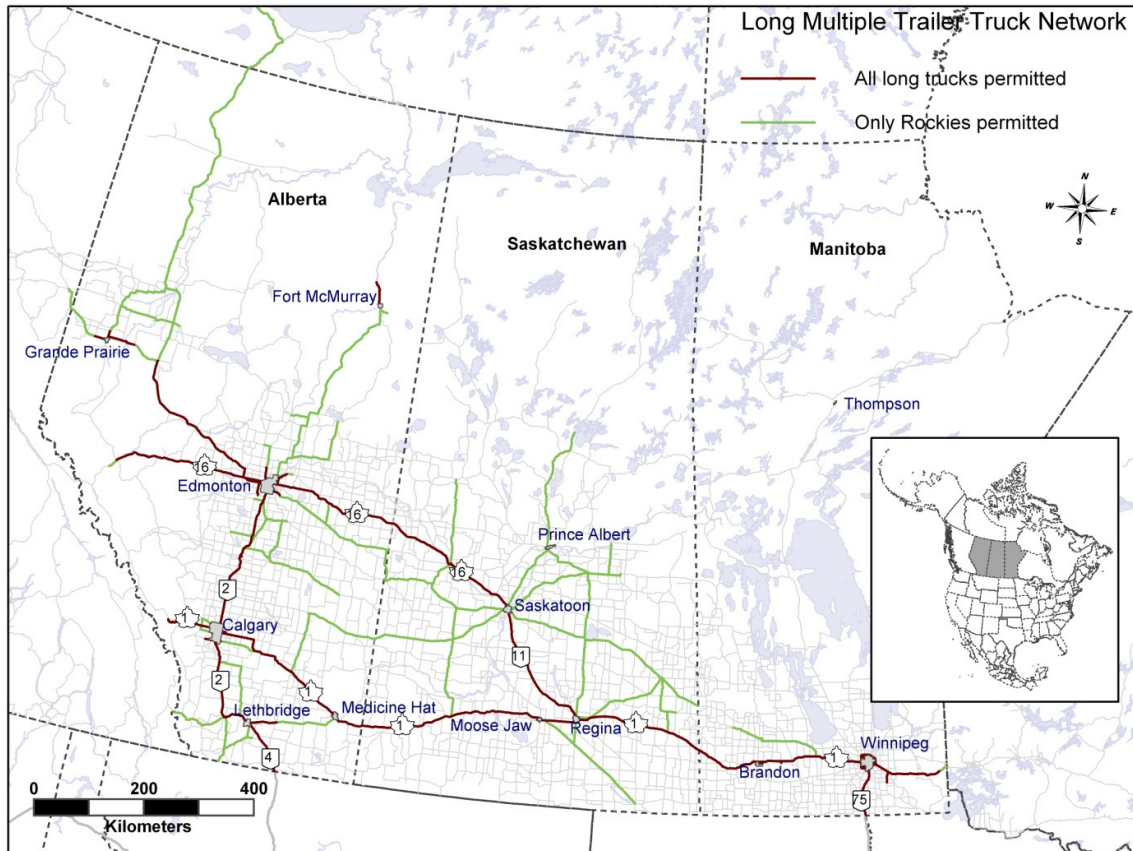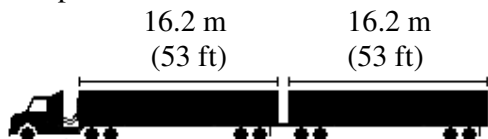
Figure 1 – Canadian Prairie Region Long Truck Network as of October 31, 2008

Source: Adapted from figure in *Intelligent Transport Systems* by Regehr, Montufar, and Middleton (2009).

