Lessons learned about the impacts of size and weight regulations on the articulated truck fleet in the Canadian prairie region

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Abstract: Three highway engineering policies directed at improving truck productivity by increasing size and weight limits have been implemented in the Canadian prairie region within the last 35 years: the 1974 Western Canada Highway Strengthening Program, the 1988 Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions, and special permitting of longer combination vehicles. As policies change, the trucking industry adjusts its fleets to take advantage of available efficiencies. Evidence of these changes and the lessons learned from the adoption of these policies are provided. Ultimately, as a result of these policies, articulated trucks now carry heavier and larger payloads, have different axle configurations, and have higher axle weight limits than they did 35 years ago. The threefold to fivefold increase in articulated truck volumes that occurred during this period would have been more dramatic had these policies not been implemented. Further research is necessary to understand the interactions among policies, vehicles, and infrastructure.

Key words: articulated trucks, fleet mix, truck size and weight regulations, highway network.

Résumé : Trois politiques de génie routier visant à améliorer la productivité des gros porteurs en augmentant les limites de dimensions et de poids ont été implantées dans la Région des Prairies du Canada au cours des 35 dernières années : le Programme canadien d'amélioration du réseau routier de l'Ouest en 1974, le Protocole d'entente sur les poids et les dimensions des poids lourds de l'Association des transports du Canada en 1988, et l'autorisation spéciale pour de longs ensembles routiers. Lorsque les politiques changent, l'industrie du camionnage ajuste sa flotte afin de profiter des nouvelles efficacités disponibles. Nous fournissons les attestations de ces changements et les leçons apprises de l'adoption de telles politiques. Il découle de ces politiques que les poids lourds articulés transportent des charges plus lourdes et plus larges en utilisant différentes configurations d'essieux, avec des poids par essieu supérieurs à il y a 35 ans. L'augmentation évidente du volume des poids lourds articulés par 3 ou par 5 durant cette période aurait été encore plus importante sans l'implantation de ces politiques. Une recherche plus approfondie est nécessaire afin de mieux comprendre les interactions entre les politiques, les véhicules et les infrastructures.

Mots-clés : poids lourds articulés, composition de la flotte, règlements concernant les dimensions et le poids des véhicules lourds, réseau autoroutier.

[Traduit par la Rédaction]

Introduction

Three uniquely Canadian and purposeful highway engineering policies have impacted the articulated truck fleet mix characteristics in the Canadian prairie region over the past 35 years: the 1974 Western Canada Highway Strengthening Program (WCHSP), the 1988 Roads and Transportation Association of Canada (RTAC) Memorandum of Understanding (MoU) on Heavy Vehicle Weights and Dimensions, and special permitting of longer combination vehicles (LCVs).

These engineering policies improved the technical productivity of trucking by allowing major increases in the weights and dimensions of large trucks operating on Canadian prairie region highways. They had fundamental civil engineering implications for highway network planning, as well as for the design and evaluation of road geometry, pavements, and bridges, which require the specification of a design vehicle and (or) detailed information about truck volume, configuration, and weight. In addition, they impacted road safety, highway financing, modal competition, and energy efficiency. All three policies represented a major divergence from the U.S. truck size and weight standards enunciated in Bridge Formula B, U.S. federal transportation bills, and state regulations.

This paper considers the impacts of these policies on the articulated truck fleet mix and provides lessons learned from their adoption. The impacts are measured through the analysis and synthesis of truck traffic data collected on Manitoba roads over a period of 35 years. The analysis focuses on

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these impacts as evidenced in trucking activity on the Canadian National Highway System (NHS) network in western Canada, and Manitoba in particular. Understanding the impacts of these policies on fleet mix characteristics provides the insight necessary for estimating future truck volumes and loadings in the Canadian prairie region, which can in turn provide a better basis upon which to make future decisions about the design, operation, and management of roads.

In addition to the direct policy impacts, changes in regional truck fleet characteristics — and the design and implementation of the policies themselves — have been influenced by many industry, regulatory, and societal factors. Globalization and international trade agreements have stimulated growth in the total quantity of freight transported in the region, in North America, and worldwide. The reduction in freight density, coupled to this growth, has resulted in increases in freight movement for all modes (AASHTO 2007; Bingham 2008). These influences are evidenced, for example, by the fourfold increase in the distance travelled by articulated trucks in the U.S. between 1970 and 2003 (Bureau of Transportation Statistics 2006). In addition, the deregulation of the domestic trucking and rail industries, the technological, infrastructure, and corporate changes within the rail industry, and the advent of intermodalism in the early 1990s have altered the competitive interface between truck and rail modes. Finally, the gradual, undirected, and unevaluated expansion of the cubic capacity of domestic freight containers and trailers — from 12.2 m (40 ft.), to 13.7 m (45 ft.), to 14.6 m (48 ft.), and to the current widely adopted 16.2 m (53 ft.) length — has increased freight transport productivity throughout North America (Clayton et al. 2003; MariNova Consulting and Partners 2006).

Highway engineering policy details

It is useful to consider truck size and weight regulations in terms of basic limits, seasonal variations in these limits (i.e., spring weight restrictions and winter weight premiums), and legally permitted oversize/overweight limits (Montufar and Clayton 2002). The 1974 WCHSP and the 1988 RTAC MoU provided increases in basic truck weight (subject to seasonal variations) and basic truck length.. Longer combination vehicles, which operate within basic weight limits, exceed basic length limits and thus require special oversize operating permits.

