On the Use of Liftable Axles by Heavy Trucks

JOHN R. BILLING, FRED P. NIX, MICHEL BOUCHER, AND BILL RANEY

Options to increase the gross weight of heavy trucks are being addressed through studies on size and weight in the United States. These options would require more axles per truck. If the truck configuration and equipment are not tightly controlled by regulation, many of these axles would be liftable axles, and the trucks would be similar to those used already in central and Atlantic Canada. Allowing heavy trucks to use liftable axles, where the axle load is controlled by the driver, may lead to axle weight compliance problems and, eventually, result in damage to roads and bridges. However, the use of liftable axles does allow truckers to haul heavy loads efficiently, which benefits shippers and consumers with a low-cost transportation service. The economic impact on trucking in central and Atlantic Canada of four alternative regulatory scenarios having different constraints on the use of liftable axles is examined in this paper. Findings indicate that the cost of even the most severe measure, an outright ban, is relatively small, no more than 1.14 percent of total industry cost. This is because there are alternative trucks with comparable payload and operating costs, but without liftable axles, to which the freight can be diverted. A few trucking operations could be faced with hauling cost increases as high as 10 to 13 percent.

Recent studies in the United States on truck weight and dimension regulations have been focused on options that increase the gross weight of large trucks (*1,2*). This would require more axles to be used, if axle loads are unchanged or are reduced, to minimize pavement wear. Unless the regulations that would give rise to these heavier trucks control configuration and axle arrangements carefully, it is likely that many of these additional axles would be liftable axles, axles that can be removed from contact with the ground by the driver. Such axles are in use in several states in the United States and are in widespread use in central Canada (Ontario and Quebec) and Atlantic Canada (four provinces). The experience with liftable axles in Canada is the subject of this paper.

Ontario has a form of regulation, based purely on a bridge formula, that does not control either vehicle configuration or the number of axles, but allows more weight to be carried within a given length if more axles are used, or if those axles are more widely spaced. This has given great freedom to the development of diverse configurations, equipped with multiple, widely spaced axles that can carry heavy payloads (*3*). Quebec and the Atlantic provinces have regulated truck configuration more closely than Ontario, but their regulations embody principles similar to those of Ontario. Trucks with multiple, widely spaced axles have difficulty turning on dry roads. Industry has resolved this difficulty through the use of liftable axles, which can be raised or lowered by the driver, usually with air pressure. The driver customarily raises a liftable axle when a turn is being made and lowers it when the turn is completed. These axles can also be raised while cruising along the highway, which might be done by a driver to improve fuel consumption and reduce tire wear when running empty or lightly loaded.

Regulations tolerate liftable axles, with no specific limitations beyond the general requirement for axle-weight compliance. Liftable axles came into use in the early 1970s, and their use has grown steadily since. The growth has resulted in quite complicated trucks that have two or more liftable axles. The use of liftable axles may reduce a truck's stability in many situations (*4*). Their use makes compliance with and enforcement of axle-load regulations difficult, so there are concerns about the use of liftable axles and damage to roads and bridges. These concerns were great enough that liftable axles were excluded from the truck configurations covered by the 1988 Memorandum of Understanding between the Canadian provinces and territories that established uniform national heavy truck weight and dimension regulations (*5*). The 1988 agreement, developed under the auspices of the Roads and Transportation Association of Canada (RTAC), recognizes six specific truck configurations (*6*). Limits on axle loads, gross weight, axle arrangements, axle spacings, and a variety of other dimensions are tailored to ensure superior stability for each configuration. These are referred to as the RTAC rules. The ten provinces and two territories are currently at various stages in the integration of the RTAC rules into their own regulations. Ultimately, standard RTAC trucks will operate from coast to coast on designated highways. Although the RTAC rules prohibit use of liftable axles on any of the RTAC configurations, the 1988 agreement does not require any province to ban the use of liftable axles. Provinces are free to continue to allow these and other existing non-RTAC truck configurations to operate. The six eastern provinces therefore will retain many aspects of their earlier regulations and local trucks, which include the wide range of trucks currently using liftable axles.

Liftable axles do add a great deal of payload to a truck for a small increase in vehicle cost. Shippers of heavy commodities benefit from the lower transportation costs resulting from the use of liftable axles.

J. R. Billing, Vehicle Technology Office, Transportation Technology and Energy Branch, Ministry of Transportation of Ontario, 1201 Wilson Ave., Downsview, Ontario, M3M 1J8, Canada. F. P. Nix, Canadian Institute of Guided Ground Transport, Queen's University, Kingston, Ontario, K7L 3N6, Canada. M. Boucher, Ecole nationale d'administration publique, Université du Québec, 945, avenue Wolfe, Saint-Foy, Québec, G1V 3J9, Canada. B. Raney, Provincial Transportation Systems Office, Ministry of Transportation of Ontario, 1201 Wilson Ave., Downsview, Ontario, M3M 1J8, Canada.

A preliminary exploration of the use of liftable axles in central and Atlantic Canada is presented in this paper. The concerns of highway and truck engineers are summarized and findings from a recent study on the economic impact of hypothetical changes to regulations that would constrain the use of liftable axles are presented.

TRUCKS WITH LIFTABLE AXLES

Configurations

Configurations are described generically by the following notation. Note that x is the number of axles on a vehicle unit and y is the number of liftable axles; the designation RTAC, used later in the paper, denotes a configuration complying with RTAC rules.

