Study of Large Truck Accident Statistics in Canada to Support Radioactive Material Transport Regulations

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Abstract: In Canada, there are approximately 760,000 shipments of radioactive material that are conducted on an annual basis, involving 900,000 packages and a total activity of about 1,700,000 TBq. Type B packages are involved in 34,500 shipments and transport 97% of the total activity. To better understand the risks associated with the transport of Type B packages, Vysus Group performed an assessment for the Canadian Nuclear Safety Commission (CNSC) of the probability of truck/trailer accidents in Canada which could lead to potential safety consequences. Since accidents involving radioactive material shipments are very rare, it was assumed that the distribution of accident probabilities would be similar to that for regular types of large truck shipments. The assessment was therefore conducted using general transport accident data on large truck accidents that occurred in Canada and Ontario in 2011-2020. Accident event trees were developed, and probabilities based on contributing factors, accident type and vehicle damage severity were obtained. The year-to-year data remained consistent throughout the 2011-2020 time period, with the exception of 2020 due to the COVID-19 pandemic disruptions. Of the accidents that led to some degree of vehicle damage, the vast majority of large trucks were only moderately or lightly damaged, which would be unlikely to pose challenges to the integrity of a Type B package. The most prevalent contributing factors were driver-related, such as driver inattention, improper passing or driving too closely; only a small fraction of all accidents studied in this report occurred due to the drivers being under the influence of alcohol or drugs. Hence, one of the main keys to minimizing the probability of accidents involving large trucks is strict regulatory requirements on truck drivers and their training. The analysis showed that probabilistic methods can be used to deepen the understanding of radioactive material transport safety.

1. INTRODUCTION

Transportation of radioactive material in Canada is subject to Canadian regulations and is regulated by the Canadian Nuclear Safety Commission (CNSC). The regulations ensure protection of the health and safety of people and the environment. The basic philosophy behind CNSC's transport regulations is that safety relies heavily on the design of the transport package. Package designs are combined with additional regulatory controls including labeling, placarding, quality assurance and maintenance records, and allow for radioactive material to be carried safely in all modes of transport such as road, rail, air and sea transportation.

In 2019, a feasibility study was conducted to determine whether sufficient data exists to undertake quantitative assessments using probabilities in an event tree for large trucks accidents in Canada [1]. Given that accidents involving radioactive material shipments are very rare, it was assumed that the distribution of accident probabilities would be similar to regular types of large truck shipments. As a result, a generic event tree involving large trucks accidents on Canadian roadways over the 2011-2015 period was developed. The conclusion was that there is, in fact, sufficiently comprehensive and detailed data for the creation and use of event trees in this context.

Building on this knowledge, a subsequent study was completed in 2024 and is the topic of this paper. Its objectives were to refine the event tree that was developed in 2019, to analyze the causes of the accidents and to create a corresponding event tree for large truck accidents in Ontario. Ontario was deemed of interest for comparison with the nationwide data, since most of Canada's nuclear power plants are in this province. Vysus Group, Sweden, provided technical support to the CNSC for this study [2].

2. APPROACH

Similar to the methodology taken during the initial study [1], general traffic accident data for large trucks was used as the basis for the event trees. Accidents during radioactive material transport are very rare worldwide. Therefore, it was not meaningful to create the event tree in this study based on statistical data on accidents involving radioactive material alone. It is important to note that the data in this study is viewed as worst case since the transport of radioactive material is subject to more stringent requirements than general transports, including factors such as vehicle performance and maintenance, driver training and emergency preparedness.

The approach taken for this study consisted of the following steps:
1. Road traffic accident data in all of Canada and in Ontario was gathered for the years 2011-2020.
2. Contributing factors and their relative occurrence were assessed.
3. The data was screened and consolidated for input into the event trees.
4. Given that the event tree developed for the feasibility study [1] had been made to align closely with U.S. data, the event tree structure was refined to align with Canadian data sources.
5. The probabilities of each branch for each of the two event trees were calculated, as well as the accident scenario probabilities.
6. The accident event trees were compiled (using the refined structure, branch point fractions and accident scenario probabilities) for Canada and Ontario.
7. The results for Canada and Ontario were compared for similarities and differences.