Western Canada Highway Strengthening Program (1974) and derivatives

The 1974 WCHSP saw the commitment of federal financial assistance to each of the western provinces to help them strengthen their pavements and bridges, provided the provinces agreed to allow heavier and larger trucks on principal highways in the region. The intention was to make trucking more competitive with rail on long interprovincial hauls, thereby reducing freight transport costs for prairie-based industrial and commercial businesses. As a result of the program, the three prairie provinces replaced their single:tandem:gross vehicle weight limits (GVWs) of 8.2:14.6:33.6 t with 9.1:16.0:50.0 t on primary highways. This had two direct effects: (*i*) it allowed standard five-axle tractor semitrailers (3-S2s) to immediately increase their GVWs to 36.6 t on major routes; and (*ii*) it permitted double-trailer combinations with six or seven (and sometimes eight) axles to be used effectively on major routes at GVWs of up to 50.0 t. Both effects in turn permitted large increases in payload and technical productivity, and thereby the theoretical opportunity to lower truck operating costs and rates per unit of freight handled (Clayton and Nix 1986).

In 1982, the prairie provinces further increased GVWs on primary highways to 53.5 t in Alberta and Saskatchewan and 56.5 t in Manitoba. In addition, GVWs on most secondary highways were increased from 33.6 to 49.0 t. This permitted double trailer combinations on primary highways to operate at the full gross vehicle weight (GVW) capability (i.e., the summation of all allowable axle weights (seven axles in Saskatchewan and Alberta and eight in Manitoba)), and also allowed them to be used effectively even off the primary highway network. This use of double trailer combinations on secondary roads meant that much of the region's dense bulk commodity movements, which originated and terminated off the primary system (e.g., grain, fertilizer, lumber, and petroleum), could now benefit from the relaxed weight and dimension limits (Clayton and Nix 1986).

Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions (1988)

As a result of a major technical analysis of Canadian commercial vehicle weights and dimensions through the mid-1980s, all Canadian jurisdictions agreed to a new common set of weight and dimension regulations applicable to major highways across the country. These regulations were directed to meet a combination of uniformity, economic, and safety objectives. For primary highways in the Canadian prairie region, these new RTAC regulations had three basic aspects: (*i*) an increase in the basic GVW limit from 56.5 to 62.5 t, depending on vehicle configuration, (*ii*) an increase in the tandem-axle load from 16.0 to 17.0 t, and (*iii*) the specification of a new tridem-axle group with an associated weight limit of up to 24.0 t, which could be used on semitrailers and in eight-axle B-train configurations. Associated with these changes were increases in the allowable lengths of semitrailers (from 14.6 to 16.2 m, an increase largely stimulated by developments in the U.S.) and those of double trailer combinations (from 23 to 25 m) in the western region and (subsequently) beyond (IBI Group and ADI Limited 1987; Nix 1993; Clayton et al. 2003). More recently, the geographical and temporal scope of RTAC truck operation has increased through the expansion of the road networks on which the vehicles can operate, and the permitting of truck operation during winter freeze-up on non-primary highways. Also, other fine-tuning adjustments in the regulations have been and continue to be made (e.g., Alberta now allows eight-axle B-train configurations to operate at a GVW of 63.5 t).

Special permitting of longer combination vehicles

In the Canadian prairie region, LCVs operate as multiple-trailer truck configurations consisting of van trailers or containers that exceed basic vehicle length limits (25 m) but operate within basic weight restrictions. They have operated

Table 1. Six major articulated truck configuration groups in the Canadian prairie region.

Configuration group	Representative truck configuration	Axle configurations
Three-, four-, and five-axle tractor semitrailers		2-S1, 2-S2, 3-S1, 3-S2 (shown)
Six-axle tractor semitrailers		3-S3
Five-, six-, seven-, and eight-axle A-trains		2-S1–2, 3-S2–2 (shown), others
Seven-axle B-trains		3-S2-S2
Eight-axle B-trains		3-S3-S2
Specially permitted LCVs		3-S2–4 turnpike (shown), others

under special permit in the Canadian prairie region since the late 1960s, principally with the purpose of increasing the technical productivity of general freight trucking (Burns 1983). These LCV operations did not emerge on a regional level as a result of a specific highway engineering policy (Nix 1995), but materialized separately in each of the three prairie provinces as demand for their operation intensified and suitable highway networks developed. Their operation represents a divergence from the U.S. federal regulatory freeze on LCV operations pursuant to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.

There are three predominant LCV configurations: (*i*) Rocky Mountain doubles (Rockies), with a maximum length of 31 m (31.5 m in Manitoba); (*ii*) turnpike doubles (turnpikes), with maximum lengths between 38 m (in Alberta) and 42 m (in Saskatchewan); and (*iii*) triple trailer combinations (triples), with a maximum length of 35 m (38 m in Saskatchewan). These dimensions represent a 50% to 100% increase in cubic capacity relative to standard tractor semitrailers, which have a maximum length limit of 23 m. Unlike U.S. LCVs, however, Canadian LCVs do not operate at higher GVWs than trucks under regular operation (Regehr and Montufar 2007).

Impacts on truck fleet mix characteristics

Analysis framework

The primary and most obvious indicator of the effects of new truck size and weight limits are changes in the types and characteristics of trucks operating on a highway. This paper focuses on impacts associated with articulated trucks (i.e., being one of the six major configuration groups used in the region); maximum basic weight and dimension regulations prescribed and allowed for year-round operation in the region (except specially permitted LCVs, which operate within basic weight restrictions but beyond basic length limits); and operations on the four cardinal direction Canadian National Highway System (NHS) corridors centred on Winnipeg, Manitoba.

An articulated truck is a tractor towing a single, double, or triple trailer combination. The six major configuration groups of articulated trucks are illustrated in Table 1.