Notation	*Configuration*
Tx	Straight truck (T4 has a tandem-steer axle);
Tx,yL	Straight truck with liftable axles;
Tx-x	Straight truck and trailer;
Tx-x,yL	Straight truck and trailer with liftable axles;
x-Sx	Tractor-semitrailer;
x-Sx,yL	Tractor-semitrailer with liftable axles;
x-Sx-x	A-train double (single drawbar dolly);
x-Sx-Sx	B-train double (two semitrailers, no dolly); and
x-Sx=x	C-train double (double drawbar dolly).

The configuration 3-S2, the 18-wheeler, is the most common large truck in both the United States and Canada. Figure 1 shows some typical configurations that use liftable axles. The most common is the 3-S3,1L triaxle semitrailer, used in Ontario, Quebec and the four Atlantic provinces, which has a fixed tandem axle at the rear of the semitrailer, and an independently suspended liftable axle (the belly axle) some distance ahead of it. The quad-axle semitrailer, allowed only in Ontario and Quebec, may have a single liftable axle and a fixed tridem axle (3-S4,1L). In Ontario, it may also have one of several arrangements of two liftable axles with a tandem axle (3-S4,2L). Semitrailers with five axles are used only in Ontario and a small number with more than five axles, in a variety of axle arrangements and usually with at least two liftable axles, operate between Ontario and Michigan. In Ontario, there are also triaxle straight trucks, T4,1L, with a liftable axle between the steer axle and the tandem drive axle. There are also small numbers of trailers that have liftable axles and are pulled by straight trucks.

Table 1 shows the large payload advantages of flatdeck semitrailers with liftable axles in the three regions. Other body styles have slightly smaller payloads, but the relative increase in payload remains about the same for each as liftable axles are added. Adding a liftable axle to the standard 5-axle tractor-semitrailer increases its payload by over 8 t (17,640 lb) in some cases, for only about a 1 t (2,205 lb) increase in tare weight. The payload increase diminishes as each additional axle is added.

Usage

Information on the use of liftable axles is available from roadside surveys, conducted by the provinces in different years, which are of varying quality.

Ontario conducted a large survey in 1988; a summary of the more important statistics is shown in Table 2. Just less than 17 percent of the trucks on the highways had liftable axles, and these accounted for one quarter of all freight hauled. The most important use of liftable axles is on 6-axle configurations, most of which are tractor-semitrailers. Vans (including refrigerated vans), flatdecks, and stake-and-rack trailers account for 80 percent of all liftable axles.

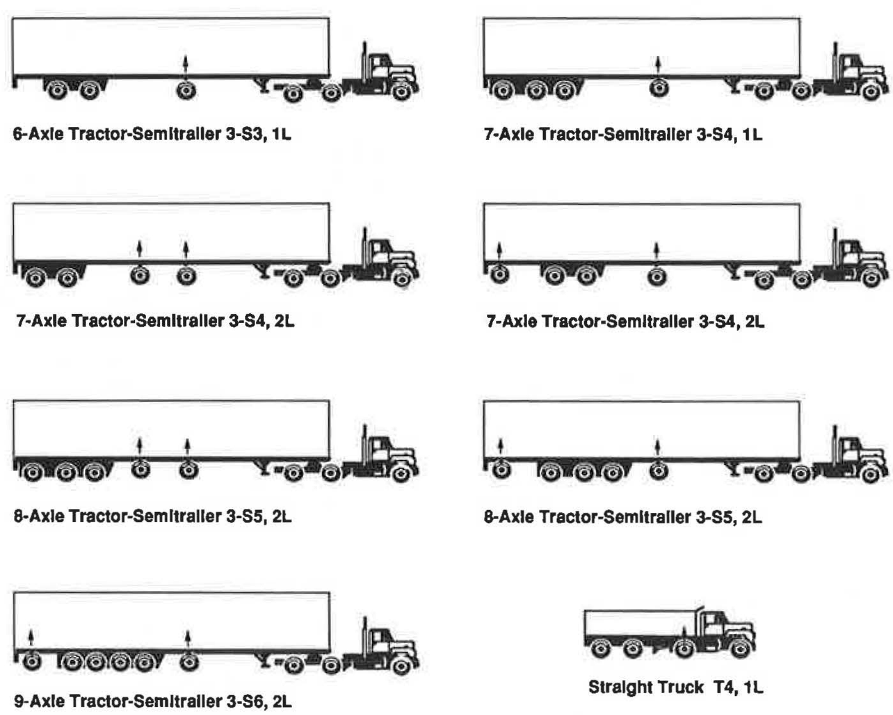

FIGURE 1 Common truck configurations that use liftable axles.

TABLE 1 PAYLOAD GAINS FOR TRACTOR-SEMITRAILERS WITH LIFTABLE AXLES (FLATDECK TRAILERS, PAYLOADS IN TONNES)

Region	Payload	3-S2	3-S3,1L	3-S4,1L	3-S5,2L
Ontario	Typical	27.0	35.7 (+32.2%)	39.6 (+10.9%)	42.5 (+7.3%)
	Maximum	32.0	40.0 (+25.0%)	45.8 (+14.5%)	46.6 (+1.7%)
Quebec	Typical	27.0	35.7 (+32.2%)	37.8 (+5.9%)	
	Maximum	33.8	42.4 (+25.7%)	39.6 (-6.8%)*	
Atlantic Canada	Typical	25.0	32.7 (+30.8%)		
	Maximum	28.8	36.5 (+26.7%)		

* Quebec recently decreased the GVW of a 3-S4,1L from 57.5 to 55.0 tonnes, but the 3-S3,1L is still allowed 57.5 tonnes, which could give it a higher payload.