3. GATHERING OF ACCIDENT DATA

Transport Canada is a federal-level institution that is responsible for transportation policies and programs throughout Canada. Transport Canada maintains the National Collision Database (NCDB) [3] that contains all police-reported motor vehicle collisions on public roads in Canada. The data from the NCDB, including the relative distribution of different accident types involving all large trucks in Canada, was the main data source for this study. In this database, the most severe consequence is reported, along with other information related to the accident. As the NCDB data that is publicly available did not include all the relevant parameters and the Ontario-specific data that was needed for this study, separate data files were obtained directly from Transport Canada for the years 2011-2020. The number of accidents that occurred in 2020 was significantly lower than in other years, most likely due to the COVID-19 pandemic. The option to screen out all the accidents in 2020 was considered but not chosen since the impact to numerical results turned out to be insignificant.

The scope of the study was limited to large trucks since those are of more relevance to the trucks used for the transport of Type B packages. As such, only accidents involving trucks larger than 4,536 kg (with or without a trailer) and truck tractors (which is a tractor-trailer, with or without a semi-trailer) were included.

4. ANALYSIS OF CONTRIBUTING FACTORS

An objective of the study was to focus on accidents caused by drivers or vehicle-related issues since those are more controllable. As such, accidents where the contributing factors that were related to the surrounding environment (e.g. animal on the road, road obstructions, road conditions) or that had no specific type of contributing factors relating to the driver or vehicle were screened out. The contributing factors were divided into four groups:

- Alcohol and drugs
- Disobeying traffic controls/rules
- Other drivers' behaviors
- Vehicle issues

Table 1 shows the number of large truck accidents in Canada and in Ontario, as well as sub-totals for the analysis of contributing factors and sub-totals for the creation of the event trees, for the time period 2011-2020.

After screening for relevant contributing factors, the average number of large truck accidents were:

- For Canada: 14,383 large truck accidents per year
- For Ontario: 6,670 large truck accidents per year

After screening for relevance regarding the event trees, the average number of large truck accidents were:

- For Canada: 12,802 large truck accidents per year
- For Ontario: 9,048 large truck accidents per year

Table 1: Number of large trucks involved in accidents in Canada and Ontario by year (2011-2020)

Year	Canada			Ontario		
	Total	For Analysis of Contributing Factors	For Event Tree Creation	Total	For Analysis of Contributing Factors	For Event Tree Creation
2011	45,364	15,609	14,294	13,768	6,789	8,557
2012	41,492	14,718	11,950	13,397	6,644	8,298
2013	43,410	15,406	12,861	14,641	7,158	9,172
2014	43,679	16,352	13,548	15,716	7,769	10,004
2015	41,572	15,561	12,852	14,432	7,100	9,250
2016	39,466	14,310	12,708	13,501	6,753	8,928
2017	41,851	13,924	12,962	13,706	6,787	9,285
2018	43,077	14,217	13,300	14,203	6,249	9,596
2019	41,669	13,384	13,206	15,432	6,665	10,084
2020	32,080	10,348	10,337	10,829	4,789	7,301
Average	**41,366**	**14,383**	**12,802**	**13,962**	**6,670**	**9,048**

5. CREATION OF ACCIDENT EVENT TREES

Accidents where there were no damages to the vehicle were screened out, on the basis that only accidents with vehicle damages would be adequate proxies for risk of damage to the transport package. The event tree structure was refined to align with the parameters in the NCDB and balance the number of branches in the different nodes. The first node, **accident type**, divided large truck accidents into three types: hit moving object, hit non-moving object, and non-collision. For the second node, **category**, two or three categories were formulated for each accident type. Details on these categories are provided in Table 2 below. For the third and final node, **vehicle damage severity**, four ranges of vehicle damage severities were defined as follows:

- Demolished: totally destroyed, not worth repairing;
- Severe: not drivable, but worth repairing, towed from the scene;
- Moderate: Still drivable but does not meet requirements of the law (exclude windshields and lights) for further use without repairs, driven away from the scene;
- Light: Superficial, driven away from the scene.

Accidents with moderate or light vehicle damage severity were combined since both were unlikely to pose challenges to the transport package integrity.

