Analysis of the Economic Costs and Benefits Related to Increasing the Ontario Weight Allowance for New-generation Wide Base Single Truck Tires

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EXECUTIVE SUMMARY

Overview of the Report Background and Structure

Ontario's Safe, Productive, Infrastructure-Friendly (SPIF) standards govern the design and manufacture of new tractor-trailers for use on Ontario roads. Under this standard, the axle weight limit for new-generation wide base single tires on non-steering axles has been capped at 8,000 kg.

The tire and trucking industries are requesting that the Ministry of Transportation, Ontario (MTO) grant an increase in this allowance to 9,000 kg, citing competitive benefits, particularly within the inter-Ontario marketplace.

This report was commissioned by the Goods Movement Policy Office in the Transportation Policy Branch at the Ministry of Transportation, Ontario (MTO). The purpose of the report is to investigate the benefits and drawbacks associated with new-generation wide base single tires and the proposed increase in permissible axle weights. The primary objectives of the review were to:

- Identify potential benefits and drawbacks (excluding those associated with accelerated deterioration of roadway infrastructure) of raising the allowable axle weights for new-generation wide base single tires from 8,000 kg to 9,000 kg;
- Quantify each benefit or drawback in monetary terms; and
- Determine the net potential benefit (in economic terms) of a shift in policy.

A secondary objective which may have bearing on their likely safety benefits is an examination of vehicle stability using new-generation wide base single tires, versus conventional dual tires. This component of the review examines the dynamic stability of various vehicle configurations through the application of new-generation wide base single tires.

Given the specialized nature of the two studies, each is treated as a separate document in this report. **Part One** provides an evaluation of the potential benefits and drawbacks to the trucking industry and society as a whole of raising the allowable axle weights from 8,000 kg to 9,000 kg. These benefits and drawbacks are understood to fall broadly within three categories, as follows: economic, environmental and societal.

Part Two of the report examines the impacts of increasing the Ontario weight allowance for new-generation wide base single tires on vehicle dynamic performance and collisions. The analysis was done on a computer simulation that looked at certain tractor-semitrailer and B-train configurations.

Each part is a standalone document with its own introduction, analysis, findings and conclusions. Both studies are bracketed by an overall introduction at the front end and overall conclusions at the back end.

Overview of the Methodologies

The gathering of information for **Part One** of the Report was done through a combination of open research, information provided directly by MTO plus data collection from a number of stakeholder groups including the tire manufacturers, truck manufactures, carriers and fleet operators with hands-on experience using wide based single tires.

The data collection methodology created a number of challenges for the Project Team. Given that much of the data was provided by stakeholders, there were issues of data quality and data integrity. As a result, the Project Team conducted a critical review of all available research information as part of the data gathering process. The report examines each information source and discusses data quality. It then makes a decision on which data source to use.

The methodologies used in **Part Two** of the report were much more scientific in its approach and involved computer simulations of the following vehicle configurations:

1. Semitrailer with a “standard spread” tandem;
2. Semitrailer with a wide spread (3.66 m (144 in)) tridem;
3. Self-steer tri-axle semitrailer with a “standard spread” tandem;
4. Self-steer quad semitrailer with a wide spread (3.66 m (144 in)) tridem;
5. 7-axle B-train double trailer with “standard spread” tandem trailers; and
6. 8-axle B-train double trailer with a “standard spread” tandem pup trailer.

The simulation study was conducted using a version of the Yaw/roll model. The Yaw/roll model is a dynamic simulation that represents the combined lateral, yaw and roll response of heavy articulated vehicles as a result of either closed or open loop steering input with relatively simple input data. The simulation tools depends on the vehicle configuration, payload weight and payload distribution, and also on the properties of steering, suspensions, tires and hitches.

The simulation approach involved creating a Load Case – which is basically maximum payload weights for each of the six vehicle configurations. Load cases for each vehicle configuration was then tested based on four tire fitments. Fitment combinations were based on tractor tires and trailer tires and included: dual-dual; dual-wide single; wide single-dual and wide single-wide single.

The simulation software generates vehicle performance based on the following manoeuvres: a high speed turn; a high speed lane change; a low-speed right-hand turn on a high friction surface; and a tight, low-speed right- hand turn on a high friction surface. The simulation tool measures the static roll threshold, off-tracking for both high speed and low speed, the load transfer ratio, rear out-swing, and friction demand. See Section 2.1 in Part Two.

Conclusions – Part One

The broader application of new-generation wide base single tires offers substantial benefits to commercial vehicle operators and society. Based on expected fuel savings of 1.5% per axle so-equipped, and a fuel price of $1.00/L, the following outcomes are forecast:

- If no regulatory change occurs, uptake of new-generation wide base single tires is expected to reach no more than 5%. On that basis, annual benefits to society and the trucking industry from the net advantages of new-generation wide base single tires will be capped at slightly less than $10 million per year.

- If the regulations are amended to permit axles equipped with new-generation wide base single tires to operate at weights up to 9,000 kg, industry uptake is expected to be in the range of 50%, and annual benefits to society and the trucking industry from the net advantages of new-generation wide base single tires will reach $79,564,800 per year.

- Of the $79.6 million savings per year, $69.3 million would go towards industry and the difference, $10.3 million, would benefit society (i.e., reduced emissions, collisions and tire disposal costs).

Conclusions – Part Two

Key findings from **Part Two** of the report include results for each of the performance criteria. Unfortunately, it was not possible to get sufficient data from tire manufacturers for the full non-linear tire characteristics file demanded by the simulation. The data provided were therefore blended with the complete characteristics of earlier generation wide single tires to produce composite characteristics for a generic 445/50R22.5 drive tire, and a generic trailer tire.

With this in mind, the findings where an average increase in the static roll threshold of 2%; decreases in high-speed offtracking of 5% for vehicles fitted with wide single tires on the tractor only, 10% for trailer only and 15% for vehicles fitted with wide single tires on both the tractor and trailer; a average decrease in the load transfer ratio of up to 3.5%; decreases in transient offtracking of 10% for tractors only fitted with wide based single tires and 18% for trailers only fitted with wide based single tires.

In terms of the impact on safety, it was found that a complete replacement of dual tires by wide based single tires could result in a .96% reduction in collisions. This translates to an estimated annual combined savings in direct collision costs and congestion costs of just under $10.1 million. Based on a 50% uptake rate this translates to an annual savings in direct collision costs and congestion costs of $5M per year.

In general the simulation showed wide based single tires will generate modest improvements in vehicle stability and a modest reduction in collisions – perhaps not enough of a reduction or costs savings to sway the total cost-benefit analysis.

Combining the economic benefits from Part One with those of Part Two, the total potential economic benefit associated with wide based single tires is in the order of $85M per year of which Part Two's contribution is roughly 6%.

PART ONE

Analysis of the Economic Costs and Benefits Related to Increasing the Ontario Weight Allowance for New-generation Wide Base Single Truck Tires

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1.0 INTRODUCTION

1.1 Background

In the Fall of 2000, truck tire manufacturers began actively marketing a new generation of 445/50R22.5 wide base single tires as an alternative to traditional dual tires. The industry cites several advantages of this new technology, including:

- Dimensionally compatible with the 11R22.5 dual tires they replace;
- Improved fuel efficiency through reduced rolling and aerodynamic resistance;
- Less overall vehicle tare weight through reduced wheel and tire mass (particularly when new-generation wide base single tires are combined with aluminum rims);
- Better ride qualities through increased sidewall flexibility; and
- Improved handling and vehicle stability.

Increased fuel efficiency potentially translates into lower operating costs, and less environmental impact through lower emissions. Less overall vehicle tare weight potentially translates into increased payload potential where vehicles that carry loose bulk commodities are operating at their maximum permissible gross weights. Lower tire mass potentially translates into lower raw material and energy inputs, and resulting emissions, during manufacture. Less embodied material potentially translates into less mass to be recycled or disposed of, and less resulting emissions, when the tire reaches the end of its useful life. Better ride qualities potentially translates into a more comfortable and less fatiguing driver environment, potentially promoting increased safety through driver alertness, and longer-term driver retention. Better ride qualities may also translate into reduced potential for cargo damage while in transit. Improved handling and vehicle stability potentially translates into improved safety performance under normal conditions, and increased potential for collision avoidance/collision severity reduction during emergency maneuvers.

Potential disadvantages identified with new-generation wide base single tires, relative to conventional dual tires, include:

- Higher purchase costs (although this is offset to some degree by the reduced number of tires and rims required);
- Durability issues;
- Their ability to be re-capped and reused more than once (the industry standard for conventional dual tires is to recap them at least twice during their life-cycle);
- The retail availability of replacement tires, should one fail; and
- The inability to “limp home” on a failed tire (an ill-advised but reported practice with conventional dual tires).

A key consideration for road and regulatory agencies is the amount of damage these new-generation wide base single tires inflict on road infrastructure. Research to-date indicates that new-generation wide base single tires do no more damage than conventional, dual tires at axle weights up to 8000 kg. Information on their impacts at higher axle weights has yet to be determined.

Ontario's Safe, Productive, Infrastructure-Friendly (SPIF) standards govern the design and manufacture of new tractor-trailers for use on Ontario roads. Under this standard, the axle weight limit for new-generation wide base single tires on non-steering axles has been capped at 8,000 kg.

The tire and trucking industries are requesting that the Ministry of Transportation, Ontario (MTO) grant an increase in this allowance to 9,000 kg, citing competitive benefits, particularly within the inter-Ontario marketplace.

The results of tests aimed at exploring the impacts on pavements of new-generation wide base single tires operating at axle weights above the current 8,000 kg cap will be available late in 2007. This information will provide key insights into the performance of new-generation wide single tires at higher allowable axle weights, as they relate to the potential for accelerated deterioration of infrastructure.

With this data soon to be available, the MTO now requires a comprehensive valuation of economic and societal costs and benefits of increasing the axle weight limit for new-generation wide base single tires to 9,000 kg. When completed, and married to the costs associated with infrastructure impact, this information will provide a sound basis for policy development.

1.2 Purpose of This Study

The purpose of this study is to:

- Identify the potential benefits and drawbacks (excluding those associated with accelerated deterioration of roadway infrastructure) of raising the allowable axle weights for new-generation wide base single tires from 8,000 kg to 9,000 kg. These benefits and drawbacks are understood to fall broadly within three categories, as follows:
    - Economic;
    - Environmental; and
    - Societal
- Quantify each benefit or drawback in monetary terms; and
- Determine the potential net cost or benefit (in economic terms) of a shift in policy.

A secondary purpose, which may have bearing on the likely safety benefits of new-generation wide base single tires, is an examination of vehicle stability using new-generation wide base single tires, versus conventional dual tires. This component of the study is to address the dynamic stability of various configurations, and is also to include commentary on opportunities to improve the stability of tankers by widening their track and lowering their centre of gravity through the application of new-generation wide base single tires.

In a further breakdown of the three key areas of potential benefit and drawback, upon which net differences in the performance of new-generation wide base single tires versus conventional dual tires are to be assessed, this study explored the following subject areas:

- Fuel efficiency impacts in rolling resistance, aerodynamic resistance and vehicle operating weight;
- Payload opportunities created by reductions in vehicle tare weight;
- Environmental impacts related to changes in fuel consumption and emissions, along with tire manufacturing, durability, reuse, and disposal;
- Changes in the likelihood of collision involvement based on relative stability, and the risk of a tire failure resulting in a crash;
- Ride quality issues for both driver and cargo;
- Whole-life costs of ownership; and
- Other costs or benefits identified though a differential analysis of the two tire types.

1.3 Methodology

The information needed to complete this study was drawn from the following:

- Open research;
- Research available from the MTO;
- Tire manufacturers;
- Truck manufacturers; and
- Fleet operators.

A key premise of this study was that, with the exception of stability analysis, sufficient credible research about new-generation wide base single tires existed to assess the potential costs and benefits of the regulatory change under consideration, and that no new research or testing was required.

In assembling the material needed to conduct this study, the authors:

- Conducted a literature search and performed a critical review of available research;
- Obtained and critically-reviewed research conducted by, or available through, the MTO;

- Obtained additional information directly through the MTO's Project Manager; and
- Contacted and received input from tire manufacturers, truck manufacturers, and fleet operators.

To provide a uniform basis for comparison, reference was made to an MTO paper which estimated the potential market for new-generation wide base single tires if the permissible axle load limit were increased to 9,000 kg[1]. Reference was also made to this paper in regards to the potential for industry uptake within that portion of the vehicle fleet for which the application of new-generation wide base single tires would be both permissible and beneficial.

In order to roll up many of the costs and benefits associated with the use of new-generation wide base single tires, it was first necessary to translate the applicable Axle-Vehicle Kilometres of Travel per day (Axle-VKT per Day) identified in the MTO study into vehicle-kilometres of travel for each major vehicle configuration. Information on the numbers of each type of unit in service in Ontario on a typical day was obtained from MTO.