TABLE 2 USE OF LIFTABLE AXLES IN ONTARIO AND QUEBEC

	Ontario		Quebec	
	Trucks	Freight	Trucks	Freight
Trucks without Liftable Axles	83.3%	74.8%	79.1%	67.6%
Trucks with Liftable Axles	16.7%	25.2%	21.2%	32.4%
Configuration				
Tractor-semitrailer	15.3%	22.7%	20.2%	30.9%
Double trailer	0.9%	1.9%	0.8%	1.1%
Straight truck	0.3%	0.2%	0.0%	0.0%
Truck-trailer	0.3%	0.6%	0.2%	0.4%
Body Style				
Van	7.9%	9.9%	7.0%	8.2%
Flatbed & stake	5.6%	9.4%	8.0%	13.2%
Dump	1.5%	3.0%	1.7%	5.8%
Tanker	0.9%	1.6%	3.3%	3.4%
Other	0.9%	1.4%	0.2%	0.3%
Number of Axles				
5 or fewer	2.2%	2.1%		
6	9.5%	13.4%		
7	1.8%	3.4%		
8 or more	1.8%	3.4%		

Quebec completed a roadside survey in 1989; the preliminary results in Table 2 show the use of liftable axles is even more widespread in Quebec than in Ontario, although the variety of trucks using them is more limited. Liftable axles are used almost exclusively by 6- or 7-axle tractor-semitrailers (as compared with double-trailer or truck-trailer combinations), particularly those with van (including refrigerated van), flatdeck, or stake-and-rack body styles.

Data from Atlantic Canada are limited. However, on the basis of results of a 1984 roadside survey, 41.3 percent of all configurations on the highway were tractor-semitrailers with 6 or more axles, mostly of 3-S3,1L configuration. It is estimated (crudely) that they accounted for 24.5 percent of truck freight tonnage in the region. In all of central and Atlantic Canada, then, something in the order of 27 to 31 percent of total truck freight tonnage, depending on how the numbers are summed, is carried by equipment with liftable axles.

Operational Considerations

All liftable axles are equipped with a valve beside the axle allowing it to be raised or lowered while the truck is stationary. In addition, most trucks and tractors come with a control that allows the driver to raise or lower the liftable axle from the cab. In some cases, a regulator in the cab also allows the driver to adjust the axle load.

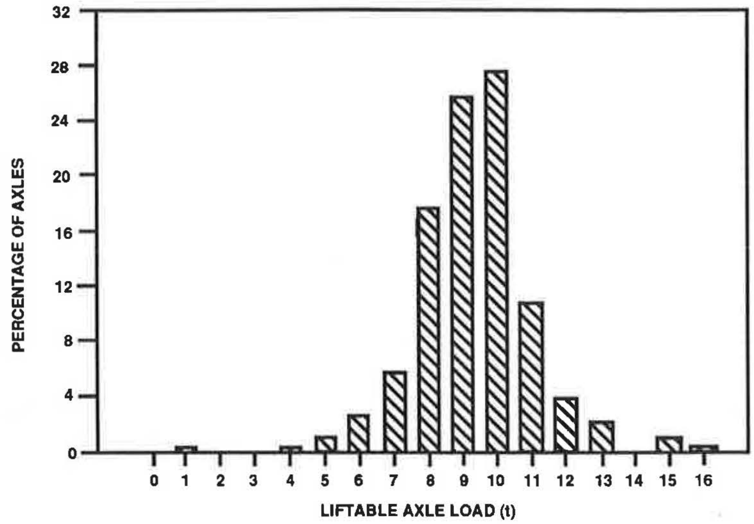

FIGURE 2 Liftable axle load distribution of 260 3-S3,1L.

Vehicle manufacturers and truckers both readily admit that life would be easier if liftable axles were banned. Load compliance is more difficult and maintenance costs are higher when these axles are used. However, shipper demands and competitive pressures require that they be used in the absence of any regulatory limitation to the contrary.

The semitrailer with liftable axles usually has tare weight and price advantages over the comparable double-trailer combination. There are cases where the B-train double can be more efficient, but in general, the long semitrailer has an operational advantage for most freight. The B-train may not split well for some loads, and it is not practical for long loads such as beams or reinforcing bars. Semitrailers also have a distinct advantage over double trailer combinations for some body styles. The cost of refrigeration units and insulation and pressure vessels increases substantially per cubic meter of trailer in switching from single to double trailers.

In on-off road operations, such as logging and mining, raising the liftable axle is considered necessary to transfer loads to the tractor drive axles to provide traction for off-road mobility. The ability to raise the liftable axle and increase the drive axle traction is also considered a safety factor when driving on a slippery road or climbing an icy hill.