Table 2: Screening and consolidation of parameters for event tree branches

Category	Value in National Collision Database	Comments
Train	Hit train	Relevant for this study and kept separate due to the context of radioactive material transport.
Other moving vehicle	Hit motor vehicle	Relevant for this study and combined.
	Hit streetcar	
Other moving object	Hit other moving object	Relevant for this study and combined.
	Hit pedestrian	
	Hit cyclist	
	Hit animal	
Structure	Hit building	Relevant for this study and combined.
	Other non-road structure	
	Other road structure	
Ground feature	Hit ditch	Relevant for this study and combined.
	Hit rock/embankment	
Other non-moving object	Hit parked vehicle	Relevant for this study and combined.
	Hit non-fixed object	
	Hit culvert	
	Hit tree	
	Hit utility pole	
	Hit curb	
	Hit sign post	
	Hit traffic barrier	
	Other fixed object	
Fire/explosion	Fire/explosion	Relevant for this study and kept separate due to the context of radioactive material transport.
Other non-collision	Other non-collision event	Relevant for this study and combined.
	Skid/spun	
	Ran off road	
	Rolled	
	Jack-knife	
	Load spill	
	Load shift	
	Submersion	
None	Not applicable	Screened out since no information is included for use in the event trees.
	Other	
	Unknown	

This work resulted in the following three-node event tree: accident type, accident category and vehicle damage severity. Using this tree, the probabilities of each branch in each of the nodes were calculated for Canada (shown in Figure 1) and Ontario (shown in Figure 2).