Given their anticipated marginal impact, transitional issues, including costs and benefits associated with the retrofit of existing fleets, and the ramp-up during the phase-in period for SPIF-compliant vehicles equipped with new-generation wide base single tires, were ignored.

Base line fuel consumption estimates and estimates of potential increases in fuel efficiency through decreases in rolling resistance, aerodynamic resistance, and vehicle operating weight were drawn from several sources which were evaluated individually as to their credibility. Credible estimates were then combined to arrive at a generalized estimate. Decreases in operating costs were then calculated based on prevailing retail fuel prices.

Payload increases associated with the regulatory change under consideration – the increase in permissible axle weights with new-generation wide base single tires from 8,000 kg to 9,000 kg - and their associated economic and competitive benefits, were excluded from the analysis as they have no material bearing on the issue. Under the current regulatory framework, operators of vehicles with conventional dual tires may operate at axle weights up to 9,000 kg. The regulatory change under consideration would only provide those operators carrying payloads at or approaching the maximum permissible gross weights the option to choose to use new-generation wide base single tires.

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[1] Estimated Vehicle Kilometres of Travel on Axles Potentially Using Single Tires if Axle Load Limit Increases to 9000 kg, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, June 2007

The regulatory change would not (as is suggested in a similar study prepared for the Transportation Ministry in Quebec[2]) provide a competitive advantage to vehicles equipped with new-generation wide base single tires, only parity with conventionally-configured vehicles. Thus the issue of increased capacity is entirely spurious, with the notable exception of its application to reductions in the tare weight of the vehicle. The incremental increase in payload derived from a reduction in tare weight, achieved through the use of new-generation wide base single tires, is their only true competitive advantage, and is the only competitive advantage pertaining to payload capacity which need be accounted for in this assessment.

Payload opportunities created by reductions in vehicle tare weight were drawn from several sources, and assessed based on their applicability to the Ontario commercial vehicle fleet. Applicable estimates were then combined to arrive at a generalized estimate of reductions in tare weight, which were then applied to estimate potential increases in fuel efficiency and payload capacity. Increased fuel efficiency derived from decreases in tare weight was deemed to be included in the efficiencies identified in overall decreases in fuel consumption, and were not analyzed individually to avoid double-counting. Increases in payload capacity were examined from the perspectives of operational efficiency (fewer truck movements to transport the same mass of product) and safety (fewer truck movements translates into less on-road exposure, a key component of safety risk).

Environmental impacts related to changes in fuel consumption were sourced from credible research and examined on the basis of emissions avoided, and the prevailing societal costs associated with neutralizing those emissions (also drawn from credible literature sources). Emissions evaluated included hydrocarbons (HC), carbon dioxide (CO2), carbon monoxide (CO) and nitrogen oxides (NOx).

Environmental impacts related to: tire manufacturing, durability, reuse, and disposal, were examined based on the relative mass of new-generation wide base single tires and conventional dual tires. Areas explored included: manufacturing resource and energy inputs (and associated emissions), life-cycle performance, and the impacts of disposal. Environmental impacts related to oil exploration, recovery and refining, and transportation of finished products, were excluded. Tire life-cycles were estimated based on industry data, and average yearly kilometers of travel, derived from MTO data.

Apart from one MTO study[3] and resulting paper[4] little quantitative information was found to substantiate any benefits to be gained through a reduction in the likelihood of collision involvement based on the relative stability of new-generation wide base single tires, or the relative risk of a tire failure resulting in a crash. Accordingly, this aspect of

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[2] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

[3] Ontario Vehicle Weights and Dimensions Reforms – Expected Safety Benefits, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, April 2005

[4] The Relationship of Collision Rates and Dynamic Performance of Heavy Trucks, Alfonso Corredor, Karl GrosKopf and Ron Madill, Ministry of Transportation Ontario, Freight Policy Office.

the study was approached qualitatively, and combined with estimates of exposure reductions derived from the anticipated increase in payload capacity.

Evidence relating to ride quality issues for both driver and cargo was found to be largely anecdotal in nature. Comparative studies of vehicle dynamics with new-generation wide base single tires and conventional dual tires were reviewed[5],[6]. The results, although positive, do not translate into improvements that may be economically quantified. Anticipated benefits in reducing driver fatigue (improving alertness and possibly reducing collision involvement), longer-term driver retention, and reductions in cargo damage, are therefore discussed in a qualitative manner only.

Evidence relating to whole-life costs of ownership was drawn from open literature, manufacturers' information, and information obtained from fleet operators. A comparative approach was taken, assuming identical vehicles, one equipped with new-generation wide base single tire, the other with conventional dual tires, on all drive and trailer axles. Purchase costs, operating and maintenance costs, and disposal costs were examined.

Other notable costs or benefits identified in the course of the review were examined though a differential analysis of the two tire types.

1.4 Contents of This Report

This report is divided into two main sections. The first is the evaluation of potential benefits and drawbacks of raising the allowable axle weights for new-generation wide single tires from 8,000 kg to 9,000 kg. These benefits and drawbacks fall broadly within three categories, as follows: economic, environmental, and societal.

Part Two of the report is an examination of vehicle stability using wide single tires, versus conventional dual tires. The examination included a dynamic performance analysis using nationally accepted yaw and roll computer simulations.

Each section is a separate entity (Parts One and Two) as they have been prepared by separate organizations. **Section 4.0 – Conclusions** – ties the findings of both reports together into an overall summary that spans the results of both studies.

Part One contains three Chapters as follows. **Chapter 1 - Introduction** presents the background of the study and the research problem. **Chapter 2 – Evaluation of Potential Benefits and Drawbacks** provides detailed estimates of the economic value of each of

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[5] Vehicle Ride Response to New Widebase Tires and Conventional Dual Tires, E. H. Law, Clemson University, Ibrahim Janajreh and Norman Frey, Michelin Americas R&D Corporation, SAE International, 2002-01-3114

[6] Ride Dynamics and Pavement Loading of Tractor Semi-Trailers on Randomly Rough Roads, C. Trangsrud and E. H. Law, Clemson University, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2004-01-2622

the costs and benefits identified, for each of the scenarios analyzed, and the results of those estimates. **Chapter 3 – Economic Assessment** summarizes the economic value of each of the costs and benefits identified, to vehicle operators, and to societal as a whole, as applicable.

As mentioned, Part Two is an analysis of the impacts of increasing the Ontario weight allowance for wide-based single truck tires on vehicle dynamic performance and collisions. That analysis was done based on computer simulation that looked at certain tractor-semitrailer and B-train configurations. The work generated the dynamic performance of these configurations, and has used these results to estimate a change in the number of collisions that might be expected from greater use of wide single tires.

Part Two contains eight Chapters as follows: **Chapter 1 – Introduction** presents a brief background to the study. **Chapter 2 – Assessment of Dynamic Performance** provides details on the performance measures and computer simulations. **Chapter 3 – Vehicle Configurations** provides an overview of the six vehicle configurations tested during the study. **Chapter 4 – Results and Discussion** presents a series of summary tables showing the test results and subsequent discussion. **Chapter 5 – Assessment of Safety Effects** correlates the dynamic performance results with vehicle-kilometres of travel (VKT) to calculate collision numbers for the various vehicle configurations. **Chapter 6 – Potential to Improve the Roll Stability of Tankers** is a special section that looks specifically at tanker trucks. **Chapter 7 – Installation Issues** identifies anticipated installation problems associated with retrofitting existing vehicles with wide base single tires. **Chapter 8 – Conclusions** provides a summary of the findings of Part Two

2. EVALUATION OF POTENTIAL BENEFITS AND DRAWBACKS

2.1. Framework

2.1.1. Amendment to Regulations

We examined one alternative regulatory framework against the status quo that may affect the use of new-generation wide-based single tires. That is:

- That the permissible axle weight for axle weight limit for new-generation wide base single tires would be increased from 8,000 kg to 9,000 kg, assuming a limitation of 10kg/mm of tire width.

2.1.2. Costs and Benefits

In conducting the analysis, we assumed the following costs and benefits would accrue from the aforementioned regulatory amendment under consideration:

- Benefits:
    - Reduction in new vehicle cost;
    - Reduction in vehicle maintenance cost;
    - Reduction in fuel consumption;
    - Reduction in emissions and environmental impact associated with reduction in fuel consumption;
    - Reduction in energy and resource consumption, and emissions, associated with tire manufacturing;
    - Reduction in environmental impact associated with tire disposal;
    - Increase in payload at weights approaching the permissible maximum gross vehicle weight, associated with reduction in tare weight of vehicle, due to lower wheel and tire mass;
    - Improved operational safety, due to improved operator comfort, stability and handling characteristics;

- Costs:
    - Increase in cost of purchasing and re-treading new-generation wide base single tires, relative to conventional dual tires;
    - Increase in environmental impact associated with tire disposal, associated with the reported inability to re-tread new-generation wide base single tires more than once;
    - Increase in the incidence of blow-outs, and additional costs associated with the immediate immobilization of the vehicle until the tire is replaced.

2.1.3. Applicability of New-Generation Wide Base Single Tires

We reviewed and validated the assumptions used by the MTO[7] in determining what portion of the commercial vehicle fleet operating in Ontario would benefit from the regulatory change under consideration. The document envisions a future environment where all vehicle configurations conform to SPIF requirements.

In the document daily travel, as measured by Axle Vehicle-Kilometres of Travel (Axle VKT per Day) in (,000) was used to estimate the proportion of travel which could potentially benefit from the regulatory change under consideration. The MTO report notes that:

> Not all axle configurations of SPIF vehicles would benefit from the potential increase in axle weights from 8,000 kg to 9,000 kg. In fact, only tandem and tridem axles meeting certain conditions would benefit from such an increase if it is assumed that industry would not switch to new-generation wide base single tires in situations where allowable weights exceed 9,000 kg when equipped with dual tires.
>
> Presumably, operators will continue to use dual tires rather than face a permissible weight reduction or penalty.
>
> Similarly, any axles currently restricted to 8,000 kg may already switch to new-generation wide base single tires without penalty. For example, some usage is expected in tractor-trailers operating between Ontario and the United States, which are limited by the US cap of 34,000 lbs (15,422kg). A basic 5% uptake for tractors and semi-trailers equipped with standard-spread tandems is proposed for this study to account for the use of new-generation wide base single tires if the weight cap remains at 8,000 kg.
>
> Tandem axles with spreads from 1.2 m to less than 1.6 m are allowed 18,000 kg with dual tires. These axles would be eligible to use single tires under the proposed increase in the axle weight limit with new-generation wide base single tires. (Tables 1, 2 and 3 of the report)

Those vehicles permitted to use new-generation wide base single tires under current regulations without penalty were excluded from the analysis. Only vehicles which would benefit from the regulatory change under consideration were included.

The MTO document goes on to separate those axles that may benefit from an increase in new-generation wide base single tire axle weights from those that would not. All values are specified in Axle VKT per Day (,000). It estimates that of the 105,267 Axle VKT per

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[7] Estimated Vehicle Kilometres of Travel on Axles Potentially Using Single Tires if Axle Load Limit Increases to 9000 kg, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, June 2007

Day for tractor-trailers in the province, only 50.4% or 53,037 Axle VKT per Day are within the population for which the use of new-generation wide base single tires is a potential (Table 4 and 5 of the report). This value is intended for use in estimating the costs and benefits associated with fuel savings, environmental impacts, and safety impacts, once factored to consider the various uptake scenarios.

Tractor steering axles are capped at a weight of 7,700 kg.

For the purposes of estimating the infrastructure impacts of increasing the weight allowances on new-generation wide base single tires, the report examined the proportion of the eligible population that operates at weights over 8,000 kg per axle. It concludes that only 11.3% of potentially-eligible configurations, or 5,968 Axle VKT per Day, operate at loads above 8,000 kg per axle (Table 6 of the report) on any given day.

This finding underscores a major impediment posed by current regulations to the broader use of new-generation wide base single tires. Although slightly more than one-in-ten axles actually operates at loads above 8,000 kg per axle on any given day, the vast majority of carriers require the *flexibility* to accommodate these loads from time-to-time. Accordingly, they do not consider the use of new-generation wide base single tires to be a viable option under current regulations.

This lack of flexibility is at the core of the MTO’s estimate of a 5% cap on the potential uptake of new-generation wide base single tire, assuming regulations remain unchanged.

A regulatory change which provides parity in allowable axle weights between conventional dual tires and new-generation wide base single tires within the population for which the use of new-generation wide single tires is a potential (53,037 Axle VKT per Day), significantly increases the uptake potential within this group.