These configurations are subject to weight and dimension limits that vary by jurisdiction, highway, truck configuration, axle type, axle spreads and spacing, tire size, season, age of vehicle, and other factors. The regulations are complex and have important operational effects. The impact of seasonal weight limits on truck fleet mix is not considered here, as the data sources are taken to represent year-round traffic conditions. The application of seasonal weight limits affects the composition of the truck fleet, particularly in the proportion of trucks carrying weigh-out commodities on secondary roads (Montufar and Clayton 2002). The scope of this analysis is limited to the fleet mix impacts on primary highways, which experience the indirect effects of fleet mix changes on secondary roads that feed the primary system.

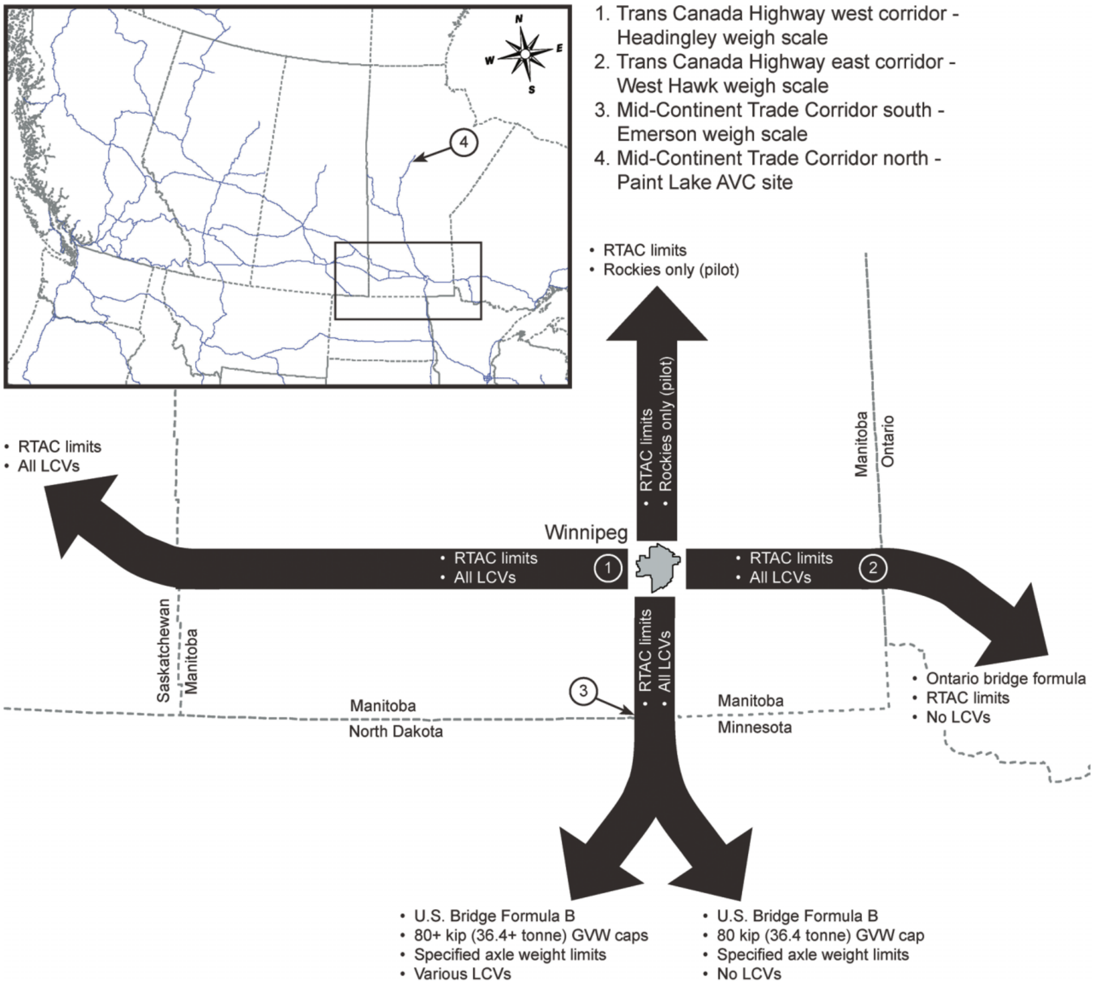
Winnipeg is situated at the crossroads of the Mid-Continent Trade Corridor and the Trans Canada Highway (Canada's main east–west highway), and is a gateway for freight transport to and from the Canadian North. Like each of the other major Canadian prairie region cities, routes connecting to Winnipeg from each of the four cardinal directions are designated as part of the NHS. In the case of Winnipeg, however, truck traffic characteristics on each of the four routes — shown schematically in Fig. 1 — are uniquely impacted by the governing Manitoba truck size and weight regulatory scheme as well as the schemes in effect in neighbouring jurisdictions.

As such, an investigation into the impacts of regulatory changes on truck fleet mix over time at certain locations along these routes is particularly instructive. While the chosen locations do not provide a total examination of the network, they do provide a useful representation of what has happened on major portions of the NHS in the Canadian prairie region over the last 35 years. Each location experienced similar increases in truck size and weight limits after the introduction of the WCHSP in 1974 (and its derivatives) and after the ratification of the RTAC MoU in 1988, as well as by being included (at various times) in the network allowing specially permitted LCVs.

Data sources

Classification surveys conducted at permanent weigh scale sites on the western, eastern, and southern legs of the analysis network provided much of the fleet mix data presented in this paper. In more recent years, these surveys were supplemented by classification data from automatic vehicle classifiers (AVCs) and weigh in motion (WIM) devices located near these scales or along the routes on which the scales are situated. Specialized algorithms (see Regehr and Montufar 2007) and industry intelligence were required to establish the proportion of certain classes of articulated trucks from AVC and WIM data (e.g., various types of A-trains and LCVs). Fleet mix and truck volume data were as-

Fig. 1. Schematic of fleet mix analysis network in relation to the Canadian National Highway System network and U.S. Interstate Highway System network. RTAC, Roads and Transportation Association of Canada; LCV, longer combination vehicles; GVW, gross vehicle weight.



sembled from documents published between 1973 and 2007, namely: Trimac (1973); Transport Canada (1974); Clayton and Lai (1986); U.S. Department of Transportation (1995); Regehr and Montufar (2007); and a series of documents and theses produced by the University of Manitoba Transport Information Group between 1989 and 2007.