Rocky Mountain double
16.2 m   8.7 m
(53 ft)   (28.5 ft)

Turnpike double
16.2 m   16.2 m
(53 ft)   (53 ft)
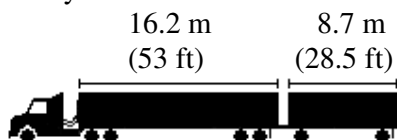
Triple trailer combination
8.7 m   8.7 m   8.7 m
(28.5 ft)   (28.5 ft)   (28.5 ft)
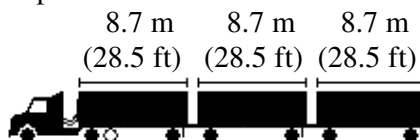
Figure 2 – Routinely-Permitted Long Trucks in the Canadian Prairie Region

3.3 Special Permit Conditions

Long truck operations in the Canadian Prairie Region are subject to unique regulations concerning weather and road conditions, temporal restrictions, driver training and qualifications, operating speed, passing activity, vehicle-related requirements, and special permit charges. These conditions are principally directed at improving safety performance and achieving economic objectives. A survey of the three Canadian Prairie Region jurisdictions conducted in 2007 reveals the following about long truck permitting practices:

- 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 by 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 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. 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. At the time of the survey, these restrictions imposed speed differentials between long trucks and other vehicles in Alberta and Saskatchewan, but not in Manitoba.

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

- Each province specifies vehicle-related requirements for long trucks differently. Requirements are based on the following considerations: minimum speed on grade, minimum power-to-weight ratio, maximum trailer sway, heavy trailers preceding lighter trailers, and off-tracking limitations.

- There is no standard method or rationale used in the Canadian Prairie Region for establishing charges for long truck permits.

4. Evidence of Long Truck Regulatory Compliance

This section provides evidence of long truck regulatory compliance by applying the methodological framework developed in Section 2. Volume indicators are used to assess long truck compliance with network restrictions; axle and gross vehicle loads are used to assess compliance with weight limits; and exposure-based collision rates provide an indication of the performance manifestation of safety-related operational conditions. None of this evidence can or does demonstrate complete compliance with existing regulations, but it does enable a pragmatic assessment of compliance with aspects of these regulations.

4.1 Compliance with Network Restrictions

Compliance with network restrictions is assessed using indicators of long truck volume. Regulations governing long trucks in the Canadian Prairie Region specify that, barring minor exceptions, Turnpikes and triples are not permitted on undivided highways. Application of a vehicle classification algorithm (see Regehr, Montufar, Middleton 2009) to weigh-in-motion (WIM) data collected on undivided highways in the long truck network provides the volume indicators used to assess compliance with this restriction. The premise behind this approach is that observations of Turnpikes and triples at these locations represent non-compliant events.

Table 1 shows the results of this analysis at nine WIM stations located on undivided highways. Average volumes are calculated by dividing the number of long trucks isolated by the classification algorithm by the number of days per year that the WIM. Effectively no Turnpikes or triples are observed at these locations, and the average daily volume of Turnpikes and triples is near zero (always less than one). These results show that at these locations, during the observed days, there was (nearly) complete compliance with the undivided highway network restriction. The table also shows the number of Rockies observed (compliant events) and their average daily volume to provide a reference indication of truck activity at these locations. The average Rocky volume at all but one location (Langenburg) is between two and 13 vehicles per day. In sum, at these nine locations, 99 percent of observed long trucks (7108 of 7195) are compliant.

Table 1 – Long Trucks Observed at WIM Stations on Undivided Highways

WIM Location	No. Days	Rockies (compliant)		Turnpikes (non-compliant)		Triples (non-compliant)	
		No. isolated	Daily average	No. isolated	Daily average	No. isolated	Daily average
Saskatchewan							
Hwy. 16 (Plunkett)	93	303	3	0	0	0	0
Hwy. 1 (Fleming)	270	3535	13	10	*	2	*
Hwy. 11 (Duck Lake)	260	1157	4	0	0	9	*
Hwy. 7 (Alsask)	57	266	5	6	*	0	0
Hwy. 16 (Langenburg)	247	10	*	1	*	2	*
Hwy. 39 (Lang)	274	719	3	0	0	13	*
Hwy. 14 (Farley)	31	75	2	0	0	0	0
Alberta							
Hwy. 2A (Leduc)	365	476	2	42	*	2	*
Northwest Territories							
Hwy. 3 (Ft. Providence)	121	567	5	0	0	0	0