For the purposes of estimating the advantages of increasing the cargo-carrying capacity of the vehicle, afforded by a reduction in the tare weight associated with aluminum wheels and new-generation wide single tires, the report examined the proportion of the eligible population that operates at weights over 8,500 kg per axle. It concludes that only 50.9% of those vehicles operating at axle loadings over 8,000 kg, or 3,039 Axle VKT per Day, operate at loads above 8,500 kg per axle (Table 7 of the report).

The report concludes that while SPIF tractor trailers are estimated to have a total axle-VKT per Day of 105.3 million:

- 53.0 million Axle VKT per Day (50.4% of the total) is eligible to benefit from new-generation wide base single tires if the weight allowance is increased from 8,000 kg to 9,000 kg (assuming 10 kg per mm of tire width). This caps the potential for benefits associated with fuel savings, environmental impacts, and safety impacts, once factored to consider the various uptake scenarios.
- Of the eligible total only 3.0 million Axle VKT per Day (5.7%) operates at axle weights in excess of 8,500 kg. This caps the productivity and exposure reduction

benefits of tare weight reductions associated with new-generation wide base single tires and aluminum rims, once factored to consider the various uptake scenarios.

It should be noted that the data provided pertains to travel on Ontario Highways only, and does not account for travel outside of the Province.

2.1.4. Affected Configurations

In order to roll up many of the costs and benefits associated with the use of new-generation wide base single tires, it was necessary to translate the applicable Axle-Vehicle Kilometres of Travel per day (Axle-VKT per Day) in (,000) identified in the MTO study into Vehicle-Kilometres of travel per Day for each major vehicle configuration. Information on the numbers of each type of unit in service in Ontario on a typical day was obtained from MTO.

To simplify the analysis and presentation of the results, Axle-VKTs per Day (,000) for vehicle configurations which make up the population of potential users of new-generation wide base single tires were assigned to the vehicle configurations identified in **Table 1**.

Table 1 – Estimated Axle-VKT per Day (,000) and Numbers of Units in Service for Vehicle Configurations with Potential for Uptake of New-generation Wide Base Single Tires if Axle Weight Limit is Modified

Configuration	Conditions	Total Axle-VKT per Day (,000) Matching Conditions	Total Number of Units in Service in Ontario (Typical Day)
Tractors			
Tandem Tractor	Tandem Spread 1.2 < 1.6 m	30,774	**126,000**
Trailers			
Tandem semi-trailer	Tandem Spread 1.2 < 1.6 m	17,396	146,000
Tridem semi-trailer	Tridem Spread 3.6 to 3.7 m	1,515	6,800
Self-steer triaxle	Tandem Spread 1.2 < 1.6 m	154	400
Self-steer quad semi trailer	Tridem Spread 3.6 to 3.7 m	1,692	6,200
B-Train Double Trailers*	Tandem Spread 1.2 < 1.6 m	1,506	4,850
Total		**53,037**	**164,250**

* Combined units – two units, with a total of five axles make up a double

From **Table 1** above it is obvious that available trailers (164,250) outnumber tandem tractors (126,000). Logic dictates that in order to operate and register Axle-VKTs per Day (,000), a trailer must be paired with a tractor and, for the duration of that pairing, will accumulate the same number of kilometers of travel.

To account for this apparent disparity, total daily kilometers of travel (,000) for each eligible vehicle configuration were examined (**Table 2**). Daily kilometers of travel (,000) for each eligible vehicle configuration was arrived at by dividing the Total Axle-VKT (,000) per Day by the number of eligible axles in each configuration. All B-Train Double Trailers were assumed to be operating as combined units.

Tractors with a tandem spread greater than 1.6 m would not benefit within the regulatory change under consideration to operate with new-generation wide base single tires at weights up to 9,000 kg per drive axle. These vehicles would likely continue to operate with conventional dual tires. For the purposes of this study, these power units have been considered as paired with trailer configurations which will also continue to operate with conventional dual tires, in order to take advantage of regulatory weight limits, and excluded from further consideration.

These assignments are considered by the authors to be reasonable, in that all eligible trailer configurations will be paired with eligible tractor configurations, to yield maximum benefits.

For self-steer tri-axle configurations, only the rear tandem set would be affected by the regulatory change under consideration. The self-steering axle is already eligible to use new-generation wide base single tires. For self-steer quad semi-trailer configurations, only the rear tridem set would be affected by the regulatory change under consideration. The self-steering axles are already eligible to use new-generation wide base single tires. For B-train double trailer configurations, only tandem sets would be affected by the regulatory change under consideration. Any B-train tridem axle set is already eligible to use new-generation wide base single tires.

Table 2 – Estimated Axle-VKT per Day (,000) and Vehicle-Kilometres of Travel per Day (,000) by Configuration

Configuration	Conditions	Total Vehicles In-Service	Total Axle-VKT per Day (,000) Matching Conditions	Number of Eligible Axles	Total Kilometres (,000) of Travel (Axle-KVT/Number of Axles)
Tractors					
Tandem Tractor	Tandem Spread 1.2 < 1.6 m	**126,000**	**30,774**	2	**15,387**
Trailers					
Tandem semi-trailer	Tandem Spread 1.2 < 1.6 m	112,000	17,396	2	**8,698**
Tridem semi-trailer	Tridem Spread 3.6 to 3.7 m	5,216	1,515	3	**505**
Self-steer triaxle	Tandem Spread 1.2 < 1.6 m	307	154	2	**77**
Self-steer quad semi-trailer	Tridem Spread 3.6 to 3.7 m	4,756	1,692	3	**564**
B-Train Double Trailers*	Tandem Spread 1.2 < 1.6 m	3,721	1,506	2	**753**
Total (Trailers)		**126,000**	**22,263**		**10,597**

* Combined units – two units, with a total of five axles make up a double

Table 2 shows a disparity in daily vehicle-kilometres of travel by eligible tandem tractors (15,387,000 km) and by all types of eligible trailers combined (10,879,000 km).

While a proportion of this travel may be explained by eligible tractors operating without a trailer, the majority is interpreted as tractors pulling trailer configurations which would not benefit from the application of new-generation wide base single tires. To address this disparity, an assignment has been made that the Axle-VKTs per Day (,000) and Vehicle-

Kilometres per Day (,000) of travel, associated with this sub-set of tractors, will occur with new-generation wide base single tires on the tractor drive axles, and conventional dual tires on all trailer axles, regardless of configuration.

Accordingly, this sub-set of tractors will be broken out for separate analysis as to cost and benefits, with those costs and benefits applicable to the tractor alone, and not to the tractor-trailer configuration as a whole. This breakout is summarized in **Table 3**.

Table 3 – Estimated Axle-VKT per Day (,000) and Vehicle-Kilometres per Day (,000) by Vehicle Configuration with Potential for Uptake of New-generation Wide Base Single Tires if Axle Weight Limit is Modified

Configuration	Conditions	Total Kilometres (,000) of Travel per Day	Total Axle-VKT per Day (,000) Matching Conditions
Tractors			
Tandem Tractor (Towing SPIF-Compliant Trailer with New-Generation Wide Base Single Tires)	Tandem Spread 1.2 < 1.6 m	**10,597**	**21,194**
Tandem Tractor (Running Alone or Towing SPIF-Compliant Trailer with Conventional Dual Tires)	Tandem Spread 1.2 < 1.6 m	**4,790**	**9,580**
Trailers			
Tandem semi-trailer	Tandem Spread 1.2 < 1.6 m	8,698	17,396
Tridem semi-trailer	Tridem Spread 3.6 to 3.7 m	505	1,515
Self-steer triaxle	Tandem Spread 1.2 < 1.6 m	77	154
Self-steer quad semi-trailer	Tridem Spread 3.6 to 3.7 m	564	1,692
B-Train Double Trailers*	Tandem Spread 1.2 < 1.6 m	753	1,506
Total (Matched Tractor and Trailers)		**10,597**	**22,263**
Total		**15,387**	**53,037**

* Combined units – two units, with a total of five axles make up a double

Tractors and trailers of the configurations identified in **Table 3**, which consistently operate at axle weights at 8,000 kg or less, currently have the option to use new-generation wide base single tires on all drive and trailer axles under current regulations.

Of the 53,037 Axle VKT per Day (,000) which would potentially benefit from the regulatory change under consideration, only 5.7% or 3,039 Axle VKT per Day (,000) operate at loads of 8,500 kg or more, and thus would benefit from a tare weight reduction associated with aluminum rims and new-generation wide single tires. **Table 4** summarizes the Axle-VKT per Day and Vehicle-Kilometres of Travel per Day at loads above 8,500 kg, on the assumption that such operation is distributed equally amongst all eligible vehicle configurations.

Table 4 – Estimated Axle-VKT per Day (,000) and Vehicle-Kilometres per Day (,000) for Vehicle Configurations Operating Above 8,500 kg per Axle, with Potential for Uptake of New-generation Wide Base Single Tires if Axle Weight Limit is Modified

Configuration	Conditions	Total Kilometres (,000) of Travel per Day	Total Axle-VKT per Day (,000) Matching Conditions
Tractors			
Tandem Tractor (Towing SPIF-Compliant Trailer with New-Generation Wide Base Single Tires)	Tandem Spread 1.2 < 1.6 m	**607**	**1,214**
Tandem Tractor (Running Alone or Towing SPIF-Compliant Trailer with Conventional Dual Tires)	Tandem Spread 1.2 < 1.6 m	**274**	**549**
Trailers			
Tandem semi-trailer	Tandem Spread 1.2 < 1.6 m	498	997
Tridem semi-trailer	Tridem Spread 3.6 to 3.7 m	29	87
Self-steer triaxle	Tandem Spread 1.2 < 1.6 m	4	9
Self-steer quad semi-trailer	Tridem Spread 3.6 to 3.7 m	32	97
B-Train Double Trailers*	Tandem Spread 1.2 < 1.6 m	43	86
Total (Matched Tractor and Trailers)		**607**	**1,276**
Total		**882**	**3,039**

* Combined units – two units, with a total of five axles make up a double

2.1.5. Potential for Industry Uptake

We reviewed and validated the assumptions used by the MTO[8] in determining the potential industry uptake on the opportunity to employ new-generation wide base single tires.

The MTO proposes a basic 5% uptake for tractors and semi-trailers equipped with standard-spread tandems to account for the use of new-generation wide base single tires if the regulation remains unchanged, and the weight cap remains at 8,000 kg. This figure reflects the portion of the industry which does not routinely require the flexibility to operate at axle weights above 8,000 kg, and therefore considers their use viable under current regulations.

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[8] Estimated Vehicle Kilometres of Travel on Axles Potentially Using Single Tires if Axle Load Limit Increases to 9000 kg, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, June 2007

The document provides the following range of expectations for uptake amongst the commercial vehicle fleet operating in Ontario that would benefit from the regulatory change under consideration:

- 30% (pessimistic);
- 70% (optimistic); and
- 50% (most likely).

In applying this expectation, we assumed that conversion to new-generation wide base single tires would occur as existing vehicles and configurations reached the end of their service life, and would be implemented as new-purchase additions to the vehicle fleet. No effort was made to assess either the retrofit of existing vehicles, or to examine the ramp-up to full industry uptake under each scenario. Accordingly, our analysis examines only a future environment when industry uptake has seen full adoption of SPIF-compliant vehicles equipped with new-generation wide single tires to limits outlined above.

2.2. Costs and Benefits

2.2.1. Reductions in New Vehicle Cost

Evidence

According to the literature reviewed, the new-purchase cost of a vehicle equipped with new-generation wide base single tires fitted to compatible aluminum rims, is reportedly less than that of similar vehicle equipped with conventional dual tires and rims.

A 2002 article in Refrigerated Transporter[9] notes that aluminum single wheels for new-generation wide base tires are relatively less costly (about $1,000 for a complete tractor-trailer) than a pair of conventional dual wheels.

A fact sheet prepared by the US Environmental Protection Agency[10] notes that one new-generation wide base single tires cost about the same as the two conventional dual tires it replaces, but the single rim costs about $130 less than the two conventional rims that would otherwise be required – a savings of about $1000 on a new vehicle so equipped.

A paper from the TRB Annual Conference, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[11] notes that the cost of one new-generation wide single tire is equivalent to the cost of two conventional tires. The cost of a single rim is $130 cheaper than the cost of two dual rims. For a new vehicle, this equates to a $1,000 savings.

These references however, are somewhat dated. The authors undertook the following discussions to obtain up-to-date information.

Retail tire prices were discussed with three major Ontario tire dealers who sell both Michelin and Bridgestone products. Their prices quoted for new-generation wide base single tires were in the range of $1,140-$1,722 each, for an average cost of $1,431 per tire. Prices for comparable, conventional dual size tires were quoted at $485-$682 each, for an average cost of $584 or $1,168 per pair.