Trans Canada Highway west corridor

Classification data on the Trans Canada Highway west corridor was collected between 1974 and 2005 at the Headingley weigh scale located 7.5 km west of Winnipeg on the Trans Canada Highway. This site processes both extraprovincial and intraprovincial truck traffic. These surveys are supplemented by AVC data available since the early 1990s. The WIM device located at MacGregor, Manitoba, (110 km west of Winnipeg) was used to develop LCV volumes. The LCV volume observed at MacGregor is applicable to the Headingley site, since the majority of LCVs passing through MacGregor also pass through Headingley.

Trans Canada Highway east corridor

Classification data on the Trans Canada Highway east corridor was collected between 1974 and 2005 at the West Hawk weigh scale, located 1.2 km west of the Manitoba–Ontario border, on the Trans Canada Highway. This site processes all truck traffic between western and central/eastern Canada that uses Canadian routes. This traffic is solely extraprovincial. The devices (WIM and AVC) installed at the Brokenhead River (85 km west of the Manitoba–Ontario border), which process essentially the same articulated truck traffic as the West Hawk scale, provide supplementary classification data.

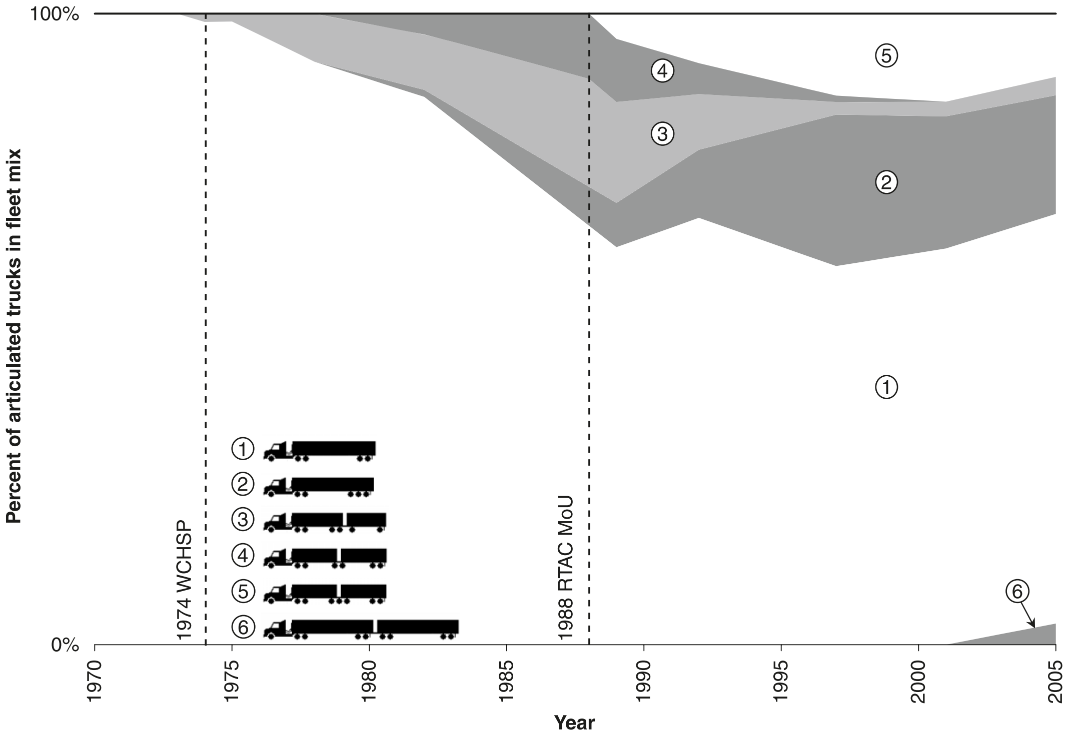
Mid-Continent Trade Corridor south

Classification data on the Mid-Continent Trade Corridor south of Winnipeg was collected between 1974 and 2005 at the Emerson weigh scale located at the international border crossing between Manitoba and North Dakota/Minnesota. The crossing joins Provincial Trunk Highway (PTH) 75 with Interstate Highway 29 in the United States, and processes primarily international truck traffic.

Mid-Continent Trade Corridor north

Classification data for the Mid-Continent Trade Corridor north of Winnipeg was collected at the AVC located on PTH 6 at Paint Lake (700 km north of Winnipeg) beginning in the mid-1990s. Weigh scale classification counts are not available for this route. Truck traffic at this site is principally involved in long distance hauling between Winnipeg and Thompson, Manitoba.

Fig. 2. Articulated truck fleet mix on the Trans Canada Highway west corridor. WCHSP, Western Canada Highway Strengthening Program; RTAC MoU, Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions.