Note: The asterisk (*) denotes a daily average greater than zero but less than one.
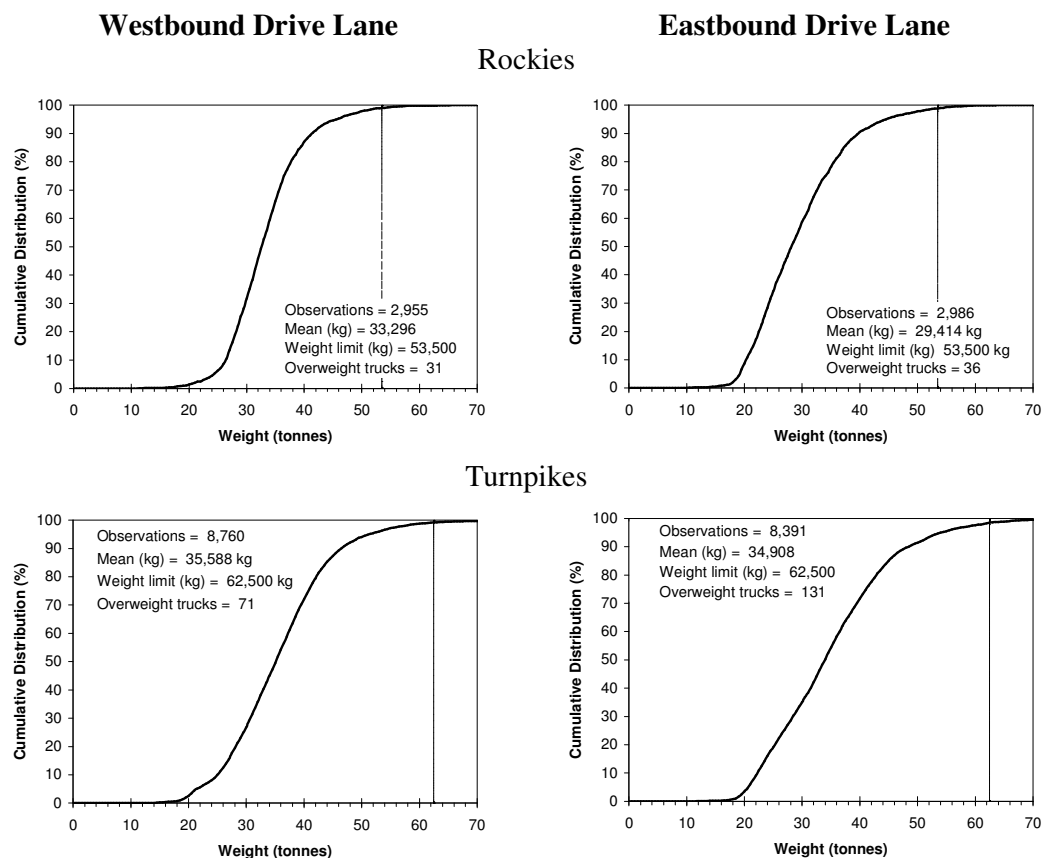
4.2 Compliance with Weight Limits

Compliance with weight limits is assessed using WIM data to determine dynamic gross vehicle and axle load distributions.

Source Data
Dynamic load distributions are developed from a full year of weight data collected in 2007 at a WIM station (M65) on the Trans Canada Highway (Highway 1), approximately 110 km west of Winnipeg, Manitoba. Piezoelectric axle weight sensors are installed in the westbound and eastbound drive lanes; no weight data are available for the two passing lanes. The WIM sensors have been calibrated regularly over the past several years for axle weights, axle spacing, vehicle length, and speed. 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).

Dynamic Load Distributions for Long Trucks
Figure 3 shows dynamic gross vehicle load distributions for Rockies (5941 observations) and Turnpikes (17,151 observations) at WIM M65 in 2007 by direction. The number of triples observed at this location is too small for meaningful analysis.