Figure 1: Event tree for road traffic accidents involving large trucks in Canada

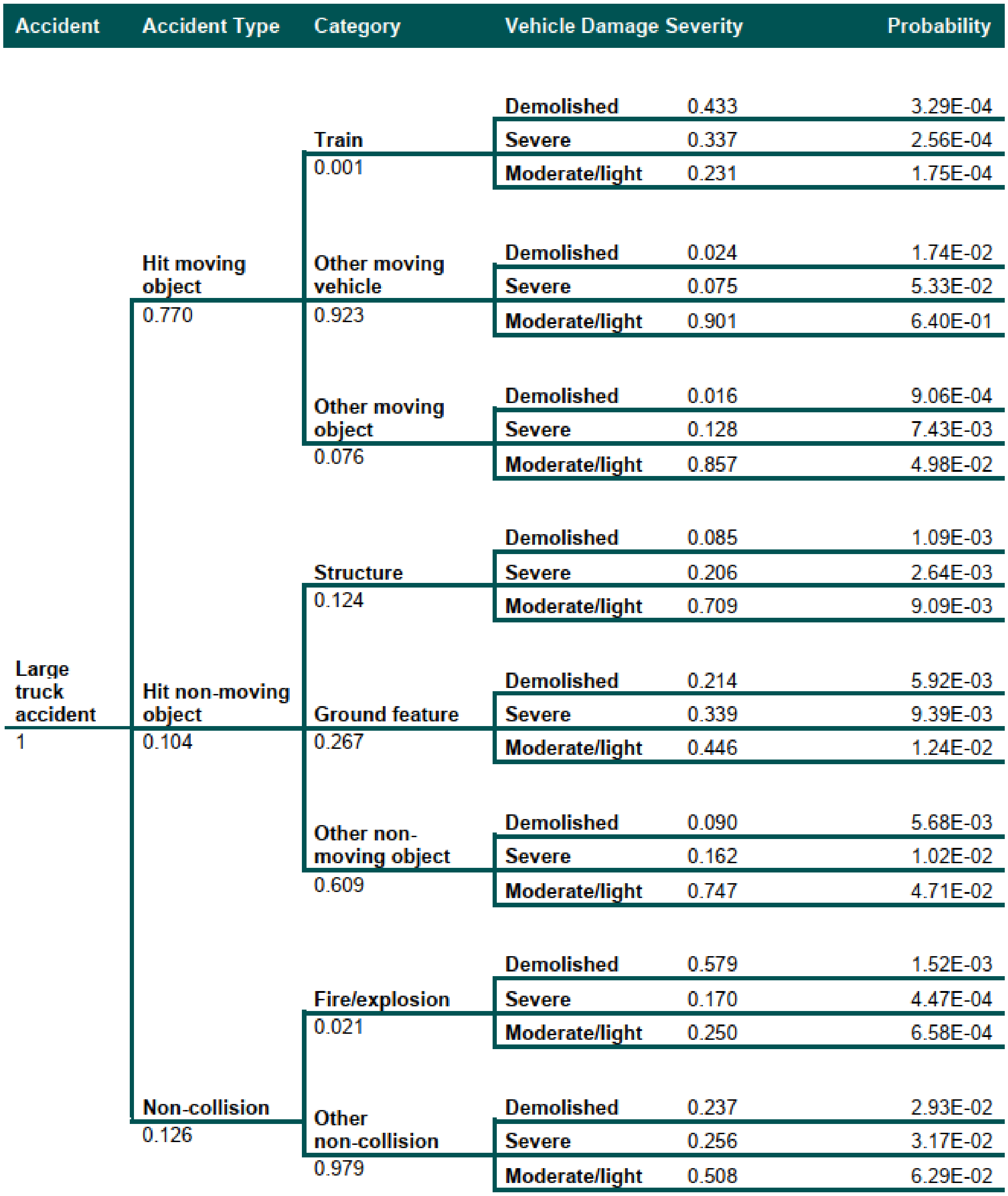
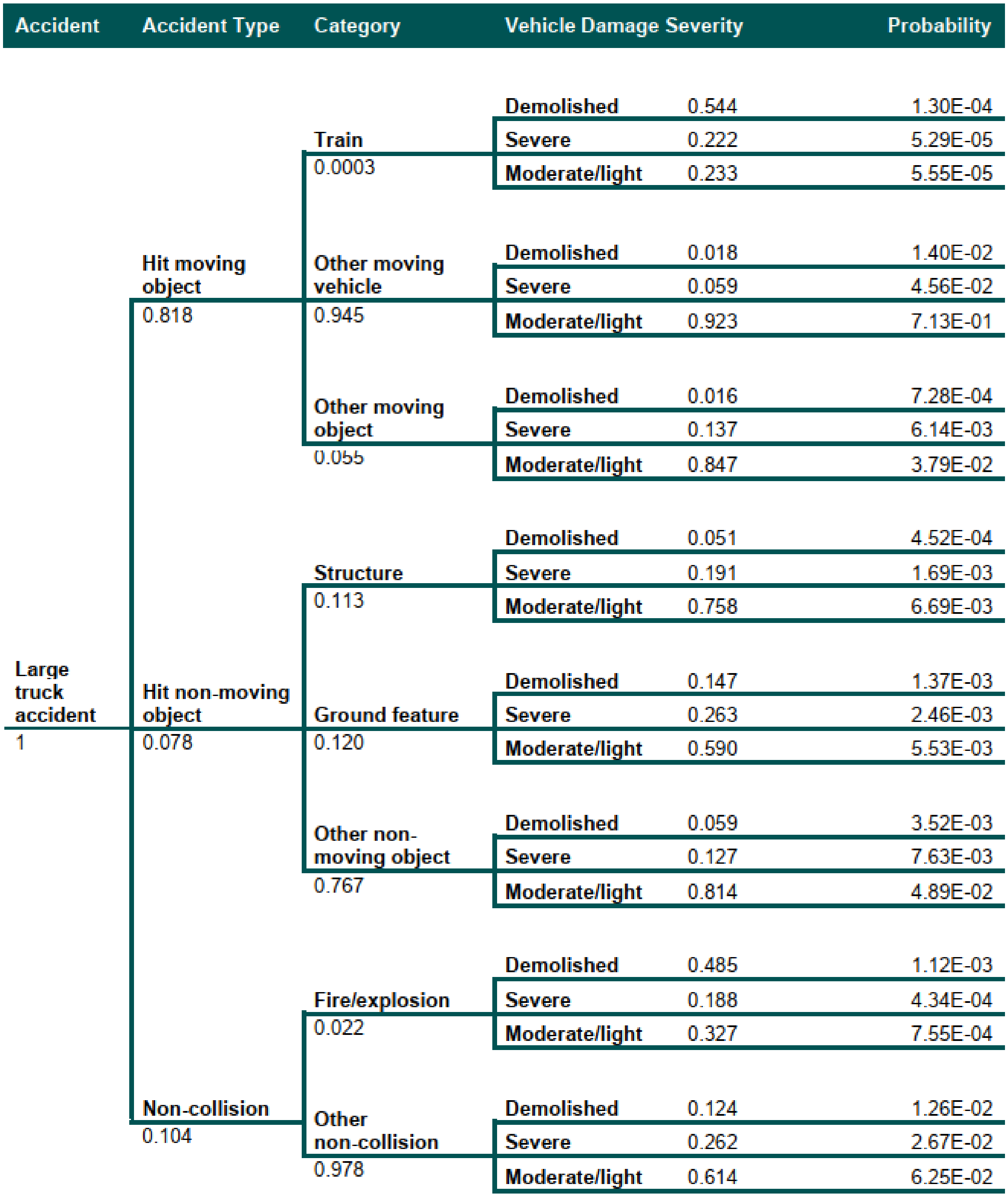