Findings

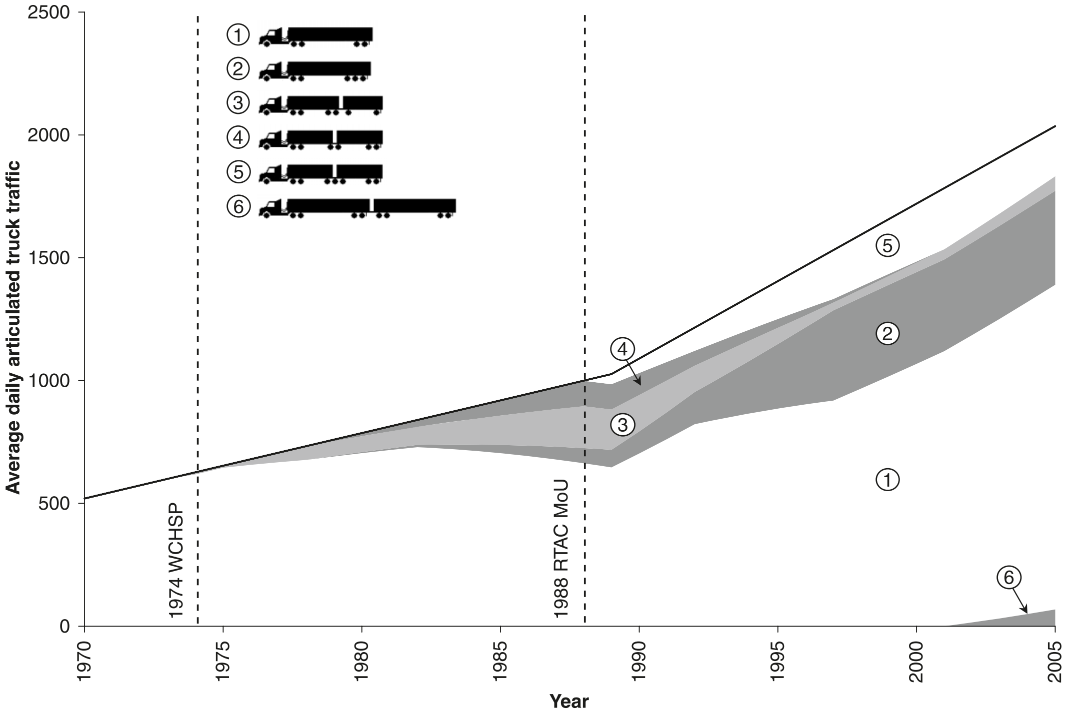
Changes in fleet mix distributions observed on each of the four corridors are presented in the following sections. Where possible, historical fleet mix details are presented in the context of absolute articulated truck volumes observed along these routes. Fleet mix changes are described in detail for the Trans Canada Highway west corridor. Only those changes that are unique for the other three corridors are highlighted in the respective sections.

Trans Canada Highway west corridor

Figure 2 shows the fleet mix of articulated trucks on the Trans Canada Highway west corridor over 35 years, from 1970, prior to the commencement of the WCHSP, and up to 2005. The following are principal observations about the fleet mix distribution along this corridor:

- Three-, four-, and five-axle tractor semitrailers were used exclusively prior to 1974, but their proportion of the fleet mix decreased gradually to about 60% by 1989 following the signing of the RTAC MoU, and have held relatively steady at this level until today (although the most recent trend may indicate a proportional increase in 3-S2s, possibly attributable to higher demand for moving low density commodities). Three- and four-axle tractor semitrailers were most prominent within this configuration group in the early 1970s, being present at a level of about 10%, and have remained a continuous presence in the fleet at various levels (but never higher than 10%) since then.
- Six-axle tractor semitrailers (3-S3s) emerged as an important configuration in 1989. These vehicles penetrated the fleet mix, reaching a level of about 25% of the total fleet by 1997, but have declined slightly over the last decade. This pattern is also evident for eight-axle B-trains, although their maximum level of penetration only reached about 15%. These trends reflect the shift of weigh-out commodities from 3-S2s to 3-S3s, and from 3-S2s and A-trains to B-trains, that occured following the signing of the RTAC MoU. The slight decline in the proportion of 3-S3s and B-trains in the fleet mix is possibly an indication that a saturation point has been reached, in that carriers (and shippers) benefiting from the relatively higher weights offered by 3-S3s and B-trains have made the necessary fleet adjustments, and other carriers realize little benefit from making similar changes.
- A-trains peaked at a level of about 15% of the total fleet prior to the enactment of the RTAC MoU, and declined quickly over the next decade to a nominal level. The penetration of 16.2 m semitrailers into the market during this period limited the incremental productivity advantage of standard A-train trucks (i.e., two 8.5 m trailers) carrying low density, cube-out commodities, thereby shifting some of this freight from A-trains to 3-S2s. The creation of the higher GVW eight-axle B-train in 1988 attracted weigh-out commodities away from A-train configurations.
- Seven-axle B-trains exhibit a similar pattern as A-trains, reaching a maximum fleet penetration of about 10% at the signing of the RTAC MoU, and then essentially disappearing from the fleet over the next decade as eight-axle B-trains became more prominent.
- Longer combination vehicles are evident in the fleet mix in 2005, at a level of about 3%. These vehicles penetrate the 3-S2 fleet since they are principally used to haul low density cube-out commodities.

Fig. 3. Articulated truck volumes on the Trans Canada Highway west corridor. WCHSP, Western Canada Highway Strengthening Program; RTAC MoU, Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions.



These observations provide evidence of the impacts of the three highway engineering and policy decisions under examination. The key fleet mix impact of the WCHSP of 1974 was the emergence of double trailer combinations (principally A-trains), which grew to a maximum fleet penetration of 15% at the time of the signing of the RTAC MoU. The effect of RTAC was evident shortly after its signing, with the emergence of the tridem-axle semitrailer and the conversion of double trailer combinations from A-trains to B-trains. For several years, LCVs have been permitted at this location, but they have only recently emerged as vehicles of importance as their network has expanded, and carriers and shippers have invested in these operations because of productivity advantages.