Weight Compliance Considerations

Weigh-scale staff in Ontario report that two-thirds or more of all weight infractions occur on trucks with liftable axles. This is not surprising. These trucks are designed to carry the heaviest loads and operate close to their allowable gross weight, so they are at greatest risk of incurring an infraction. However, the actual loads carried by liftable axles are also a major factor in the number of infractions. The liftable axle load is controlled by the driver, who can adjust it to any level. If the liftable axle load is too high, the liftable axle is overloaded. If it is too low, other axles may be overloaded. Weigh-scale data show that actual liftable axle loads may vary from zero, when the axle is raised, to 16 t (35,273 lb) or more. A typical distribution is shown in Figure 2, from a survey conducted by the Ontario Ministry of Transportation. The trucks in this sample are all virtually identical 3-S3,1Ls, within 5 percent of their allowable gross weight. However, fully 48 percent had their liftable axles sufficiently far off the 10 t (22,046 lb) load that there would be an axle weight infraction, even if the load were perfectly distributed. Unfortunately, fines for weight infractions in Ontario and Atlantic Canada are small, and provide little incentive for tight control of liftable axle loads.

Roadway and Bridge Considerations

The number of equivalent single axle loads (ESALs) generated by a truck with liftable axles varies with the load on the liftable axle, as shown in Figure 3 for five typical heavy truck configurations under Ontario axle and gross weight regulations. Axle load equivalencies are based on the fourth-power law, with 5 t for a front axle with single tires, and 10 t for a single axle, 17 t for a tandem axle, and 24 t for a tridem axle with dual tires (*7*). Figure 3 shows further that whenever the

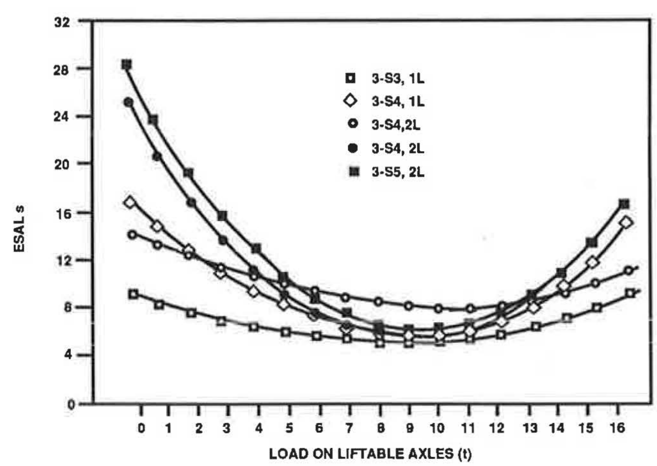

FIGURE 3 Heavy truck ESAL dependence on liftable axle load.

truck is operated with a significant liftable axle overload, or an underload that overloads the remaining fixed axles, there is an increase in the number of ESALs it generates. This is because the increase in ESALs for an overloaded axle is always greater than the reduction in ESALs for the corresponding underloaded axles. When liftable axles are raised, the number of ESALs per truck may increase by a factor between two and four. The high numbers of ESALs arising from trucks whose liftable axles are incorrectly loaded is considered to be a major contributor to rutting and other load-related damage to highways and municipal roads.

Figure 4 compares the bridge loading effects of various trucks with liftable axles against the Ontario bridge formula (OBF), the current technical basis for regulation in Ontario. Even with liftable axles properly deployed, the regulations allow loads on some configurations that exceed the OBF by a small amount. However, with the liftable axles raised, there are a number of axle groups whose loads exceed the OBF by 10 t (22,046 lb) or more, with a legal load distribution on the truck when the liftable axles are properly deployed. Gross weight overloads, or improper load distribution, simply make the situation worse. The high overloads occur primarily on tandem and tridem axles, and particularly affect the deck structures of some designs of bridge, and the main longitudinal members of short span bridges.

Vehicle Stability Considerations

The use of liftable axles on long semitrailers allows considerably more load to be carried, as shown in Table 1. For commodities of moderate density, such as lumber, grocery and food products, bulk liquids, and powders, this results in a considerable increase in the height of the payload center of gravity. This, by itself, tends to reduce the rollover threshold of the truck, and to deteriorate other aspects of its dynamic performance. With the liftable axles deployed, the truck cannot turn, and may be at risk of a jackknife when trying to turn on a wet and slippery pavement. When liftable axles are raised so that the truck can turn, the truck's resistance to rollover may be substantially reduced (*4*). This is when the truck is most susceptible to rollover. This clearly introduces a safety hazard for which the driver must compensate by reducing speed. Drivers of these trucks appear quite cautious when traversing freeway ramps.

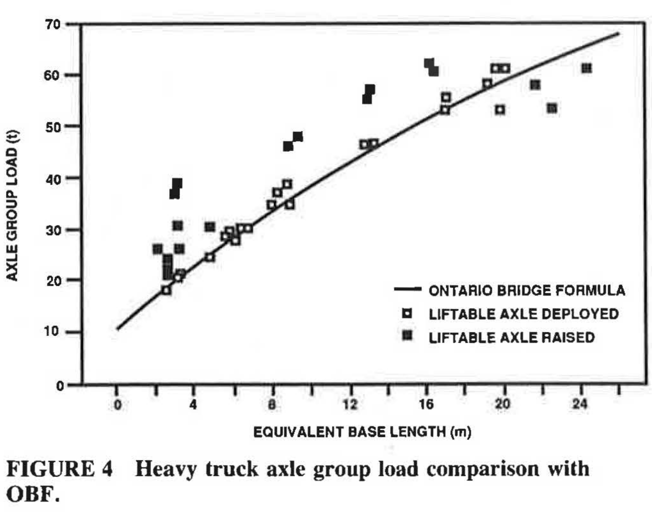

FIGURE 4 Heavy truck axle group load comparison with OBF.