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[9] Is it Super to Go Single?, Refrigerated Transporter, Prism Business Media, November 2002

[10] A Glance at Clean Freight Strategies – Single Wide-Based Tires, SmartWay Transport Partnership, US Environmental Protection Agency, Office of Transportation and Air Quality, EPA420-F-04-004 (www.epa.gov/smartway) February 2004

[11] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

This suggests a cost-premium for new-generation wide base single tires, on a per axle basis, as follows:

Tire cost:

{$1,431 (one single) - $1,168 (two conventional)} x 2 stations/axle =

$526 **more** per axle for new-generation wide base single tires

Rim cost:

One single rim versus two dual rims (from[11]) - $130 less

$130 x 2 stations/axle =

$260 **less** per axle for new-generation wide base single tire rims

Net cost per axle:

$266 **more** per axle equipped with new-generation wide base single tires

Discussions with Ralph Beaveridge of Michelin yielded a “recommended base price” for a new X-One wide base single tire of $1,236, and a recommended base price for an equivalent tire in a dual set of $685 per tire, or $1,370 per pair.

This suggests a cost-savings for new-generation wide base single tires, on a per axle basis, as follows

Tire cost:

{$1,236 (one single) - $1,370 (two conventional)} x 2 stations/axle =

$268 **less** per axle for new-generation wide base single tires

Rim cost:

One single rim versus two dual rims (from[11]) - $130 less

$130 x 2 stations/axle =

$260 **less** per axle for new-generation wide base single tires

Net cost per axle:

$528 **less** per axle equipped with new-generation wide base single tires

New vehicle manufacturers likely receive lower prices for new tires, based on their ability to purchase in bulk, and the opportunities they afford tire manufacturers to market products as original equipment to customers. Details of such arrangements are proprietary, but likely apply equally to new-generation wide base single tires and conventional tires.

On this basis, the authors believe that Michelin's recommended base prices for competitive single and dual tire solutions are more reflective of future, new tire costs as a component of new equipment purchases, and that the retail prices quoted by Ontario tire suppliers are more reflective of the current "niche" market for these products in the replacement tire marketplace.

The cost per rim for new generation wide base single tires, relative to the cost to purchase two rims for conventional dual tires, appears consistent within the literature reviewed, and is accepted by the authors as being representative of their cost as a component of new equipment purchases.

Accordingly, a cost savings of $528 per axle is assigned to new vehicles purchased with new-generation wide base single tires and aluminum rims, over those purchased with conventional dual tires and rims.

A 2006 National Research Council Canada study[12] found that almost 90% of Canadian-registered tractors were 10 years old or less and almost 96% of trailers were 20 years old or less.

For economic analysis purposes, the service life of a tractor unit was estimated at 10 years, and a trailer unit at 20 years. These estimates were based on distributions of the age of the Canadian heavy truck fleet, as reported by Natural Resources Canada[13], which indicates that 42% are less than 5 years only, and only 17% are 14 years old or more. For tractor units, service life is heavily influenced by emissions requirements. For trailers, the issue is more one of wear and tear, maintainability and reliability.

In the future condition assumed in this study, we anticipate that fleet operators will be replacing a portion of their equipment on an annual basis. Using the service life estimates outlined above, a fleet operator would replace 10% of their tractor fleet and 5% of their trailer fleet with new equipment annually.

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[12] A Further Assessment of the Effect of Automatic Slack Adjusters on Brake Adjustment, J. R. Billing, for Transport Canada, Centre for Surface Transportation Technology, Road Safety and Motor Vehicle Registration, CSTT-HVC-TR-102June 2006

[13] Canadian Vehicle Survey – Summary Report, Natural Resources Canada, May 2007

Analysis

This benefit is derived from the lower purchase cost of new vehicles equipped with new-generation wide base single tires and aluminum rims, relative to the purchase cost of an equivalent vehicle equipped with conventional tires and rims. The benefit accrues to the vehicle operator.

This reduction is applicable only to the axles of tractor and trailer units that would be made eligible and would benefit under the regulatory change being considered.

The scope of the benefit is $528 per axle so-equipped.

Assumptions regarding the benefit are that tractors have a useful life of 10 years, trailers a useful life of 20 years, and that an equal portion of the fleet is replaced on an annual basis (10% and 5% respectively).

The annual reduction in new vehicle costs, assuming 100% uptake amongst eligible vehicles, is provided in **Table 5.**

Table 5 –Annual Reduction in New Vehicle Cost (Assumes 100% Uptake)

Configuration	Conditions	Number of Eligible Axles	Replacement Rate/Year	Total Number of Units in Service in Ontario (Typical Day)	Annual Savings ($) - Assumes 100% Uptake
Tractors					
Tandem Tractor	Tandem Spread 1.2 < 1.6 m	2	0.10	**126,000**	$13,306,000
Trailers					
Tandem semi-trailer	Tandem Spread 1.2 < 1.6 m	2	0.05	146,000	$7,709,000
Tridem semi-trailer	Tridem Spread 3.6 to 3.7 m	3	0.05	6,800	$539,000
Self-steer triaxle	Tandem Spread 1.2 < 1.6 m	2	0.05	400	$21,000
Self-steer quad semi-trailer	Tridem Spread 3.6 to 3.7 m	3	0.05	6,200	$491,000
B-Train Double Trailers*	Tandem Spread 1.2 < 1.6 m	2	0.05	4,850	$256,000
Total					**$22,322,000**

* Combined units – two units, with a total of five axles make up a double

2.2.2. Reductions in Maintenance Costs

Evidence

A paper from the TRB Annual Conference, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[14] notes that tire pressure maintenance, while critical, is simplified with new-generation wide base single tires, requiring less time for pre-trip inspection. Increased focus on air pressure as a safety and fuel economy issue has reduced the frequency of tire failures on an industry-wide basis. Central inflation monitoring and central inflation systems are becoming more commonplace as well.

In discussions with trucking industry representatives, anecdotal information was provided that suggests tire damage due to impact from road debris was less frequent, likely due to the smaller target offered by the new-generation wide base single tires as compared to conventional dual tires, and the reduced opportunity for sidewall damage from debris captured between dual tires.

The Genivar study[15], conducted for Ministry of Transportation Quebec notes that reduced annual maintenance costs are anticipated with new-generation wide-base single tires. The study notes that while inspection time-savings are negligible, tire maintenance costs based on 10,000 km intervals are reduced. The study assumes a requirement of 15 minutes per vehicle to service wide singles, 30 minutes to service an equivalent vehicle equipped with conventional dual tires, at a per-hour service technician's rate of $50/hr.

The authors propose to apply the same potential for savings to this study.

Analysis

This benefit is derived from the shorter time required to service a vehicle equipped with new-generation wide single tires on all drive and trailer axles, relative to the time required to service an equivalent vehicle equipped with conventional dual tires. The benefit accrues to the vehicle operator. Reduced driver inspection time is considered negligible.

The scope of the benefit is as follows, a service technician's rate of $50.00/hr:

- 15 minutes of time saved in tire service, once every 10,000 km, for a combined tractor and trailer unit equipped with new-generation wide single tires; and

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[14] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

[15] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

- 7.5 minutes of time saved in tire service, once every 10,000 km, for a tractor unit only equipped with new-generation wide single tires.

The full time savings apply only to combined tractor and trailer units with new-generation wide single tires on all tractor drive axles and trailer axles. An allowance of 15 minutes of time saved is made for tractor units equipped with new-generation wide single tires pulling trailers with conventional dual tires.

Table 6 illustrates total kilometers of travel per day by tractors and tractor-trailer combination units that would benefit under the proposed regulation, their annual inspection requirements, and the potential value of time which would be saved on tire inspections on an annual basis, assuming 100% uptake amongst eligible vehicles**.**

Table 6 –Annual Reduction in Maintenance Costs (Assumes 100% Uptake)

Configuration	Conditions	Total Kilometres (,000) of Travel per Day	Annual Kilometres (,000)	Annual Number of Inspections	Time Savings (Hours)	Annual Benefit (at $50/hr)
Tandem Tractor (Running Alone or Towing SPIF-Compliant Trailer with Conventional Dual Tires)	Tandem Spread 1.2 < 1.6 m	4,790	1,748,350	174,835	21,854	$1,093,000
Tandem Tractor and Tandem semi-trailer	Tractor Tandem Spread 1.2 < 1.6 m Trailer Tandem Spread 1.2 < 1.6 m	8,698	3,174,770	317,477	79,369	$3,968,000
Tandem Tractor and Tridem semi-trailer	Tractor Tandem Spread 1.2 < 1.6 m Trailer Tridem Spread 3.6 to 3.7 m	505	184,325	18,433	4,608	$230,000
Tandem Tractor and Self-steer triaxle	Tractor Tandem Spread 1.2 < 1.6 m Trailer Tandem Spread 1.2 < 1.6 m	77	28,105	2,811	703	$35,000
Tandem Tractor and Self-steer quad Semi-trailer	Tractor Tandem Spread 1.2 < 1.6 m Trailer Tridem Spread 3.6 to 3.7 m	564	205,860	20,586	5,147	$257,000
Tridem Tractor and B-Train Double Trailers*	Tractor Tandem Spread 1.2 < 1.6 m Trailer Tandem Spread 1.2 < 1.6 m	753	274,845	27,485	6,871	$344,000
Total		**15,387**	**5,616,255**	**561,626**	**118,552**	**$5,927,000**

* Combined units – two units, with a total of five axles make up a double

2.2.3. Increases in Fuel Efficiency

Evidence – Base Case

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[16] defines a typical truck configuration (US) and operating parameters, and arrives at a fuel economy base-line of 6.1 MPG (38.6 L/100 km).

The Genivar study[17], conducted for Ministry of Transportation Quebec notes that assumed consumption is 40-51 L/100 km for all heavy truck classes.

Natural Resources Canada[18] reports average fuel consumption for heavy trucks in Canada as 35.1 L/100 km. Yearly travel for heavy trucks based in Ontario is estimated at 78,000 km/year. Tractor-single trailer combinations consume 34.1 L/100 km. B-Train configurations consume about 2L/100 km more (36.5 L/100 km) than that consumed by single-trailer combinations, suggesting that they are more efficient in terms of litres of fuel consumed per unit weight of cargo transported.

Analysis of recent trends indicates that the fuel consumption rate for heavy trucks has been decreasing over time, due to more efficient and aerodynamic equipment, and emphasis on conservation-minded driving by operators. Emission standards for 2007 and newer truck engines and the particulate filters that are required to meet the new standards, coupled with the lower energy content of ultra low sulfur diesel fuel, are expected by some to reverse this overall trend, increasing fuel consumption rates by approximately 2% in order to achieve substantially lower emissions[19].

However, some engine manufacturers, notably Caterpillar, believe there is no significant difference in fuel economy between the new, compliant engines and those used in the previous generation of vehicles, if the vehicles are appropriately equipped, geared, and are driven with a view to fuel conservation.

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[16] Energy Efficiency Strategies for Freight Trucking: Potential Impact on Fuel Use and Greenhouse Gas Emissions, Jeffrey Ang-Olson, Will Schroeer, ICF Consulting, 81st Meeting of the Transportation Research Board, published Transportation Research Record

[17] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

[18] Canadian Vehicle Survey – Summary Report, Natural Resources Canada, May 2007

[19] * "FULL STEAM AHEAD" by Rolf Lockwood. "Today's Trucking Magazine", http://www.todaystrucking.com/decisioncenter.cfm?subsection=story&intDocID=17965&intDecisionCenterID=8&CFID=934&CFTOKEN=67

For the purposes of this study, these impacts will affect all emissions-compliant vehicles equally, regardless of tire choice. The authors therefore have chosen to apply as a baseline the consumption rates reported by Natural Resources Canada, specifically:

- **34.1 L/100 km for tractor-single trailer combinations; and**
- **36.5 L/100 km for B-Train configurations.**

Evidence – Increased Fuel Efficiency

The Cost 334 Report[20] noted that Vehicle Operating Costs (VOC) is significantly affected by the choice of tire fitment. Thus, tires with reduced rolling resistance lead to reduced fuel costs, and tire fitments lighter than those used previously bring about potential increases in payload, with associated economic benefits.

The work of COST 334 in the area of VOC made use of the “Past”, “Current”, and “Possible Future” scenarios identified by the Group as being appropriate in Europe. The work also examined more particular situations, such as the possible use of prototype wide single tires on the drive axles of heavy goods vehicles.