Westbound Drive Lane   **Eastbound Drive Lane**

Rockies

Observations = 2,955
Mean (kg) = 33,296
Weight limit (kg) = 53,500
Overweight trucks = 31

Observations = 2,986
Mean (kg) = 29,414 kg
Weight limit (kg) 53,500 kg
Overweight trucks = 36

Turnpikes

Observations = 8,760
Mean (kg) = 35,588 kg
Weight limit (kg) = 62,500 kg
Overweight trucks = 71

Observations = 8,391
Mean (kg) = 34,908
Weight limit (kg) = 62,500
Overweight trucks = 131

Figure 3 – Dynamic Gross Vehicle Load Distributions for Rockies and Turnpikes by Direction at M65 in 2007

Observations about these distributions follow:

- Based on the dynamic weight measurements, about 99 percent (5874 of 5941) of Rockies in both directions comply with their GVW limit of 53,500 kg. Similarly, about 99 percent (16,949 of 17,151) of Turnpikes in both directions comply with their GVW limit of 62,500 kg. By comparison, 94 percent of eight-axle B-trains, which are also limited to a GVW of 62,500 kg but do not require a special operating permit, comply with their GVW limit at the same location over the same time period.

- Despite having a GVW limit of 53,500 kg (most Rockies operate with A-dollies), nearly nine of 10 Rockies (in either direction) operate at GVWs less than the 39,500-kg GVW limit for five-axle tractor semitrailers. Similarly, about seven of 10 Turnpikes (in either direction) operate at GVWs less than the GVW limit for five-axle tractor semitrailers, despite being subject to a 62,500-kg limit.

- Each of the four cumulative distributions shown in Figure 3 exhibit a sigmoidal (S-shaped) functional form, which is typical for trucks carrying a wide range of commodities (Fekpe and Clayton, 1994). Three heuristic rules for long truck (cubic) traffic follow from this form: (1) empty trucks comprise the lowest 10 percent of GVW observations; (2) the GVW of partially loaded trucks is evenly distributed between the lowest 10 percent and highest 15 percent of GVW observations (linear portion); and (3) the heaviest loads comprise the highest 15 percent of GVW observations. Neither the Rocky nor Turnpike distributions exhibit peaks distinguishing empty from loaded vehicles.

Table 2 shows the results of an analysis of axle load distributions by axle group (steering, single, tandem, and tridem) for Rockies and Turnpikes. Of the 91,874 observations of single axles, tandems, and tridems, approximately 99 percent comply with prescribed axle weight limits. Steering axles (23,092 observations) are less compliant, with about 95 and 92 percent of the observations complying with the prescribed limit for Rockies and Turnpikes, respectively. However, these measurements reflect tractor weight characteristics rather than freight characteristics and are also observed on other truck configurations.

Table 2 – Dynamic Axle Load Statistics for Rockies and Turnpikes at M65 in 2007

	Observations in both directions	Mean (kg)	Weight limit (kg)	Compliant observations (%)
Rockies				
Steering axles	5941	4194	5,500	95.4
Single axles	9927	4169	9,100	99.4
Tandems	13,078	8761	17,000	99.0
Tridems	498	10,729	24,000	99.6
Turnpikes				
Steering axles	17,151	4432	5,500	92.2
Single axles	4487	4180	9,100	99.5
Tandems	62,577	7904	17,000	98.9
Tridems	1307	11,708	24,000	99.0

4.3 Compliance with Safety-Related Conditions

Compliance with safety-related conditions is assessed through a synthesis of recent, relevant literature in which exposure-based collision rates for long trucks are reported. Collision rates are not a direct measure of compliance with detailed safety-related conditions (e.g., vehicle specifications, driver requirements); however, they do provide a surrogate measure of the objective of these regulations, which is on-road safety performance as a function of exposure. Collision rates for long trucks reported in relevant Canadian literature are shown in Table 3.