Absolute truck volumes provide context for the fleet mix distribution changes. Figure 3 shows the distributions on the Trans Canada Highway west corridor in terms of absolute truck volumes. Over the years under study, articulated truck traffic volumes increased more than threefold, from a daily volume of about 600 in 1973 to about 1000 in 1989, and then to the current level of about 2000 trucks per day. In this context, the following points are evident:

- Even though 3-S2s have declined significantly on a proportional basis over the last 35 years, their numbers have roughly doubled in an absolute sense.
- Vehicle types that have increased in a proportional sense since 1989 (such as 3-S3s and eight-axle B-trains), have expanded even more dramatically when absolute volumes are considered.
- The penetration of LCV traffic into the articulated truck fleet mix is intensified by considering that each LCV observed represents up to two 3-S2s removed from the fleet. In other words, a 3% penetration in terms of vehicles represents up to 6% penetration in terms of the cubic volume of freight hauled.

Trans Canada Highway east corridor

Figure 4 shows the fleet mix distribution on the Trans Canada Highway east corridor since 1970. The principal difference between the fleet mix distribution on the east corridor and that in the west corridor was that no LCVs were observed on the former owing to Ontario's prohibition of these vehicles. Many of the changes observed on the west corridor also occurred on the east corridor, namely the gradual decline of 3-S2s in the fleet mix, the rise and fall of A-trains and seven-axle B-trains during the 1980s and 1990s, and the emergence of 3-S3s and eight-axle B-trains subsequent to the signing of the RTAC MoU. Today, the fleet has established a mix of about 60% 3-S2s, 20% 3-S3s, and 10% eight-axle B-trains. Daily articulated truck volumes were (approximately) 200 in 1974, 400 in 1989, and 1150 in 2005.

Mid-Continent Trade Corridor south

Figure 5 shows the fleet mix distribution on the Mid-Continent Trade Corridor south of Winnipeg since 1970. Fleet mix patterns on this route are controlled by U.S. truck size and weight policy. From a classification perspective, this policy has not changed substantially over the last 35 years. The fleet mix has been historically dominated by 3-S2s, which make up over 90% of articulated truck traffic in each of the observation years at this location. This is confirmed by findings reported by the Transportation Research Board (TRB 1986) and Nix et al. (1998). Other vehicle types that have been observed in very small proportions over the years are: three- and four-axle tractor semitrailers in the early 1970s, A-train double configurations in 1981 and 1996, eight-axle B-trains in 1996, and 3-S3s since the 1990s. Daily articulated truck volumes at the Emerson scale were (approximately) 200 in 1974, 600 in 1994, and 750 in 2002.

Fig. 4. Articulated truck fleet mix on the Trans Canada Highway east corridor. WCHSP, Western Canada Highway Strengthening Program; RTAC MoU, Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions.

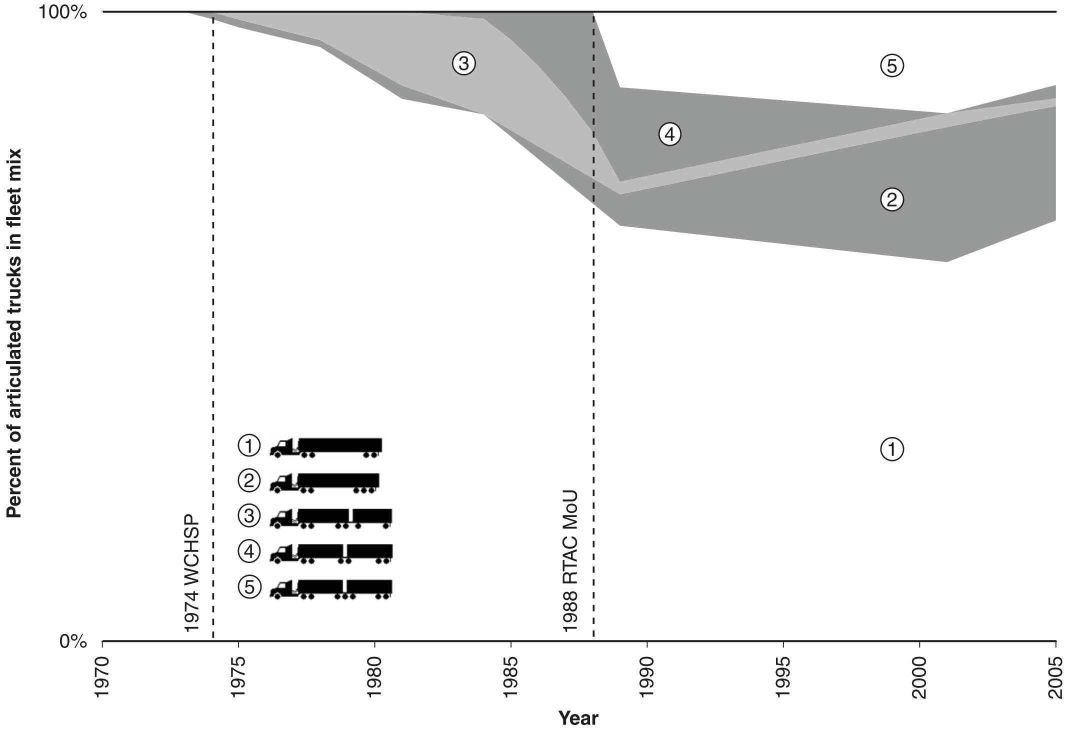
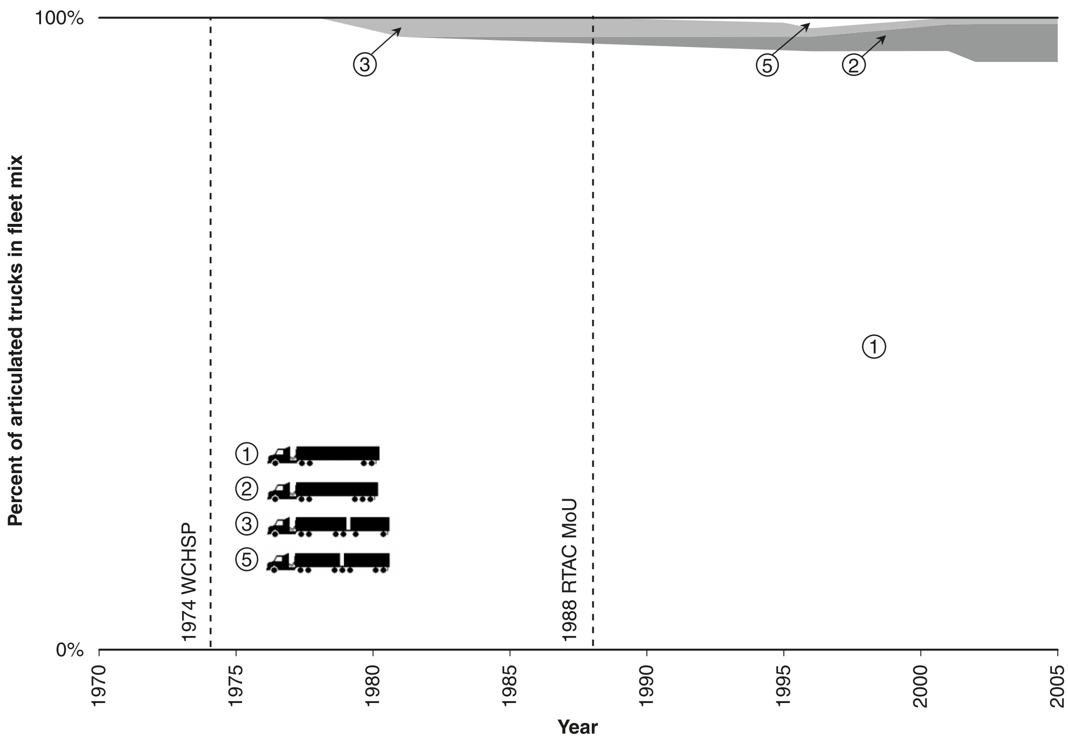