As a result of this work, it was concluded that:

- The choice of tire fitment on the driven axle of a 40 tonne gross vehicle weight truck-semi-trailer vehicle can affect the VOC by up to 1%, as a result of 2% changes in fuel consumption.
- A further saving of 1% is available to truck operators from the use of lighter tires and wheels, when these weight savings are translated into increased payload.
- VOCs are strongly influenced by taxes, particularly fuel taxes.
- When VOC is considered without taxes, differences between the past and current tire configurations selected by COST 334, may be up to 3% in VOCs.
- A further 0.5% saving is available between the current and possible future tire configurations.

A paper on work done by Michelin with Freightliner and presented at the SAE Truck and Bus Meeting 2000[21] simulated on-road conditions and examined the performance of Michelin’s new ultra wide base tire (X-One) relative to conventional dual tires in relation to fuel economy improvement, mass reduction, handling, ride, wear, and noise. The study evaluated a five-axle tractor semi-trailer equipped with new-generation wide base single tires and aluminum rims on all drive and trailer axles - four axles in total).

Fuel economy tested under SAE J 1376 procedures was found to improve by 4%.

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[20] COST 334 – Effects of Wide Single Tyres and Dual Tyres, R. R. Addis, March 2000

[21] On Vehicle Testing of Michelin New Wide Base Tire, Matt Markstaller and Al Pearson, Freightliner L.L.C, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2000-01-3432

A fact sheet prepared by the US Environmental Protection Agency[22] notes that nearly 13% of truck energy use is accounted for in tire rolling resistance, and that new-generation wide single tires are lighter and produce less rolling resistance relative to conventional dual tires. An identified 2-5% fuel economy improvement means 400 less gallons consumption per year, and a reduction of 4 tonnes (metric) of carbon dioxide greenhouse gases.

A 2002 article in Refrigerated Transporter[23] notes that fuel economy improvements of about 5% are considered average. One fleet achieved a 10% increase by switching both tractor and trailer tires. Industry representatives suggest that these results are reflective of "ideal" conditions, and note the influence of drivers, road conditions, and traffic on fuel economy.

Mixing duals (on tractors) and singles (on trailers) does not yield the best fuel economy results.

A promotional brochure from Michelin[24] highlights fuel and weight savings, increased stability, reduced inventory requirements, fewer mounts/dis-mounts, and ease of inspection. Fuel saving (in conjunction with aluminum wheels) is estimated at 4%.

A study conducted by the US Environmental Protection Agency[25] examined the influence of wide single tires and aerodynamic improvements on fuel economy and emissions, alone and in combination.

Conventional dual tires were replaced with new-generation wide single tires on aluminum wheels on the drive and trailer axles of a five-axle tractor semi-trailer. Two brands of tires were evaluated. The truck's electronic control module was reprogrammed per manufacturer's specifications to account for different wheel diameter. Tests involved various drive cycles, replicating a broad range of operating conditions.

Results with new-generation wide single tires showed similar and statistically-significant improvements in fuel economy of between 3% and 13% at 95% confidence. NOx emissions were found to decrease between 9% and 33%.

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[26] defines a typical truck

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[22] A Glance at Clean Freight Strategies – Single Wide-Based Tires, SmartWay Transport Partnership, US Environmental Protection Agency, Office of Transportation and Air Quality, EPA420-F-04-004 (www.epa.gov/smartway) February 2004

[23] Is it Super to Go Single?, Refrigerated Transporter, Prism Business Media, November 2002

[24] Michelin X-One Promotional Material, www.Michelintruck.com, MWL41924, November 2005

[25] Effect of Single Wide Tires and Trailer Aerodynamics on Fuel Economy on NOx Emissions of Class 8 Line-Haul Tractor-Trailers, L. Joseph Bachman, Anthony Erb, and Cheryl L Bynum, US Environmental Protection Agency, Paper No. 05CV-45, SAE International, 2005

configuration (US) and operating parameters, and arrives at a fuel economy base-line of 6.1 MPG.

Estimates of vehicle miles travelled, fuel usage and carbon emissions are based on 1999 statistics – 132,386 million VMT, 26,241 million gallons of fuel used, and 72.2 million metric tons of carbon equivalent (MMTCE) emissions.

They reference Michelin test results of 3.7-4.9% increase in fuel economy, and Bridgestone claims of 2-5% improvement.

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[27] notes that tire rolling resistance accounts for 35% of energy requirement. New-generation wide single tires reduce rolling resistance by as much as 12%, resulting in fuel savings of 2-10%. A recent Canadian survey of operators found savings of 3.3-12%.

Using a base-line of 241,400 km/year a typical long-haul truck could save as much as 3,785 litres of fuel per year.

The Genivar study[28], conducted for Ministry of Transportation Quebec, notes that Quebec carriers report fuel savings of 3.5-12%. The study used an average of 3.2%, and assumed consumption of 40-51 L/100 km.

In discussions, Rejean Lafamme of Robert Transport reports an increase of 9.6% with the use of new-generation wide single tires on tractor-trailers with the tires fitted to the drive axles of the tractor and all trailer axles.

This higher-than-anticipated result is supported by recent Canadian-based tests by FPInnovations[29], which released the official results of its Energotest 2007 testing sessions in December 2007, at which many types of fuel-saving devices were tested to rigorous standards.

The research group conducted the tests with the cooperation of Robert Transport and Cascades Transports in October. The objective was to validate fuel-saving claims on a wide variety of components and devices. FPInnovations noted in a release. "Robert Transport and Cascades Transport, each with a proven track record in environmental and economic leadership, partnered to create Energotest 2007."

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[26] Energy Efficiency Strategies for Freight Trucking: Potential Impact on Fuel Use and Greenhouse Gas Emissions, Jeffrey Ang-Olson, Will Schroeer, ICF Consulting, 81st Meeting of the Transportation Research Board, published Transportation Research Record

[27] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

[28] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

[29] www.feric.ca/energotest2007-en

Some of the technologies proved to exceed expectations. New-generation wide base single tires showed a 10% fuel savings during the test. Aerodynamic technologies also improved fuel mileage by up to 7%.

The authors note that tests conducted in the United States focus on five-axle tractor-trailer configurations (tractor and trailer duals replaced with new-generation wide base single tires and lighter, aluminum rims), and were conducted at gross weights applicable to that jurisdiction. The results point to an approximate 1% decrease in fuel consumption for each axle equipped with new-generation wide base single tires (2-5% overall).

Experience in Canada is more limited, but consists of both controlled and “over-the-road” experience. These evaluations have yielded substantially consistent and more optimistic results, approximating a 2.5% decrease in fuel consumption for each axle equipped with new-generation wide base single tires (3-12% overall), when these tires and aluminum rims are used on all drive and trailer axles.

The selection of a value representative of potential fuel savings associated with the use of new-generation wide base single tires and lighter, aluminum rims is a critical aspect of this study. The monetary value of the forecasted savings are expected to influence the study outcomes more than any other factor, and potentially more than all other factors combined.

> **Accordingly, in the absence of definitive evidence, the authors have chosen to assess the impacts of this potential benefit by examining the outcomes of fuel savings between 1.0 and 2.5% per axle (4-12.5% overall), in 0.5% increments, with 1.5% (6-9.5% overall) appearing most likely.**

Analysis

This benefit is derived from the lower rolling resistance and aerodynamic drag of new-generation wide base single tires, relative to the rolling resistance and aerodynamic drag of conventional dual tires. The benefit accrues to the vehicle operator.

The scope of the benefit is 1.0 to 2.5% per axle equipped with new-generation wide base single tires and lighter aluminum rims. Only axles which would be made eligible by the regulatory change under consideration are included.

Table 7 illustrates annual fuel savings anticipated.

Table 7 –Annual Reduction in Fuel Consumption (Assumes 100% Uptake)

Configuration	Total Kilometres (,000) of Travel per Day	Fuel Comsumption (L/100 km)	Number of Eligible Axles	Fuel Saved (L/Year)			
% Savings Per Eligible Axle				**1.0%**	**1.5%**	**2.0%**	**2.5%**
Tandem Tractor (Running Alone or Towing SPIF-Compliant Trailer with Conventional Dual Tires)	4,790	34.1	2	11,924,000	17,886,000	23,847,000	29,809,000
Tandem Tractor and Tandem semi-trailer	8,698	34.1	4	43,304,000	64,956,000	86,608,000	108,260,000
Tandem Tractor and Tridem semi trailer	505	34.1	5	3,143,000	4,714,000	6,285,000	7,857,000
Tandem Tractor and Self-steer triaxle	77	34.1	4	383,000	575,000	767,000	958,000
Tandem Tractor and Self-steer quad Semi-trailer	564	34.1	5	3,510,000	5,265,000	7,020,000	8,775,000
Tridem Tractor and B-Train Double Trailers*	753	36.5	4	4,013,000	6,019,000	8,025,000	10,032,000
Total	**15,387**			**66,277,000**	**99,415,000**	**132,552,000**	**165,691,000**

* Combined units – two units, with a total of five axles make up a double

The value of this benefit is reliant on fuel prices, which fluctuate in response to world oil prices. To take this into account, the economic benefits of fuel savings have been estimated based on a per-litre price for diesel fuel ranging from $0.80 to $1.20 per-litre. **Table 8** illustrates the results.

Table 8 –Annual Reduction in Fuel Costs (Assumes 100% Uptake)

		Fuel Cost Per Litre				
Percentage Savings Per Eligible Axle	**Litres of Fuel Saved Per Year**	**$0.80**	**$0.90**	**$1.00**	**$1.10**	**$1.20**
1.0%	66,277,000	$53,022,000	$59,649,000	$66,277,000	$72,905,000	$79,532,000
1.5%	99,415,000	$79,532,000	$89,474,000	$99,415,000	$109,357,000	$119,298,000
2.0%	132,552,000	$106,042,000	$119,297,000	$132,552,000	$145,807,000	$159,062,000
2.5%	165,691,000	$132,553,000	$149,122,000	$165,691,000	$182,260,000	$198,829,000

2.2.4. Emissions Reductions Associated with Increased Fuel Efficiency

Evidence

A study conducted by the US Environmental Protection Agency[30] examined the influence of new-generation wide base single tires and aerodynamic improvements on fuel economy and emissions, alone and in combination. It notes that the aerodynamic properties and reduced rolling resistance of new-generation wide base single tires, relative to conventional dual tires is the key to their performance in reducing both fuel consumption and greenhouse gas emissions.

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[30] Effect of Single Wide Tires and Trailer Aerodynamics on Fuel Economy on NOx Emissions of Class 8 Line-Haul Tractor-Trailers, L. Joseph Bachman, Anthony Erb, and Cheryl L Bynum, US Environmental Protection Agency, Paper No. 05CV-45, SAE International, 2005

A significant finding was that emissions reductions are significantly disproportional (greater) than fuel economy improvement.

Emissions evaluated included hydrocarbons (HC), carbon dioxide (CO2), carbon monoxide (CO) and nitrogen oxides (NOx). Test followed a modified version of SAE J1321 test procedure.

Conventional dual tires were replaced with new-generation wide base single tires on aluminum wheels on the drive and trailer axles of a five-axle tractor-trailer. Two brands of tires were evaluated. The truck's electronic control module was reprogrammed per manufacturer's specifications to account for different wheel diameter. Tests involved various drive cycles, replicating a broad range of operating conditions.

Results with new-generation wide single tires showed similar and statistically-significant improvements in fuel economy of between 3% and 13% at 95% confidence. NOx emissions were found to decrease between 9% and 33%.

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[31] notes that consumption of one litre of fuel results in the emission of 68g of CO, 2,730g of CO2, and 9.6g of NOx. The cost of neutralizing the associated gas emission is estimated at $0.312 per litre (USD).

The Genivar study[32], conducted for Ministry of Transportation Quebec, uses a similar emissions composition, adding HC, and arrives at Canadian-based a cost to neutralize emissions of $0.279/L of diesel fuel, based on the following individual costs:

- CO – cost to neutralize $1,339/t
- CO2 – cost to neutralize $30/t
- NOx – cost to neutralize $6,214/t
- HC – cost to neutralize $4,872/t

These costs are applied based on the emissions produced by burning each litre of fuel, in the following amounts:

- CO – 68g
- CO2 – 2,730g
- NOx – 9.6g
- HC – 9.7g

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[31] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

[32] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

Table 9 illustrates the application of these values.

Table 9 –Cost to Neutralize Emissions from One Litre of Diesel Fuel Burned

Emission Element	Production (g) per L of Fuel Burned	Cost to Neutralize per Tonne	Cost to Neutralize per L of Fuel Burned
CO	68	$1,339	$0.091
CO2	2,730	$30	$0.082
Nox	9.6	$6,214	$0.060
HC	9.7	$4,872	$0.047
Total			**$0.280**

It is expected that with new emissions standards for 2007, and the introduction of ultra low sulfur diesel fuel, emissions of particulate matter (PM), CO, NOx and HC will be substantially (90%) eliminated, but that CO2 (a key greenhouse gas) emissions will increase. This, in turn, is expected to impact the above-mentioned mitigation costs, and the financial benefits to society of fuel savings.