Figure 2: Event tree for road traffic accidents involving large trucks in Ontario



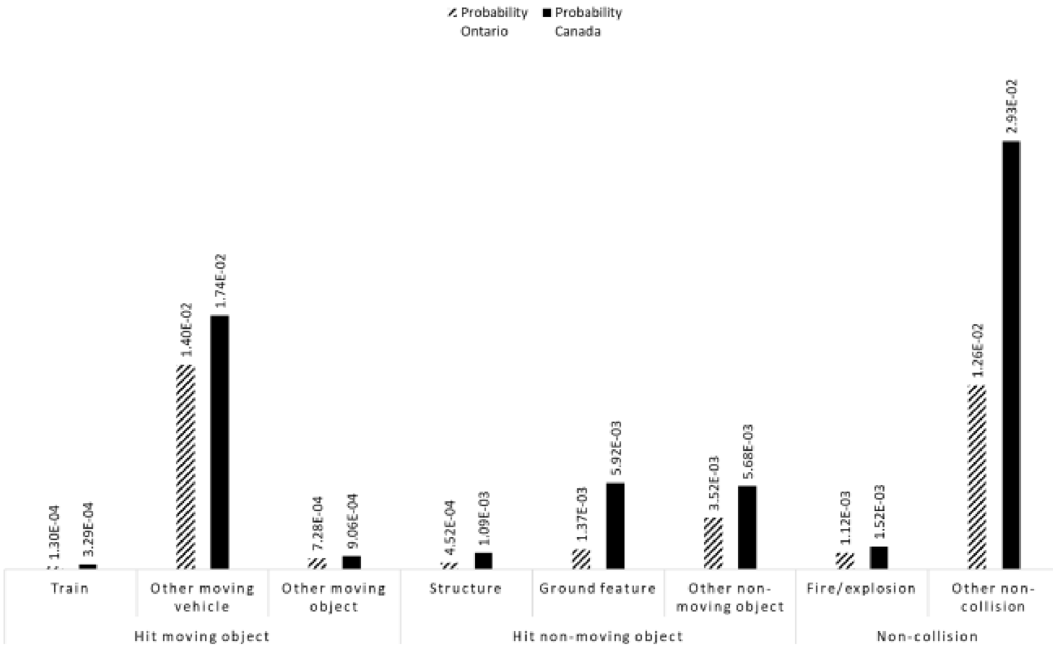
6. COMPARISON OF LARGE TRUCK ACCIDENTS IN CANADA AND ONTARIO

The probabilities that were developed for the event trees were computed and are tabulated in Table 3, showing the comparison between the probabilities in Canada and Ontario. Accidents leading to a demolished vehicle are of particular interest in this study, due to the importance of retaining transport package integrity following an accident. For this reason, the probabilities of accidents leading to a demolished vehicle damage are shown in Figure 3. As can be seen in Figure 3, the likelihood that an accident in Ontario led to a demolished large truck was lower than compared with all of Canada. Of note, the most prevalent accident scenario across Canada to lead to a demolished vehicle is with the large truck being involved in a non-collision accident, more specifically not involving a fire or an explosion, such as the vehicle running off the road, rolling, or jack-knifing.