Summary

When trucks are allowed to operate with liftable axles and when there are no means to ensure control of axle loads, there is a loss of compliance with axle weight law. In some cases, axle loads on trucks whose liftable axles are raised can exceed the allowable load by over 10 t (22,046 lb). These trucks impose considerably more road and bridge damage than if they operated with liftable axles properly deployed. There are also serious dynamic performance deficiencies of heavy truck configurations equipped with liftable axles, which gives rise to concerns about the safety of this equipment. Trucks equipped with liftable axles can, at the will of the driver, operate far outside the technical limits set for roadway design, bridge safety, and intrinsic truck safety.

ECONOMIC ANALYSIS OF TRUCKS WITH LIFTABLE AXLES

Regulatory Scenarios

Concerns about performance of trucks with liftable axles have led Ontario Ministry of Transportation, Ministère des Transports du Québec, and Transportation Development Center of Transport Canada to undertake a joint program of research to explore technical options that might provide opportunities for tighter regulatory control. This section summarizes aspects of one study in this program (*8*). It documents the cost of trucks with liftable axles, the operating costs of such trucks, operational considerations that go into the decision to use such an axle, and how the cost and operational factors compare with trucks that do not use liftable axles. Five scenarios are developed as a basis for this study. There are large differences between the scenarios to test the sensitivity of truck choices and trucking costs to changes in regulations. The scenarios are

1. The base case, where use of liftable axles is uncontrolled within the gross and axle load limits of each province.
2. RTAC rules are added to the current regulations, and the allowable load on liftable axles is reduced from 10 to 8 tonnes.
3. RTAC rules are added to the current regulations and the allowable load on liftable axles is further reduced to 6 tonnes.
4. RTAC rules are added to the current regulations and use of liftable axles is prohibited.
5. The base case, except each vehicle in Ontario is limited to one liftable axle, as in Quebec and Atlantic Canada.

Scenarios 2, 3, and 4 include the addition of RTAC rules, because only one of the six provinces in central and Atlantic Canada has actually completed the necessary steps to adopt these rules formally. The others are in the process of adoption, and in the meantime are allowing RTAC trucks to operate under permit.

The study looks only at trucking costs. The high axle loads possible with liftable axles raised exceed the technical standards for roads and bridges by such a wide margin that technical reasons alone demand constraints on the use of liftable axles. The study therefore did not examine road, bridge, or safety costs.

Costing Methodology

A detailed costing methodology was developed for evaluation of the impacts of the five regulatory scenarios. The intent was to compare the relative costs of one truck configuration with another, and then to use these results to predict the consequences of each of the regulatory scenarios. The methodology is based on the widely used biannual computation of trucking costs undertaken for Transport Canada by Trimac Consulting (*9*). Because Trimac procedures only consider a limited number of configurations, many modifications had to be made to allow the costing process to be sensitive to the changes in trucking costs because of the large variety and number of configurations in this study. The result is a series of models that develop costs by

- Region: Ontario, Quebec, and Atlantic Canada.
- Regulatory scenario: 1 to 5, as listed previously.
- Configuration: 24 basic configurations (e.g., 3-S3,1L, T3-4, etc).
- Body style: one of seven (e.g., van, refrigerated van, flatdeck, etc).
- Gross Vehicle Weight (GVW): a typical maximum, using the maximum axle loads allowed by each province's regulations, although these may be rarely seen, and a high, from axle loads typical of trucks that carry dense commodities.
- Tare weight: a typical high and low tare weight; there are trucks outside this high-low range.
- Payload: a maximum calculated by subtracting the low tare weight from the maximum GVW, and a high payload calculated by subtracting the high tare weight from the high GVW.

Additional inputs are built into the model to describe factor prices, productivity, and other aspects of operation. While the analysis is conducted for particular values of these inputs, they may be varied to examine the sensitivity of the model and its results to the assumptions. Factor prices are standard 1988 Trimac values for such things as labor rates and fuel prices, equipment prices supplied by manufacturers, and others, such as the cost of capital or the level of overhead as user-supplied data. The basic productivity relationships used by Trimac are retained for such things as cargo load-unload rates. However, new relationships are developed to assess the range of configurations being considered, such as how fuel consumption is affected by GVW, the effect of an empty backhaul on GVW, the effect of wide-spread axles on tire and maintenance costs, and the effect of axle load on tire and maintenance costs. Finally, annual utilization as determined by the annual hours of operation and the extent of non-trip distances, the trip speed, and empty or full backhaul is specified by the user. Users are able to specify any haul distance, but most of the published results use the base 160 km (100 mi) found in Trimac's procedures.