Analysis

This benefit is derived from the lower rolling resistance and aerodynamic drag of new-generation wide base single tires, relative to the rolling resistance and aerodynamic drag of conventional dual tires. It is dependent on the amount of fuel conserved (**Section 2.2 3**). The benefit accrues to society as a whole, as the costs to mitigate environmental impacts are borne by society.

Table 10 examines the reduced cost to society of emissions mitigation if 100% of vehicle configurations which would benefit from the regulatory change under consideration were to take up the opportunity to use new-generation wide base single tires. It assumes that a 90% reduction in the production of PM, CO, NOx and HC is attained through new engine technologies fuel compositions, but does not account for expected increase in CO2 emissions. (The research team was unable to find a reliable source for the amount of the CO2 increase.)

Mitigation costs are therefore factored as follows:

$$0.1*(\$0.091+\$0.060+\$0.047) + 0.082 = \$0.102/L$$

Applying a mitigation cost of $0.102/L to the expected range of fuel savings from Table 7, the savings to society in emissions mitigation costs are as follows:

Table 10 –Emissions Neutralization Costs Avoided Through Increased Fuel Economy (Assuming 100% Uptake)

% Savings per Eligible Axle	Fuel Saved L/Year	Annual Neutralization Costs Avoided ($)
1.0%	66,277,000	$6,760,000
1.5%	99,415,000	$10,140,000
2.0%	132,552,000	$13,520,000
2.5%	165,691,000	$16,900,000

Given that one litre of diesel fuel produces 2.73 kg of CO2 when burned; saving 99,415,000 litres of fuel annually would avoid the emission of:

(99,415,000 litres * 2.73 kg/litre)/1000 kg/tonne = 271,403 tonnes of CO2

2.2.5. Reduced Tire Noise

Evidence

COST 334[33] addressed the comparative effects on tire-road noise of new-generation wide single and dual tires. It found no significant overall difference between the noise generated by each tire fitment, when used on drive axles or trailer axles.

A paper on work done by Michelin with Freightliner and presented at the SAE Truck and Bus Meeting 2000[34] reviewed noise testing results. Tests were conducted per title 40 part 205 of the Code of Federal Regulations. The X-One was found to be marginally quieter.

Analysis

No economic impact was determined to be associated with the issue of tire noise.

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[33] COST 334 – Effects of Wide Single Tyres and Dual Tyres, R. R. Addis, March 2000

[34] On Vehicle Testing of Michelin New Wide Base Tire, Matt Markstaller and Al Pearson, Freightliner L.L.C, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2000-01-3432

2.2.6. Payload Advantages Accruing from Reduced Vehicle Tare Weight (Due to Lower Wheel and Tire Mass)

Evidence

A paper on work done by Michelin with Freightliner and presented at the SAE Truck and Bus Meeting 2000[35] examined the performance of Michelin's new-generation wide base single tire (X-One) relative to conventional dual tires in relation to fuel economy improvement, mass reduction, handling, ride, wear, and noise.

It determined that Wheel End Weight is reduced from 352 lb (160 kg) to 240 lb (109 kg), depending on tire and rim selection. On a tractor-trailer with tandem drives and tandem trailer axles, this equates to a weight savings of 896 lb (407 kg).

A fact sheet prepared by the US Environmental Protection Agency[36] notes that total weight savings is estimated at 800 – 1000 lbs (364-455 kg), reducing fuel consumption and/or increasing cargo capacity.

A 2002 article in Refrigerated Transporter[37] notes that weight savings on a five-axle tractor-trailer with aluminum wheels is estimated at 392 lb (178 kg) for the tractor and 328 lb (149 kg) for the trailer. Other estimates put the savings at 200-250 lb (91-114 kg) per axle.

A promotional brochure from Michelin[38] highlights weight savings of 740 (aluminum wheels to aluminum wheels)-1,370 lbs (Steel wheels to aluminum wheels) – 336-623 kg.

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[39] notes that new-generation wide single tires installed on both the tractor and trailer, in conjunction with aluminum rims, reduce the tare weight of the vehicle by 388 kg. For "cube-out" applications, this could result in a further fuel savings. For "max-out" applications, it could increase cargo capacity by 2%.

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[35] Ibid

[36] A Glance at Clean Freight Strategies – Single Wide-Based Tires, SmartWay Transport Partnership, US Environmental Protection Agency, Office of Transportation and Air Quality, EPA420-F-04-004 (www.epa.gov/smartway) February 2004

[37] Is it Super to Go Single?, Refrigerated Transporter, Prism Business Media, November 2002

[38] Michelin X-One Promotional Material, www.Michelintruck.com, MWL41924, November 2005

[39] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

The Genivar study[40], conducted for Ministry of Transportation Quebec notes that increased payload due to reduced mass of wheels and tires is estimated at 1.6-2.4% depending on configuration.

Analysis

In assessing vehicle dynamic performance and collisions, Part 2 of this report used tare weights for vehicles configured with new-generation wide base single tires and conventional dual tires on eligible axles as outlined in **Table 11**.

Table 11 –Reduction in Tare Weights by Vehicle Configuration

Configuration	Number of Eligible Axles	Tractor Tare Weight (With Duals) kg	Trailer Tare Weight (With Duals on Eligible Axles) kg	Tractor Tare Weight (With Singles) kg	Trailer Tare Weight (With Singles on Eligible Axles) kg	Tare Weight with Duals kg	Reduction in Tare Weight with Singles kg	Percent Reduction in Tare Weight
Tandem Tractor (Running Alone or Towing SPIF-Compliant Trailer with Conventional Dual Tires)	2	8,164	0	7,982	0	8,164	182	0.022
Tandem Tractor and Tandem semi-trailer	4	8,164	6,350	7,982	6,170	14,514	362	0.025
Tandem Tractor and Tridem semi-trailer	5	8,164	7,484	7,982	7,214	15,648	452	0.029
Tandem Tractor and Self-steer triaxle	4	8,164	7,484	7,982	7,304	15,648	362	0.023
Tandem Tractor and Self-steer quad Semi-trailer	5	8,164	8,618	7,982	8,348	16,782	452	0.027
Tridem Tractor and B-Train Double Trailers*	4	8,164	9,850	7,982	9,670	18,014	362	0.020
Average								**0.024**

* Combined units – two units, with a total of five axles make up a double

An average of the difference in tare weights in **Table 11** indicates that vehicles eligible to use new-generation wide base single tires under the regulatory revision being considered would achieve a 2.4% reduction in tare weight, allowing for an equivalent increase in payload capacity.

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For vehicles operating at their maximum permissible gross vehicle weight, this reduction in tare weight offers the opportunity to carry additional payload. With additional payload per vehicle-trip, fewer trips would be required to move the same mass of cargo. This benefits the operator, through increased efficiency, and society as a whole, through reduced exposure to the risk of a collision involving a tractor-trailer.

The aforementioned benefits would only apply to bulk carriers, who can incrementally increase their cargo to take advantage of small decreases in the tare weight of their vehicle. A 2005 study[41] for Transport Canada indicates that liquid and dry bulk goods accounted for 16.2% of all goods moved by truck. This suggests that only 16.2% of vehicles operating at axle loadings above 8,500 kg could reasonably be expected to take advantage of the reduction in vehicle tare weight by increasing the mass of bulk cargo carried.

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[40] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

[41] Transportation in Canada 2005 - http://www.tc.gc.ca/pol/en/Report/anre2005/7C_e.htm

Of the 15,387,000 kilometres per day (**Table 6**) traveled by vehicles that would potentially benefit from the change in regulation under consideration, only 5.7% of that travel occurs at axle loads over 8,500 kg., and only 16.2% of that travel involves bulk goods. Therefore, the proportion of daily kilometers that would be impacted by the potential for increased payload is:

15,387,000 * 0.057 * 0.162 = 142,000 km/day

A 2.4% decrease in travel resulting from a 2.4% increase in payload capacity would reduce movement associated with bulk goods by the following:

142,000 km/day * 0.02 = 2,840 km/day

Using an owner-operator compensation of $1.50 per mile, or ($1.50/mile * 0.625 miles/km) $ 0.94/km., this increase in efficiency would save operators the following amount on an annual basis:

2,840 km/day * $0.94/km * 365 days/year = $974,000/year.

The benefit of increased efficiency to the operator is $974,000/year

2.2.7. Improved Operational Safety

Safety pertains to the expected change in the frequency (likelihood) and severity of collisions (while accounting for exposure) involving commercial vehicles if the axle weight limit for new-generation wide single tires was increased from 8,000 kg to 9,000 kg, assuming a limitation of 10kg/mm of tire width.

The safety impact of new-generation wide single tires is expected to be influenced by industry uptake, and by their performance relative to conventional dual tires in the following areas:

- Handling, braking, and traction performance;
- Static and dynamic stability (resistance to rollover based on a wider track and lower centre of gravity);
- Reliability (resistance to puncture or blow-out) and controllability under such conditions;
- Increase in permissible gross vehicle weight, and lighter tare weight, leading to reductions in exposure risk as fewer truck trips are required to move the same quantity of loose bulk commodities. This benefit is confined to vehicles which “max-out” rather than “cube-out”. It is of no benefit where the freight comes in discrete increments like pallets, and each increment weighs 2-3000 lb; you need to save at least one increment in weight to carry an additional increment of cargo;
- Likelihood of “wheel-off’ incidents;

- Ease of inspection;
- Compatibility with other equipment providing safety benefits; and
- Influence on driver fatigue.

Expectations as to potential impacts on operational safety are as follows:

- Uptake – Industry uptake is expected to be between 30% (pessimistic) and 70% (optimistic), with 50% being most likely.
- Handling, braking, and traction performance – these attributes are expected to be equal or better, given their broad and even contact patch with the roadway, particularly for vehicles equipped with power steering, air-ride suspensions, traction control, and anti-locking brakes.
- Static and dynamic stability (resistance to rollover based on a wider track and lower centre of gravity) – are expected to be equal or better, given their wider relative track width and the potential to purpose-design vehicles to take advantage of lower centers of gravity afforded by their configuration.
- Reliability (resistance to puncture or blow-out) and controllability under such conditions - Reliability is expected to be equal or better, given that the tires reportedly run cooler. Controllability during an on-road tire failure is an area of potential concern. With conventional dual tires a blow-out in one tire leaves a second, albeit overloaded, tire in service. Whether failure of a new-generation wide single tire would result in greater controllability issues requires further investigation.
- Exposure reductions – incremental reductions are anticipated to be minimal, given the small proportion of the commercial vehicle fleet which operates at maximum permissible weights, and the relatively small reduction in tare weight afforded by the specification of aluminum wheels and new-generation wide single tires;
- Likelihood of "wheel-off' incidents – are expected to be equal or better, given that axle and bearing manufacturers have addressed early concerns about the stresses imposed by new-generation wide single tires, rims used in conjunction with them are generally of "Budd" variety and are less prone to wheel-off incidents (wheel nuts must become loose and/or studs must shear to permit wheel separation), and inspection is simplified; and
- Ease of inspection – is expected to result in equal or better safety performance as the inspection process is simplified (no inner tire to inspect), and there are fewer tire pressures to check.

Evidence - Increase in Safety Related to SPIF-Compliant Configurations

A recent study by the MTO[42] highlights the safety concerns associated with (non-SPIF) lift-axle-equipped vehicles, and provides a comparative analysis of collision statistics for existing SPIF tractor-trailers and non-SPIF tractor-trailers, supporting the hypothesis that

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[42] The Relationship of Collision Rates and Dynamic Performance of Heavy Trucks, Alfonso Corredor, Karl GrosKopf and Ron Madill, Ministry of Transportation Ontario, Freight Policy Office.

the superior performance measurement standards to which SPIF tractor-trailers are designed results in superior safety performance.

These performance measurement standards include the following:

- Static Rollover Threshold – The maximum severity of steady turn that a vehicle can tolerate without rolling over.
- Load Transfer Ratio – The fractional change in load between the left and right side tires of the vehicle during an obstacle avoidance manoeuvre.
- Transient High-Speed Offtracking – The maximum lateral distance of the rearmost trailer axle relative to the tractor steering axle during and obstacle avoidance manoeuvre.
- Low-Speed Offtracking – The inboard offtracking of the rearmost trailer axle to the tractor steering axle during a typical 90-degree, right hand turn intersection.
- Rear Outswing – The extent of intrusion of the left-hand side of the vehicle into the lane to the left of the vehicle as it makes a right-hand turn.
- Lateral Friction Utilization – A measure of the effort required by the steer axle to turn the vehicle.
- High-Speed Offtracking – The outboard offtracking of the rearmost trailer axle to the tractor steering axle during a steady turn of 0.2 g lateral acceleration.
- Friction Demand in a Tight Turn – Drive axle tire-pavement friction necessary to turn a corner when pulling a trailer with widely spaced axles. (Further testing has shown this measure to be largely irrelevant. It has therefore not been used in this analysis.)