Table 3: Comparison of large truck accident probabilities

Accident Type	Category	Vehicle Damage Severity	Probability	
			Canada	Ontario
Hit moving object	Train	**Total**	**7.60E-04**	**2.38E-04**
		Demolished	3.29E-04	1.30E-04
		Severe	2.56E-04	5.29E-05
		Moderate/light	1.75E-04	5.55E-05
	Other moving vehicle	**Total**	**7.11E-01**	**7.73E-01**
		Demolished	1.74E-02	1.40E-02
		Severe	5.33E-02	4.56E-02
		Moderate/light	6.40E-01	7.13E-01
	Other moving object	**Total**	**5.82E-02**	**4.48E-02**
		Demolished	9.06E-04	7.28E-04
		Severe	7.43E-03	6.14E-03
		Moderate/light	4.98E-02	3.79E-02
Hit non-moving object	Structure	**Total**	**1.28E-02**	**8.82E-03**
		Demolished	1.09E-03	4.52E-04
		Severe	2.64E-03	1.69E-03
		Moderate/light	9.09E-03	6.69E-03
	Ground feature	**Total**	**2.77E-02**	**9.36E-03**
		Demolished	5.92E-03	1.37E-03
		Severe	9.39E-03	2.46E-03
		Moderate/light	1.24E-02	5.53E-03
	Other non-moving object	**Total**	**6.30E-02**	**6.00E-02**
		Demolished	5.68E-03	3.52E-03
		Severe	1.02E-02	7.63E-03
		Moderate/light	4.71E-02	4.89E-02
Non-collision	Fire/explosion	**Total**	**2.63E-03**	**2.31E-03**
		Demolished	1.52E-03	1.12E-03
		Severe	4.47E-04	4.34E-04
		Moderate/light	6.58E-04	7.55E-04
	Other non-collision	**Total**	**1.24E-01**	**1.02E-01**
		Demolished	2.93E-02	1.26E-02
		Severe	3.17E-02	2.67E-02
		Moderate/light	6.29E-02	6.25E-02