The models compute costs in terms of dollars per tonne, dollars per kilometer, dollars per tonne-kilometer, and annual costs. Dollars per tonne-kilometer is the principal measure used in the subsequent analysis. Table 3 shows an example of the results from this costing procedure. Because not all 24 configurations are allowed by all provinces, it contains only 53 costs for one truck body style. There are actually 3,710 costs, from 53 configurations over the three regions, for two weights, under five scenarios, and seven body styles. Important aspects of Table 3 are as follows:

- Body style is van;
- High GVW and high tare weight, so payload is high;
- Haul distance is 160 km (100 mi);
- Backhaul is assumed;
- 2,000 annual hours of operation;
- Non-trip distance is 5 percent of total;
- Load and unload rates are Trimac's, for bulk freight (30.27 and 32.72 t/h);
- Regulatory scenario is the base case;
- Average trip speed is 80 km/h (50 mi/h);
- Axle spreads over 1.8 m (71 in.) increase maintenance and tire costs by 10 percent;
- Axle spreads over 2.0 m (79 in.) increase maintenance and tire costs by 20 percent;
- Axle loads over 8 t (17,637 lb) increase maintenance and tire costs by 20 percent;
- Axle loads over 9 t (19,841 lb) increase maintenance and tire costs by 30 percent;
- Fuel consumption is a function of GVW;
- Overheads are 23.4 percent of truck operating costs; and
- Pre-tax cost of capital is 20 percent.

This analysis is concerned only with dense freight. The comparison of costs is not valid for LTL freight, automobiles, livestock, or any other commodity whose density is less than about 320 kg/m^3 (20 lb/ft^3). Costs are shown as a percentage of 3-S2 costs within each region, as this is the most common large truck configuration in Canada, although it is not used widely to haul dense commodities in the area of this study.

This analysis of trucking costs, with all factors except configuration held constant, leads to a number of observations. First, the RTAC configurations, as originally set out in the 1988 agreement, cannot haul freight at anywhere near the cost of some of the current liftable axle equipment in Ontario, and only the RTAC 3-S3-S2 B-train is competitive in Quebec and Atlantic Canada. The multi-axle semitrailer combinations (mainly in Ontario) are quite efficient haulers of heavy, dense commodities, in respect of truck operating costs.

A second observation is that operating cost is not the only factor in a carrier's decision to use one configuration instead of another, there are a range of operational considerations that also influence the choice. Sectors of the trucking industry using owner-operators have difficulty switching to truck-trailer equipment, as owner-operators own tractors so they can haul anyone's trailer; some shippers require that trailers be left for extended periods of time for loading or unloading, which also militates the use of truck-trailers; and some freight cannot be easily handled by double-trailer combinations.

A third observation is that a regulatory scenario that simply reduces the allowable loads on liftable axles may not be ef-

TABLE 3 SUMMARY OF TRUCK WEIGHTS, PAYLOADS, AND TRUCKING COSTS

	Ontario			Quebec			Atlantic Canada		
	GVW	Payld	Cost	GVW	Payld	Cost	GVW	Payld	Cost
Trucks	(t)	(t)		(t)	(t)		(t)	(t)	
T3	24.9	15.6	132%	25.0	15.7	130%	24.0	14.7	134%
T4, 1L	34.9	24.3	93%						
T4	33.9	23.3	99%	34.0	23.4	98%			
T3-2	42.9	28.4	95%	44.0	29.5	91%	42.0	27.5	92%
T3-3	53.0	37.4	79%	53.0	37.4	78%	51.0	35.4	77%
T3-4	61.7	44.8	71%	57.5	40.6	74%	56.5	39.6	73%
T4-4, 1L	63.5	45.3	70%						
3-S2	42.0	26.1	100%	42.0	26.1	100%	40.0	24.1	100%
3-S3	47.3	30.3	90%	48.0	29.0	88%	47.0	30.0	86%
3-S3, 1L	52.0	35.0	83%	52.0	35.0	83%	49.0	32.0	81%
3-S4	60.1	42.0	76%						
3-S4, 1L	57.3	39.2	78%	55.5	37.4	80%			
3-S4, 2L	60.1	42.0	76%						
3-S5, 1L	61.5	42.1	73%						
3-S5, 2L	61.5	42.1	73%						
3-S6, 1L	61.5	40.8	76%						
3-S6, 2L	61.5	40.8	76%						
3-S3-S2	61.5	40.4	81%	59.0	37.9	84%	56.5	35.4	84%
3-S3-S2, 1L	61.5	40.4	81%	59.0	37.9	84%			
3-S2-3	61.5	39.7	82%	57.5	35.7	89%	50.0	28.2	101%
RTAC 3-S3	45.0	28.0	92%	45.0	28.0	92%	45.0	32.5	86%
RTAC 3-S2-S	256.0	36.0	90%	56.0	36.0	90%	56.0	36.0	85%
RTAC 3-S3-S	262.0	40.9	80%	62.0	40.9	79%	62.0	40.9	75%
RTAC 3-S2-3	58.5	37.2	86%	58.5	37.2	86%	58.5	37.2	82%

fective where excess axle load capacity exists, as it does in many of the configurations with two liftable axles. Carriers claim that, while these configurations do not necessarily allow any payload advantages, they do allow tolerance in loading commodities such as coils of steel to meet axle weight laws.