The report notes the limited research available on the correlation between performance measurements standards and on-road collision involvement, citing relevant research that remains in dispute.

It approaches the question by examining collision rates for vehicles in-service that likely meet SPIF requirements, and those which do not. Limitations of this approach, which stem from incomplete information about vehicle characteristics, are discussed.

The results suggest a 4.5% reduction in collision rates for tractor-trailers if SPIF standards were universal. This is equated to a yearly reduction of 241 collisions, from a base-case of 5,360 collision involving tractor-trailers. In terms of severity, a yearly reduction of 4.5% is equated to a reduction of:

- 4 fatalities from a base-case of 91 fatalities per year;
- 87 injuries from a base-case of 1,929 injuries per year; and
- 192 property damage-only collisions from a base-case of 4,272 PDO collisions per year

These reductions are then subjected to an economic analysis using MTO-generated, willingness-to-pay values for fatalities and injuries to arrive at an annual societal benefit of $34.1 million. Using a per-incident value of $9,400, PDO collisions avoided are estimated to have an annual value of $1.8 million. Monetary benefits to society of reductions in congestion, associated with the avoidance of the identified collisions, are estimated at $8.6 million, for a total societal benefit of $44.5 million.

The results of COST 334[43] work in the area of vehicle handling are based on the experimental testing of selected vehicle types in a range of test conditions. These are supported by theoretical work using widely accepted simulation models of vehicle behaviour, which were validated by full-scale tests. The vehicles considered were:

- A rigid truck, conforming to ISO 3833;
- A rigid truck and trailer conforming to ISO 3833; and
- An articulated vehicle (tractor and semi-trailer) conforming to ISO 3833.

On the basis of the work carried out, it was concluded that:

- In general, the use of wide single tires on drive axles, when compared with dual tires, improves vehicle under-steering in the direction of increased lateral stability, for the vehicles and tires tested.
- In the case of the 2-axle rigid truck, the handling behaviour brought about by the use of the wide base single tire on the drive axle also reduced the lateral acceleration lag of the vehicle during a given driving manoeuvre.
- One of the benefits previously claimed for the use of wide single tires is that the wider spring base they provide leads to increased vehicle stability, i.e. reduced risk of “rollover”. This conclusion supports this view, but suggests that the improvement is mainly due to the increased lateral stiffness of the tire.
- In relation to sudden tire defects (punctures) in the drive axle tires, no increased risk due to the use of wide single tires was established by the simulated tests carried out.

A paper on work done by Michelin with Freightliner and presented at the SAE Truck and Bus Meeting 2000[44] examined vehicle handling in an emergency. Under controlled conditions, as speed and lateral acceleration was increased, the tires showed a tendency towards increasing understeer, levelling out at 0.35 g’s.

A Rapid Air Loss Test was also conducted. This test was conducted on the drive axle of a fully-loaded (80,000 lb Gross Vehicle Weight - GVW) tractor-trailer at 45, 55 and 60 MPH. Hard brakes were applied during the latter two stops (the vehicle was equipped with an anti-locking brake system). Directional control was reportedly easily retained. A final test involving rapid air loss on both drive axles was conducted at 60 MPH, with some lateral yaw. Additional tests were conducted using a loaded, unbaffled tanker trailer. Again tires on one side of both drive axles were rapidly deflated, and control was maintained.

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[43] COST 334 – Effects of Wide Single Tyres and Dual Tyres, R. R. Addis, March 2000

[44] On Vehicle Testing of Michelin New Wide Base Tire, Matt Markstaller and Al Pearson, Freightliner L.L.C, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2000-01-3432

A report prepared by the National Research Council[45] refers to data from Transport Canada that highlights crash severity involving tank trucks. It notes that less than 5% of heavy truck crashes result in a rollover, but that rollovers result in 25% of all operator fatalities.

In Canada, Transport Canada's Dangerous Goods Directorate recorded 810 rollovers in 1,874 crashes involving heavy trucks carrying dangerous goods between 1990 and 1998. 83% of the rollovers involved tank trucks.

The study involved tilt tests of 18 common tank truck configurations conforming to SAE J2180 test procedures to the extent possible.

It notes that national regulatory authorities have settled on a static rollover threshold of 0.35 g for any legal truck, and 0.40 g for any legal tank truck.

7 (41%) of 17 distinct vehicles were found to have a threshold under 0.35 g when loaded to their allowable gross weight in Ontario, and lift axles (if equipped) were raised. 83% were found to have a threshold under 0.40 g when loaded to their allowable gross weight in Ontario, and lift axles (if equipped) were raised.

The report notes that roll stability augmentation systems exist, which add to the capability of anti-lock braking systems now required on tank trucks.

A 2002 article in Refrigerated Transporter[46] notes that stability gains from the slightly wider track are claimed by some manufacturers. Goodyear claims only "equivalency".

The Genivar study[47], conducted for Ministry of Transportation Quebec notes that improvements were based on improved stability, traction quality, braking distances, frequency of blowouts, and stability under blow-out conditions.

- The report notes that 6 of the 7 carriers using new-generation wide single tires reported significant safety improvements in stability, handling and driver comfort;
- Blow-outs were the same or slightly less frequent;
- Two stated that handling under blow-out conditions was better;
- Could not characterize the effects on accident frequency, as tires are seen to have only a minor role; and
- No relevant safety studies were identified based on a search of open literature.

An MTO study[48] examined tractor-trailer collision rates by trailer class from 1995 to 2002. It found a relationship between semi-trailer class and collision rate (based on

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[45] An Assessment of Tank Truck Roll Stability, J. R. Billing and J.D. Patten, P.Eng., National Research Council, Centre for Surface Transportation Technology, CSTT-HVC-TR-059, March 2005

[46] Is it Super to Go Single?, Refrigerated Transporter, Prism Business Media, November 2002

[47] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

millions of vehicle-kilometres of travel (Table 8 in the MTO report), which is reproduced in **Table 12** below.

Table 12 – Collision Rate by Trailer Class

Semi-Trailer Class	Collision Rate/VKT (million)
Tractor & 1-2 axle semi-trailer	0.45
Tractor & 3-axle semi-trailer	0.60
Tractor & 4-axle semi-trailer	0.66
Tractor & 5-axle semi-trailer	1.03
Tractor and A or C-trains	1.33
Tractor and B-train	0.36
Average	0.51

The report provides an indication of the expected improvement in safety performance, by class, prior to the introduction of SPIF standards (Table 13 in the MTO report). Conversion of the vehicle fleet to SPIF standards results in the expected, future collision rates for each class of vehicle as presented in **Table 13**.

Table 13 – Expected Future Tractor-Trailer Collision Rates (Assumes all Configurations are SPIF Compliant)

Semi-Trailer Class	Collision Rate/VKT (million)
Tractor & 1-2 axle semi-trailer	0.45
Tractor & 3-axle semi-trailer	0.56
Tractor & 4-axle semi-trailer	0.57
Tractor & 5-axle semi-trailer	0.79
Tractor and A or C-trains	1.15
Tractor and B-train	0.34
Weighted Average	0.49

The report examines the frequency and severity (Table 14 of the MTO report) of 2002 reported tractor-trailer collisions. It then estimates the number of persons involved by injury severity. The Social Costs of Motor Vehicle Crashes in Ontario (MTO- March 1994) is then used to assess the potential for reduction in number of injuries and fatalities which would be avoided if SPIF standards were universal amongst the vehicle classes examined.

The report identifies the following involvement in 2002 tractor-trailer crashes:

- Fatalities – 91; and
- Injuries - 1,929.

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[48] Ontario Vehicle Weights and Dimensions Reforms – Expected Safety Benefits, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, April 2005

Societal costs of collisions are reported, in 2004 dollars, as:

Per Fatality	$7.1 million
Per Injury	$65,000
Property Damage Only	$9,400

The report concludes that:

- Reduced fatalities and injuries will result in an annual societal cost reduction of $34.1 million;
- Reduced property damage only collisions will result in an annual societal cost reduction of $1.8 million; and
- Reduced congestion associated with the avoidance of these collisions will result in an annual societal cost reduction of $8.6 million.

Thus the annual benefit to society is estimated at $44.5 million.

Analysis - Increase in Safety Related to New-generation Wide Base Single Tires

Tables 24 and 25 from Part 2, reproduced here, provide an estimate of the annual societal benefit of collisions and congestion avoided by 100% uptake in the use of new-generation wide base single tires on:

- All currently-eligible SPIF configurations (operating within the current 8,000 kg per axle limit); and
- All potentially-eligible SPIF configurations (if the per axle weight limit on new-generation single tires were raised from 8,000 kg to 9,000 kg).

Part 2 Table 1: Reduction in Direct Cost of Collisions for a Fleet with Wide Single Tires

Collision Type	Casualties	Reduction	Change	Unit Cost	Cost Saving
Fatal	88.9	0.96%	0.9	$7,547,000	$6,431,000
Injury	1885.2	0.96%	18.1	$69,000	$1,246,000
Property Damage	4175.0	0.96%	40.0	$10,000	$400,000
Total					$8,077,000

Part 2 Table 2: Reduction in Congestion Cost for a Fleet with Wide Single Tires

Road Class	Collision Type	Proportion of Total	Estimated Reduction	Average Cost	Cost Saving
GTA Freeways	**Fatal**	28.4%	0.2	$440,000	$95,000
	Injury	28.4%	2.7	$149,000	$399,000
	PDO	28.4%	11.4	$46,000	$523,000
Non-GTA Freeways	**Fatal**	43.6%	0.3	$188,000	$62,000
	Injury	43.6%	4.1	$64,000	$263,000
	PDO	43.6%	17.4	$19,000	$331,000
Other Provincial Hwys	**Fatal**	28.0%	0.2	$97,000	$21,000
	Injury	28.0%	2.6	$33,000	$87,000
	PDO	28.0%	11.2	$10,000	$112,000
Total			50.2		$1,893,000

The annual societal benefit of increased stability leading to fewer casualties and congestion associated with collisions, assuming 100% uptake, is $9,970,000.

Analysis - Increase in Safety Related to Exposure Reductions Accruing from Greater Bulk Payload Capacity

MTO[49] estimates Total Axle VKT per Day (,000) on Ontario Highways at 105,267 Axle-VKT per Day (,000). Of that total, 50.4% have the potential to benefit from the regulatory change under consideration. Of those with the potential to benefit, only 5.7% operate at axle weights over 8,500 kg. Of that group, only 16.2% carry bulk commodities (**Section 2.2.6**).

105,267 Axle-VKT (,000) per Day * 0.504 * 0.057 * 0.162 =

489.91 Axle-VKT per Day (,000)

Expressed as a percentage of Total Axle VKT per Day, this is:

{489.91 Axle-VKT (,000) per Day /105,267 Axle-VKT (,000) per Day} =

0.0047 or 0.47% of the total.

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[49] Estimated Vehicle Kilometres of Travel on Axles Potentially Using Single Tires if Axle Load Limit Increases to 9000 kg, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, June 2007

A 2.4% (0.024) increase in the payload capacity of bulk carriers, resulting from a proportional decrease in vehicle tare weight through the application of new-generation wide base single tires and aluminum rims to axles with the potential to benefit from the regulatory change under consideration, would result in a 2.4% decrease in the number Axle-VKTs per Day required to move the same mass of cargo. This decrease in the requirement for Axle-VKTs per Day translates into a 2.4% reduction in exposure and collision potential.

Applying this expectation to the 0.47% of total exposure represented by potentially-benefiting axles on bulk goods carriers operating at axle weights over 8,500 kg., we find:

0.0047 * 0.024 = 0.00011

MTO[50] reports that tractor-trailers were involved in 5,360 collisions in 2002, and that 241 collisions would be prevented annually once SPIF vehicles are fully introduced. On that basis, the expected number of collision per year based on 2002 statistics is 5,119.

Applying our exposure reduction factor of 0.00011 to the 5,119 collisions, we find the following potential for collision reduction:

0.00011 * 5,119collisions/year = 0.58 collisions/year

In summary, bulk goods movement represents less than one-half of one percent of the Axle VKT per Day in Ontario. A 2.4% increase in cargo capacity, and corresponding reduction in on-road exposure would avoid slightly more than one collision every two years.