Table 3 – Long Truck Collision Rates Calculated by Canadian Studies

Jurisdiction	Author(s)	Collision rates (collisions/100 million kilometres-travelled)		Year(s) of analysis	Exposure data sources
Alberta	Regehr, Montufar, and Rempel, 2009	Turnpikes: Rockies: Triples: All long trucks:	16 32 62 25	1999-2005	Principally WIM
Québec	L-P Tardif & Associates Inc., 2006	Turnpikes: Rockies: Triples: All long trucks:	24 n/a n/a n/a	2001-2005	Carrier-reported
Saskatchewan	Trialpha Consulting Limited, 2000	Turnpikes: Rockies: Triples: All long trucks:	0 0 0 0	1999	Carrier-reported
Alberta	Woodrooffe, 2001	Turnpikes: Rockies: Triples: All long trucks:	20 10 17 16	1995-1998	National Roadside Survey
Canada	Nix, 1995	Turnpikes: Rockies: Triples: All long trucks:	n/a n/a n/a 15-19	1991-1992	Carrier-reported

Note: n/a = not available.

Regehr, Montufar, and Rempel (2009) calculate collision rates for five articulated truck groups: Rockies, Turnpikes, triples, legal-length doubles (primarily eight-axle B-trains), and single-trailer trucks (with five or six axles). The rates are calculated for travel on the Alberta long truck network using seven years of collision and exposure data. The exposure estimates are developed principally from WIM data. The results show that Turnpikes have the lowest collision rate of all articulated truck types (16 collisions per 100 million kilometres-travelled). This rate is half the rate calculated for Rockies, one-third the rate for legal-length doubles and single-trailer trucks, and one-fourth the rate for triples.

An earlier study in Alberta by Woodrooffe (2001) also concludes that long trucks out-perform articulated trucks not subject to special permits by a factor of five for single-trailer trucks and 6.5 for legal-length doubles. Woodrooffe specifically attributes this difference to the safety-related permit conditions placed on long truck operations in Alberta. A specialized roadside survey conducted in 1999 provided the basis for the exposure estimates in this study. The other three studies (L-P Tardif & Associates, 2006; Trialpha Consulting Limited, 2000; and

Nix, 1995) do not provide collision rate comparisons between long trucks and other articulated configurations and are based on carrier-reported exposure data.

5. Concluding Remarks

Long trucks operate under special permits granted because of the productivity advantages they offer for hauling low density freight. These permits specify regulations related to networks, size and weight, and safety, and thereby define a higher level of expected regulatory performance than for trucking not subject to special permits. This paper presents a framework for assessing compliance of long truck operations with these regulations, and uses exposure-based indicators to provide evidence of compliance.

Specifically, compliance with network-related restrictions is assessed by measuring long truck volumes (by class) at nine WIM stations on undivided highways. The results show that 99 percent of observed long trucks are Rockies, which represent compliant events at these locations. An analysis of (dynamic) gross vehicle and axle load distributions also indicates a high level of compliance, with about 99 percent GVW and axle group observations (except steering axles) complying with prescribed (static) weight limits. Finally, a review of literature regarding long truck safety performance provides an indication of the manifestation of safety-related regulations through the calculation of exposure-based collision rates by vehicle type. Where comparisons are available, long trucks out-perform articulated trucks not subject to special permit conditions, implying that the safety-related conditions placed on long truck operations improve their safety performance (as measured by collision rates).

Despite being difficult to measure or evaluate directly, complete compliance with all regulations at all times and places is the ultimate goal of truck regulatory and enforcement programs. This expectation is particularly applicable for long truck operations which are granted permits because of their productivity advantages, but are subject to a unique set of conditions incremental to those specified for non-permitted operations. From a traditional enforcement perspective, these additional requirements pose a challenge as they demand more inspection resources. However, the special permit mechanism also presents an opportunity to move towards performance-based or alternative compliance schemes, in which carriers demonstrate compliance and provide an auditable record of performance. Adoption of advanced vehicle and driver monitoring and reporting technologies (which could be a mandated requirement of the permit), coupled with more intelligent exposure data mining and fusion techniques will enable an even more comprehensive understanding of exposure and ultimately compliance.

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