Fig. 5. Articulated truck fleet mix on the Mid-Continent Trade Corridor south. WCHSP, Western Canada Highway Strengthening Program; RTAC MoU, Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions.



Mid-Continent Trade Corridor north

Since the mid-1990s, the proportion of single trailer truck traffic on the Mid-Continent Trade Corridor north of Winnipeg has remained consistently between 55% and 60% of the total fleet. The most notable change during this period is the demise of A-train doubles, which have been largely replaced by eight-axle B-trains (for hauling weigh-out commodities) and 3-S2s (for cube-out commodities). This shift follows patterns observed elsewhere in the region and is attributable to the ratification of the RTAC MoU and the wide-scale adoption of 16.2 m semitrailers. Rockies were permitted for the first time on this route during a one-year pilot program beginning in the fall of 2006 (MacLeod 2006). This program permitted two round-trips per day between Winnipeg and Thompson, Manitoba. Daily articulated truck volumes at this location were (approximately) 60 in 1993, 80 in 2002, and 110 in 2005.

Implications for network planning and highway engineering

Four observations are made regarding the influence of truck size and weight regulations on truck fleet mix characteristics, and on the corresponding implications for network planning and highway engineering. First, truck size and weight policies define the highway networks on which trucks travel. These networks are critical to local, regional, and international freight movements. Each of the three highway engineering policies has, through the definition and enforcement of the respective regulatory schemes, helped over time to create a network on which the newly regulated vehicles are allowed to operate. These networks are also influenced by specific origin–destination relationships and political, social, and economic demands. The extent of these networks changes with time as these influences are balanced. For example, RTAC weight limits were initially allowed on primary highways in the region, but the RTAC network eventually expanded to include critical production and attraction points requiring access to this network. Although the RTAC network continues to change with time, it has largely reached a saturation point.

Special permitting of LCVs in the Canadian prairie region is inextricably linked to road network characteristics. Alberta, Saskatchewan, and Manitoba all restrict the movement of turnpikes and triples to four-lane divided highways, and the movement of Rockies to the same as well as to two-lane undivided highways that: (*i*) meet specified geometric criteria (e.g., paved shoulder width), (*ii*) provide critical connectivity to key freight generators and attractors, or (*iii*) represent a critical linkage for northern or remote regions. Recently, however, increasing pressure has been placed on highway agencies to expand Rocky Mountain double operations to a larger two-lane network to promote freight productivity and to stimulate economic development, particularly for remote regions. One example outcome is the permit of pilot Rocky operations on PTH 6 between Winnipeg and Thompson, Manitoba in 2006. In addition, the ongoing expansion of the four-lane divided highway network has, as of the fall of 2007, provided turnpike and triple connectivity between the following cities: Edmonton and Calgary, Alberta, Saskatoon and Regina, Saskatchewan, and Winnipeg, Manitoba..

Establishing highways as part of the LCV network, however, does not necessarily result in significant LCV traffic volumes. Longer combination vehicle operations require three conditions be met: (*i*) a network on which LCV operations are permitted, (*ii*) an origin–destination pair with sufficient demand to warrant trucking industry investment in LCV operations between these locations, and (*iii*) travel distances long enough for the industry to realize material technical productivity benefits by using LCVs instead of conventional articulated truck combinations.

Second, even though the truck size and weight regulatory environment is relatively uniform in the Canadian prairie region, it is in some cases superseded by different regulatory schemes in jurisdictions outside the region. These cases occur on highways that principally serve truck traffic on major connections between the Canadian prairie region and outside jurisdictions. Examples of this type of situation are:

- on PTH 75 in Manitoba, which connects Winnipeg to the U.S. border, on Highway 39 in Saskatchewan, which connects Regina to the U.S. border, and on Highway 4 in Alberta, which connects Lethbridge to the U.S. border (trucks going into/out of the U.S. are governed by U.S. Bridge Formula B, and U.S. size and weight limits for LCVs are generally more restrictive than Canadian ones);
- on PTH 1 in Manitoba, which connects Winnipeg and Ontario (trucks going into/out of Ontario are affected by the Ontario Bridge Formula, and LCVs are not permitted in Ontario); and
- on Highways 3, 1, 16, and 43, which connect Albertan cities to British Columbia (British Columbia does not allow LCVs, except for on a short portion of Highway 43 where Rockies are permitted).