Finally, under any of the regulatory scenarios examined, reasonable alternatives to liftable axle trucks do exist for most freight. That is, if load limits for liftable axles are reduced, liftable axles are restricted to one per combination, or are banned altogether, there are alternative configurations to carry freight without a large increase in hauling costs. There are some circumstances in which this generalization does not hold. For example, carriers using refrigerated vans with liftable axles may face fairly large cost increases if they switch to double-trailer configurations. But these cases aside, it is generally true that most freight can be hauled by alternative configurations with only a small increase in hauling costs under the regulatory scenarios examined. Indeed, in some cases, hauling costs could actually fall under some of the scenarios to the extent that the change in regulations encourages operators to switch to truck-trailer combinations. The T3-4 can haul dense freight at the lowest cost in all three regions, though there are institutional and operational factors that may make the use of such equipment difficult.

Impact of Regulatory Scenarios on Freight Costs

The final stage in the evaluation of the regulatory options is to integrate the results of the costing model with a large-scale model of freight flows in central and Atlantic Canada. This is difficult, as Statistics Canada data on freight flows (*10*), and road-side survey data on vehicle configurations are only weakly related. The methodology is as follows.

First, a detailed examination is made of every configuration under each of the five regulatory scenarios. Where hauling costs increase for equipment with liftable axles, it is assumed that freight shifts to the nearest alternative configuration. For example, if in Scenario 3 the reduction in liftable axle loads to six tonnes increased the hauling costs of the 3-S3,1L to a point higher than the 3-S3, it is assumed that some or all freight would shift to the 3-S3. Some of this 3-S3,1L freight would also shift to the 3-S4,1L and some might shift to the T3-3 configuration. Generally, but not always, a freight shift implies an increase in trucking costs for shippers. This step, the reassignment of freight, was the key to the whole analysis.

The data from roadside surveys shown, in part, in Table 2, are used to construct a distribution of the freight hauled in each region by each configuration, and an index of cost-per-tonne is constructed from the cost model for each configuration.

The frequency distribution of freight volume given by the roadside survey is used to distribute annual tonnes of originating truck freight measured in Statistics Canada's surveys: 106 299 144 tonnes for Ontario; 55 779 124 tonnes for Quebec; and 20 448 510 tonnes for Atlantic Canada. Having obtained a measure of the annual tonnes carried by each configuration, each of these numbers is multiplied by its respective cost index. Those numbers are summed and a new frequency distribution of costs-per-tonne times total tonnes is obtained. Those percentages are then multiplied by Statistics Canada's 1987 measure of total operating expenses of carriers domiciled in each region: $5.5 billion for Ontario, $2.5 billion for Quebec, and $0.9 billion for Atlantic Canada.

Finally, the regulatory scenarios are evaluated by taking the minimum/maximum change in costs (as a result of the freight shifts) times the estimated total annual trucking costs attributed to each configuration. This evaluation does compare changes affecting under one-third of all freight, those dense commodities now carried by trucks with liftable axles, with total industry costs. This was done because the demarcation between dense freight that would be affected by the changes in regulatory scenario, and the freight unaffected, is not known with precision.

A summary of the results, Table 4, shows the total impact of any of the regulatory scenarios is relatively small in relationship to total trucking costs in central and Atlantic Canada. The main reason is that under any of the scenarios examined, there always exists some configuration capable of hauling the heavy payloads displaced from the trucks made uneconomic or eliminated by that scenario. None of the regulatory options closes off the ability of truckers to haul payloads in the

TABLE 4 SUMMARY OF INCREMENTAL COSTS OF SCENARIOS

Millions of 1987 Canadian Dollars

	Ontario		Quebec		Atlantic Canada		Total	
Scenario	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
2-8 t axle	-4.3	13.9	-0.4	12.9	-0.9	1.1	-5.6	27.9
3-6 t axle	-8.7	28.2	-0.8	26.1	-1.8	2.2	-11.3	56.5
4-Ban axle	-13.8	53.2	-0.7	45.4	-2.7	3.2	-17.2	101.8
One axle	15.0	52.6	-------	-------	-------	-------	15.0	52.6

------ no effect

Percentage of Total Trucking Cost

	Ontario		Quebec		Atlantic Canada		Total	
Scenario	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
2-8 t axle	-0.08	0.25	-0.02	0.51	-0.11	0.13	-0.06	0.31
3-6 t axle	-0.16	0.51	-0.03	1.03	-0.21	0.26	-0.13	0.63
4-Ban axle	-0.25	0.96	-0.03	1.80	-0.32	0.38	-0.19	1.14
One axle	0.27	0.95	-------	-------	-------	-------	0.17	0.59

------ no effect

40-tonne range. Indeed, in Atlantic Canada, the new RTAC B-train allows much higher payloads than any existing equipment with liftable axles. Further, the analysis may over emphasize the impact in Quebec. The roadside survey does not reflect more recent changes in regulation which make the B-train much more attractive. Table 3 shows it can haul freight at lower cost than any liftable axle equipment. A trend to use of these B-trains could reduce substantially the impacts shown in Table 4 for Quebec.

Although the overall impact appears to be relatively small, there are some operators or commodities that do not have a ready alternative truck configuration of near comparable cost. Refrigerated vans, propane tankers, and end-dump trailers are all trucks that could see significantly increased costs under any of the scenarios. Some commodities could see costs increasing by as much as 10 to 13 percent (or, in isolated cases, even more).