Figure 3: Comparison of large truck accidents resulting in a demolished vehicle

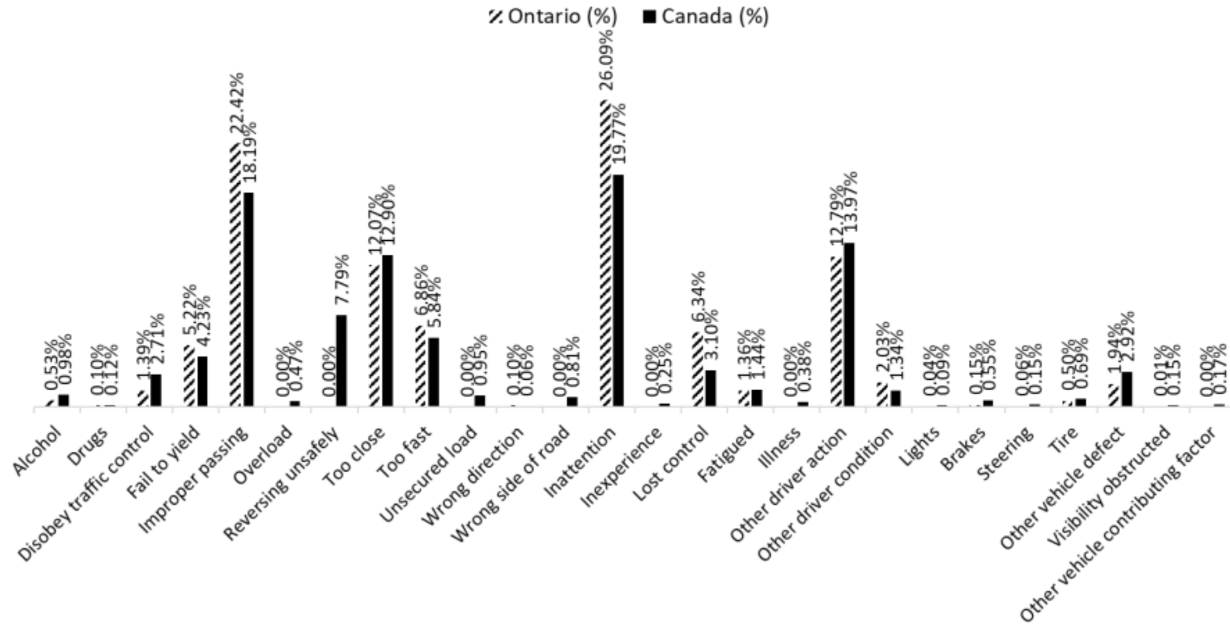


As can be seen in Table 4, driver-related factors contributed to the vast majority of large truck accidents during 2011-2020 in both Canada and Ontario. As shown in Figure 4, the most common of those factors were driver inattention and improper passing. Driving too closely and other driver actions were also prevalent factors Only a small fraction of the accidents studied occurred due to large truck drivers being under the influence of alcohol or drugs.

Table 4: Comparison of groups of contributing factors

Group	Vehicle Damage Severity	Canada	Ontario
Alcohol and drugs	Demolished	0.23%	0.08%
	Severe	0.12%	0.11%
	Moderate/light	0.24%	0.31%
	No visible/unknown/not provided	0.52%	0.12%
Disobeying traffic controls/rules	Demolished	1.28%	0.88%
	Severe	2.02%	2.66%
	Moderate/light	16.49%	27.74%
	No visible/unknown/not provided	34.16%	16.78%
Other driver behaviours	Demolished	2.46%	2.11%
	Severe	3.06%	4.11%
	Moderate/light	14.44%	23.75%
	No visible/unknown/not provided	20.27%	18.65%
Vehicle issues	Demolished	0.24%	0.14%
	Severe	0.30%	0.22%
	Moderate/light	0.94%	1.07%
	No visible/unknown/not provided	3.23%	1.27%

Figure 4: Comparison of driver- and vehicle-related factors that contribute to large truck accidents



7. DISCUSSION

The data on large truck accidents in Canada and Ontario is generally well aligned. This is likely partly because 34% of all Canadian large truck accidents in the NCDB occurred in Ontario (see Table 1). After screening, that percentage increases further. Of the accidents used in the contributing factors analysis, 46% were Ontarian accidents; for the event trees, 71% of Canadian accidents occurred in Ontario.

Of the accidents that resulted in some degree of vehicle damage, most of the large trucks were only moderately or lightly damaged (see Figures 1 and 2). Except for train collisions and fire/explosions, the least likely outcome in all accident categories was a demolished vehicle.

Compared with all of Canada, a higher percentage of large truck accidents in Ontario only led to a moderate or light vehicle damage severity. And conversely, the likelihood of demolished large trucks in Ontario was lower (see Figure 3). The reason for that has not been studied in this report but is assumed to be due to lower average speeds in urban areas, where a larger percentage of the accidents in Ontario likely occurred.

In both Canada and Ontario, driver-related factors contributed to the vast majority of large truck accidents during 2011-2020. The most common of those factors were driver inattention and improper passing. Driving too closely and other driver actions were also prevalent factors (see Figure 4). Compared with all of Canada, large truck accidents due to inattention or improper passing were more common in Ontario (see Figure 4). Only a small fraction of all accidents studied in this report occurred due to large truck drivers being under the influence of alcohol or drugs (see Table 4 and Figure 4).

8. CONCLUSION

This study has confirmed that methods based on the probabilities of accident scenarios can be a valuable complement for understanding of safety-related aspects of radioactive material transports on Canadian roadways. Given the prevalence of driver-related factors among general large truck accidents in both Canada and Ontario, it can be assumed that the key to minimizing the probability of accidents involving large trucks overall is strict requirements on truck drivers and their training. As such, information on driver-related and other regulatory requirements and industry practices that are in place to prevent large truck accidents in Canada and other countries are of interest.

Further studies are recommended to explore other aspects that can inform probabilistic assessments of radioactive material transport safety. This includes a study on time of day, weather conditions, speed and other types of parameters that are available in the data files used in this study. Comparisons with car accidents might also provide valuable insights in future studies. Since a significant portion of large truck accidents in Canada occur in Ontario, it would also be of value to separate out the Ontario accidents from all of Canada and then study differences between accidents in Ontario and the rest of Canada.

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