Third, not all truck fleet changes result from purposeful engineering analysis or policy decisions. Industry influences occasionally induce change in truck fleets or characteristics without specific regulatory or policy direction. One important example was the emergence of LCVs in the Canadian prairie region, which was a result of significant industry pressure on provincial regulatory agencies to permit longer and more productive trucks. As a result of this pressure, the principal truck configurations used were not initially subject to engineering or policy analyses as were those used pursuant to WCSHP or RTAC decisions. A second example of industry influence is the gradual increase in the cubic capacity of domestic containers and trailers. The current wide-scale adoption of 16.2 m trailers and domestic containers was largely unplanned and unevaluated (Clayton et al. 2003).

Fourth, in addition to fleet mix impacts, changes in truck size and weight regulations affect truck volumes and the cubic and weight capacity of the payloads the trucks carry. These characteristics are fundamental inputs to nearly all aspects of highway engineering. Principal examples are:

- the analysis of traffic operations impacts of articulated trucks and the related design of road geometry (Harkey et al. 1996; Elefteriadou et al. 1997);
- the development and use of load spectra for mechanistic-empirical pavement design (Hajek et al. 2002; AASHTO 2008), and the design and evaluation of bridge structures (Ghosn and Moses 2000; National Cooperative Highway Research Program 2003);
- the determination of the safety performance of articulated trucks in terms of collision rates (Regehr et al. 2009); and
- the analysis of energy, fuel, and emissions impacts of different types of articulated trucks (ATRI 2008).

Lessons learned

Three uniquely Canadian and purposeful highway engineering policies have impacted articulated truck fleet mix characteristics in the Canadian prairie region over the past

35 years: the 1974 Western Canadian Highway Strengthening Program, the 1988 Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions, and special permitting of longer combination vehicles. These policies have made direct and observable impacts on truck fleet mix characteristics. Evidence of these changes was provided along the four cardinal direction corridors of the National Highway System connecting to Winnipeg, Manitoba. This analysis approach highlights unique fleet mix impacts of truck size and weight regulations on each of these corridors and the hinterlands they service.

In response to these policy changes, the truck industry has adjusted its fleets and operating practices to conform to the requirements of the policies and to take advantage of the efficiencies they encourage. Several lessons can be learned by observing these changes:

- As a direct result of these policies, articulated trucks on many highways in the Canadian prairie region are heavier and larger, carry more weight and cubic payload, have different axle configurations, and have higher axle weight limits than they did 35 years ago. This translates into a fleet that carries more payload per unit of tare, and ultimately requires fewer vehicles to move the same amount of freight, from both a weight and cubic perspective. The threefold to fivefold increase in articulated truck volumes evident in the Canadian prairie region since the early 1970s would have been more dramatic without the implementation of these policies. Further research is needed to quantify this effect and its implications for civil engineering. For example, pavement and bridge deterioration may be accelerated by increases in truck weight limits; however, the deterioration may be mitigated, eliminated, or even reversed if these increases result in a reduction of truck volumes or if they apply only to vehicles with axle configurations designed to compensate for the higher loads.
- Regulations that prohibit the effective use of tridems but do permit the effective use of double trailer combinations lead to about one quarter of the fleet being doubles, as evidenced on the west and east corridors prior to the RTAC MoU.
- Regulations permitting the effective use of a tridem-axle group lead to the penetration of tridem-axle vehicles (i.e., 3-S3s and eight-axle B-trains) from nominal levels to a saturation point of about one third of the fleet, as evidenced on the west, east, and north corridors following the RTAC MoU. This transition takes about 10 to 12 years.
- Regulations that encourage the use of B-trains rather than A-trains, when coupled with the adoption of 16.2 m semis — which effectively offer the same cubic capacity as two 8.5 m trailers in a standard double configuration — lead within about eight years to the effective termination of A-train combinations. This is evident on the west and east corridors.
- Regulations and networks that permit the effective use of LCVs lead to the adoption of these vehicles, provided there is sufficient distance and demand for cubic freight between origin and destination.
- The 8 to 12 year time lag effects observed between the implementation of a policy and the point at which carriers have fully adjusted their fleets is helpful for estimating costs and benefits of potential changes in truck size and weight policies.
- Despite relative uniformity of regulations within the region, fleet mixes are sometimes nearly completely controlled by truck size and weight policies in neighbouring jurisdictions. This situation is apparent on the south corridor, which connects to the U.S., where the fleet mix has been unaffected by Canadian policy changes.
- Wide-scale changes in truck size and weight characteristics have sometimes occurred without purposeful engineering analysis and evaluation.

From a civil engineering perspective, it is important to understand the impacts that highway engineering and policy decisions have on transportation infrastructure and the vehicles that use it. Although the direction of the fleet mix changes is generally anticipated correctly, the changes cannot be directly forecasted since they interface with many sectors of industry and government and do not transpire in isolation from other influencing trends. With an aging infrastructure and rapidly increasing demand for freight movement, however, civil engineers and policy makers are required more than ever to understand the interactions among policies, vehicles, and infrastructure, and to make more informed decisions concerning these matters. It is critical, therefore, to learn from the outcomes of past experience, and to develop and maintain a detailed truck traffic knowledge base through technologically sophisticated measurement and more purposeful evaluation efforts.

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