A sensitivity analysis for both the assumptions employed in the cost model and the model of freight flows was concluded. Although the full results are complex, it should be noted that the values shown in Table 4 maximize the potential impact of the regulatory scenarios. That is, the minimum/maximum values shown have been deliberately set very far apart. The true impact if the scenarios were actually implemented, if any, would be expected to lie somewhere within this range.

There are weaknesses in this methodology. There is no strict relationship between freight flows measured by Statistics Canada's survey of shipping documents, according to the origin or destination of the freight, and financial data computed by Statistics Canada from a census survey based on the province of domicile of carriers. Further, the measure of total operating expenses includes many activities not related to the movement of the freight, such as international activity, storage, and warehousing. There are many assumptions and parameters used in the cost model, from the factor prices used, to the fuel consumption specified, to trip length chosen for the analysis. Finally, no account was taken of transitional (changeover) costs for truck operators. These costs are believed to depend strongly upon how the changes would be implemented. If liftable axles were banned outright on short notice, there is little doubt that transition costs would be very high. However, if existing equipment was allowed to continue operating under a grandfather clause, transition costs would be quite low because carriers would not be forced to buy new equipment until the existing equipment became uneconomic to operate. These and other weaknesses aside, the study does provide an initial estimate of the range of changes in costs that would be expected from a change in regulations regarding liftable axles.

Summary

The economic analysis has a wide range of uncertainty. However, even with the most pessimistic of assumptions, none of the regulatory scenarios used in this study has a major impact in terms of total trucking costs. Even the most draconian measure, an outright ban on liftable axles, results in a cost change between reduction of 0.19 percent and an increase of 1.14 percent. These percentages have been calculated in terms of total private and for-hire truck operating expenses; in fact, the regulatory options examined would affect only a portion of this activity—that involved with the hauling of dense freight. Some of these operators could experience cost increases of as much as 10 to 13 percent (or in isolated cases, even higher). Whatever the case, the overall minor impact of the scenarios, and the limited cases of more serious impacts, needs to be weighed off against the technical impacts of liftable axles on the infrastructure.

CONCLUSIONS

There are serious weight compliance, roadway wear, bridge loading, and intrinsic truck safety issues associated with the use of liftable axles on heavy trucks. There is a solid technical basis for regulatory measures that would limit the application and use of liftable axles. The trade-off, however, is the benefit shippers and consumers derive from the lower transportation costs made possible by the use of trucks with liftable axles. Clearly, regulatory change is not contemplated without careful consideration of this trade-off.

Findings from a study that is part of the process of weighing this trade-off have been presented in this paper. It found the impact of four regulatory scenarios, even one which banned liftable axles altogether, to be quite small in terms of overall trucking activity in central and Atlantic Canada. This is because there are already alternative trucks of comparable payload that could replace those with liftable axles. It was also found that scenarios that simply reduced allowable loads on liftable axles may have no impact where operators already have excess axle capacity over allowable gross weight.

In Canada, the issue is how their current widespread and uncontrolled use of liftable axles might be curtailed. There are clearly major drawbacks to both highway agencies and truckers if liftable axles come into widespread use, because control of axle loads cannot be guaranteed. Alternative vehicles can be configured to provide high gross weights without the use of liftable axles. This task can be achieved in a manner that provides an improvement in both intrinsic truck safety and system safety, as well as providing the productivity improvement of higher gross weights.

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REFERENCES

1. *TRB Special Report 225: Truck Weight Limits: Issues and Options.* TRB, National Research Council, Washington, D.C., 1990.
2. *TRB Special Report 227: New Trucks for Greater Productivity and Less Road Wear.* TRB, National Research Council, Washington, D.C., 1990.
3. A. C. Agarwal and J. R. Billing. *The Effect of Ontario's Weight*

Regulations on Commercial Vehicle Design. Presented at International Symposium on Heavy Vehicle Weights and Dimensions, Kelowna, B.C., June 1986.
4. J. R. Billing, C. P. Lam, and J. Couture. Development of Regulatory Principles for Multi-axle Semitrailers. Presented at 2nd International Symposium on Heavy Vehicle Weights and Dimensions, Kelowna, B.C., June 1989.
5. *Memorandum of Understanding on Interprovincial Heavy Vehicle Weights and Dimensions*. Roads and Transportation Association of Canada, Ottawa, Feb. 1988.
6. *Recommended Regulatory Principles for Interprovincial Heavy Vehicle Weights and Dimensions*. CCMTA/RTAC Vehicle Weights and Dimensions Study Implementation Committee Report, Roads and Transportation Association of Canada, Ottawa, Sept. 1987.
7. J. T. Christison. *Pavement Response to Heavy Vehicle Test Program: Part 2—Load Equivalency Factors*. CCMTA/RTAC Vehicle Weights and Dimensions Study Technical Report Volume 9, Roads and Transportation Association of Canada, Ottawa, July 1986.
8. F. P. Nix and M. Boucher. *Economics of Liftable Axles on Heavy Trucks*. Report CV-90-04, Transportation Technology and Energy Branch, Ministry of Transportation of Ontario, Nov. 1990.
9. Trimac Consulting Services Ltd. *Operating Costs of Trucks in Canada—1988*. Transport Canada, Ottawa.
10. *Trucking in Canada 1987*. Statistics Canada, Catalogue #53-224, Ottawa, 1988.

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