Using adjusted unit costs for collisions from Part 2, Table 24 as follows:

- Fatal - $7,547,000
- Injury - $69,000
- PDO - $10,000

The average societal benefit of a collision avoided is shown in **Table 14**, as follows:

Table 14 – Weighted Societal Cost of Collision

	Casualties	Weighting Factor	Societal Cost	Weighted Value - Societal Cost
Fatalities	88.9	0.014	$7,547,000	$109,110.00
Injuries	1885.2	0.307	$69,000	$21,154.12
PDO	4175	0.679	$10,000	$6,789.61
Total	6149.1			**$137,054**

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[50] Ontario Vehicle Weights and Dimensions Reforms – Expected Safety Benefits, Ministry of Transportation Ontario, Freight Policy Office, Modal Policy Partnerships Branch, April 2005

Using adjusted unit costs for congestion from Part 2, Table 25, the average societal benefit of congestion stemming from one collision avoided is shown in **Table 15**, as follows:

Table 15 – Weighted Societal Cost of Congestion

	Collisions Class	Expected Collision Reduction (MTO)	Weighting Factor	Average Cost Per Collision Class	Weighted Value
GTA Freeways	Fatal	1	0.004	$440,000	$1,826
	Injury	13	0.054	$149,000	$8,037
	PDO	54	0.224	$46,000	$10,307
Non-GTA_Freeways	Fatal	2	0.008	$188,000	$1,560
	Injury	20	0.083	$64,000	$5,311
	PDO	84	0.349	$19,000	$6,622
Other Provincial Highways	Fatal	1	0.004	$97,000	$402
	Injury	12	0.050	$33,000	$1,643
	PDO	54	0.224	$10,000	$2,241
Total		**241**			**$37,950**

Applying these values to the annual, expected reduction in collisions anticipated from exposure reductions through increased payload capacity, and assuming 100% uptake, we find:

0.58 collisions/year * ($137, 054 societal costs + $37,950 congestion costs) =

$101,500/year in societal costs avoided.

2.2.8. Driver Comfort and Workforce Retention

Evidence

A paper on work done by Michelin with Freightliner and presented at the SAE Truck and Bus Meeting 2000[51] examined vehicle ride characteristics. Accelerometer results from on-road tests suggest deflection is 28% lower for the X-One, translating into less harshness. Using ISO 2631-1974 methodology, the calculated ride number was determined to be improved by 12% with the X-One.

A paper on work done by Michelin with Freightliner and presented in 2002[52] notes that drivers suggest that new-generation wide single tires provide a smoother ride relative to conventional dual tires. The authors attempt to explain their reaction through modelling of the vertical dynamic response of vehicles equipped with the two tire types.

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[51] On Vehicle Testing of Michelin New Wide Base Tire, Matt Markstaller and Al Pearson, Freightliner L.L.C, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2000-01-3432

[52] Vehicle Ride Response to New Widebase Tires and Conventional Dual Tires, E. H. Law, Clemson University, Ibrahim Janajreh and Norman Frey, Michelin Americas R&D Corporation, SAE International, 2002-01-3114

The evaluation found a 9-12% reduction in acceleration with new-generation wide single tires, and a 2-6% reduction for first-generation wide single tires, relative to conventional dual tires.

A paper on work done in 2004[53] explores the improved ride performance of new-generation wide single tires using dynamic models and ISO 2631 standards for ride quality over 2.5 and 8 hours.

The study found improvements in vertical and longitudinal weighted rms acceleration numbers of 0.98% and 2.04% respectively. The greatest improvements were seen in the region of 11 Hz, which is the wheel hop frequency. Vertical and longitudinal weighted acceleration numbers of 38 % and 37.6% respectively.

Whether these findings translate into meaningful improvements in ride comfort for drivers, reductions in wear and tear on equipment, or goods damage reductions, is unclear.

Analysis

> **For the purposes of this study, we have assumed that ride quality improvements have no economic impact.**

2.2.9. Decreased Cost of Purchasing and Re-treading New-generation Wide Single Tires

Evidence – Replacement Tire Cost

A paper on work done by Michelin with Freightliner and presented at the SAE Truck and Bus Meeting 2000[54] found that in over 57 million miles of travel involving 578 tires and air-ride suspensions, only 10 were removed from service due to damage from road hazards. Tread wear was found to equal that of conventional tires, with uniform wear patterns.

A fact sheet prepared by the US Environmental Protection Agency[55] notes that tire wear is comparable to conventional tires and that new-generation wide single tires can be re-treaded.

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[53] Ride Dynamics and Pavement Loading of Tractor Semi-Trailers on Randomly Rough Roads, C. Trangsrud and E. H. Law, Clemson University, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2004-01-2622

[54] On Vehicle Testing of Michelin New Wide Base Tire, Matt Markstaller and Al Pearson, Freightliner L.L.C, Ibrahim Janajreh, Michelin Americas R&D Corporation, SAE International, 2000-01-3432

[55] A Glance at Clean Freight Strategies – Single Wide-Based Tires, SmartWay Transport Partnership, US Environmental Protection Agency, Office of Transportation and Air Quality, EPA420-F-04-004 (www.epa.gov/smartway) February 2004

Limitations noted include unfamiliarity, limited availability, the requirement for different re-treading methods, and the need to monitor air pressures closely. Adverse impacts on some types of wheel ends are also noted.

Retail tire prices were discussed with three major Ontario tire dealers who sell both Michelin and Bridgestone products. Their prices quoted for new-generation wide base single tires were in the range of $1,140-$1,722 each, for an average cost of $1,431 per tire. Prices for comparable, conventional dual size tires were quoted at $485-$682 each, for an average cost of $584 or $1,168 per pair. This suggests a cost-premium for new-generation wide base single tires, on a per axle basis, as follows:

{$1,431 (one single) - $1,168 (two conventional)} x 2 stations/axle =

$526 **more** per axle for new-generation wide base single tires

Discussions with Ralph Beaveridge of Michelin yielded a “recommended base price” for a new X-One wide base single tire of $1,236, and a recommended base price for an equivalent tire in a dual set of $685 per tire, or $1,370 per pair. This suggests a cost-savings for new-generation wide base single tires, on a per axle basis, as follows

{$1,236 (one single) - $1,370 (two conventional)} x 2 stations/axle =

$268 **less** per axle for new-generation wide base single tires

On this basis, the authors believe that Michelin’s recommended base price for new-generation wide base single tires is more reflective of the likely future retail purchase price of replacement new-generation wide base single tires once a substantial marketplace for this product is established, and that current retail prices quoted by Ontario tire suppliers reflect a premium currently being charged for a “niche” product with limited sales potential.

> **Accordingly, a cost savings of $268 per axle is assigned to the future cost of purchasing replacement new-generation wide base single tires, relative to the purchase of conventional dual tires.**

Evidence – Recapping Cost

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[56] notes that manufacturers are currently limiting new-generation wide single tires in line-haul service to one re-tread. This hurts the whole-life value, as most conventional tires can be re-treaded 2-3 times.

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[56] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

The Genivar study[57], conducted for Ministry of Transportation Quebec notes that reduced costs are associated with purchasing and re-treading tires, however wide singles appear to wear out faster, and can be re-treaded only once. Conventional tires are approved for two re-treadings by makers but many operators re-tread 3 or more times. Assessment was based on the following:

- Service life of 425,000 km for wide singles, 420,000 for conventional;
- Wide single – re-tread once, conventional re-tread twice;
- Wide single cost $850 new, $544 re-treaded; and
- Conventional cost $525 new, $248 re-treaded.

Discussions with tire industry representatives suggest that the industry standard for new-generation wide base single tires has been to limit their re-treading to a single occurrence ever since their introduction in Canada. However, this appears to be an introductory limitation which was intended to give manufacturers time to determine if the tire casings were sufficiently durable to allow for more than one re-treading.

The inspection procedures for tire casings in Michelin's proprietary Michelin Retread Technologies (MRT) process applies to all types and models of tires processed by this method, not just wide based singles[58]. Michelin has now determined that their X-One tires may be re-treaded more than once, provided the casings pass rigorous testing in their proprietary Michelin Re-treading Technology (MRT) process. All tires that go through the MRT process are tested using the same protocols, whether dual type or wide-base singles. Michelin is not setting a definitive limit on the number of re-treads, only the requirement that casings first pass the MRT inspection, which are the same criteria for dual tires.

Similarly, the procedures used by Goodyear[59] and Bridgestone/Bandag are not specific to wide based singles but also apply to all tires sizes and types.

The issue of a dependable process for casing inspection and re-treading is important, as it allows a manufacturer to establish and maintain a quality product, and having a proprietary process assures a high degree of control over this process. Michelin now has this, and since Bridgestone has recently purchased Bandag (a world leader in tire re-treading), it is reasonable to assume they will also follow this same protocol, if for no other reason than to maintain a competitive position with Michelin.

For the purposes of this study, it will be assumed that new-generation wide base single tires and conventional dual tires have an equivalent durability and capacity to be re-treaded, and that new-generation wide base single tires incur no penalty in terms of

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[57] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

[58] http://www.michelintruck.com/assets/pdf/MRT_Process_Folder.pdf

[59] http://www.goodyear.com/truck/pdf/radialretserv/Retread_All_V.pdf

reduced service-life that would increase tire disposal costs or environmental impact, relative to conventional dual tires.

Three major Ontario tire retailers indicated that the cost for retreading a pair of equivalent dual tires was about 50% of a new tire price, $250-$300. No one could give prices for retreading wide singles, but suggested a similar ratio of costs. It is important to note that the retread price is for the retreading process only, with the customer supplying a worn-out casing in satisfactory condition.

Ralph Beaveridge of Michelin provided pricing for retreaded new-generation wide base single tires, and equivalent dual tires. Michelin's retread prices were $496 for (one) wide based single tire, and $492 for a dual set (two tires). These prices are acknowledged to vary somewhat, depending on markup or discount at the dealer level, but authors believe them to be representative.

Analysis

Total life available:	420,000 km	
Average cost (new) (Michelin prices)		
2 new-generation wide base single tires	$2,472.00	(@ $1,236.00 each)
4 dual tires	$2,740.00	(@ $685.00 each)
Difference (in favor of singles):	$268.00 per pair or $134 each	
Average cost (re-treaded)		
2 new-generation wide base single tires	$ 992.00	(@ $496.00 each)
4 dual tires	$ 984.00	(@ $246.00 each)
Difference (in favor of duals):	$ 8.00 per pair or $4.00 per tire	

Analysis – Requirement for New Replacement Tires

Table 16 illustrates the number of new-generation wide base single tires that would be bought as components of new vehicles, as new replacement tires, or would be retreaded. The calculation assumes that all tires are retreaded twice during a 420,000 kilometre service life, 100% uptake, and that a sufficient number of acceptable casings are available within the overall system.

Table 16 – Annual Requirement for New Single Tires and Retreading

Configuration Matching Conditions	Total Axle-VKT per Day (,000) Matching Conditions	Total Axle-VKT per Year Matching Conditions	Annual Tire Consumption (Based of 420,000 km Service Life)	Proportional Reduction for New Tires on New Vehicles Entering Market	Number of New Replacement Tires Required Annually	Number of Retreadings Required Annually
Tandem Tractor	30,774	11,232,510,000	53,500	0.1	48,150	107,000
Trailer	22,263	8,125,995,000	38,700	0.05	36,765	77,400
Total	**53,037**	**19,358,505,000**	**92,200**		**84,915**	**184,400**

The cost to purchase one new-generation wide base single tire as a replacement is $134 less than the cost of two conventional tires.

84,915 single tires per year * $134 = $11,378,000

The cost of retreading one new-generation wide base single tire is $4 more than the cost to retread two conventional tires.

184,400 single tires per year * $4 = $1,475,000

The net cost advantage to operators, assuming 100% uptake, is $9,903,000 per year.

2.2.10. Reductions in Energy and Resource Consumption and Emissions Associated with Tire Manufacturing and Recapping

Evidence – New Manufacture

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[60] notes that an average dual tire assembly (discounting rims) weights 72.5 kg, where a new-generation wide base single tire (again discounting the rim) weighs 53.6 kg, a difference of 18.9 kg or 36% less.

This difference in mass is understood to be associated primarily with the difference in the number of sidewalls and beads (two for the new-generation wide base single tire versus four for the dual pair).

Goodyear[61] claims that new-generation wide base single tires result in 35% less disposable material.

This difference in materials also reflects a reduction in material and energy inputs into tire manufacture.

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[60] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

[61] http://eu.goodyear.com/uk_en/tires/repository/marathon_lhd_495_45R225/index.jsp

Manufacturing one tire of a size common to dual tire sets (e.g.: 11Rx24.5) requires 20 US gallons of oil, or 40 US gal for two such tires in a dual set. This equates to .96 barrels of oil for the dual set, using the standard 42 US gal/barrel common to the petroleum industry.

By pro-rating on the basis of a 35% reduction of weight, this suggests that one new-generation wide based single tire requires 26 US gallons of oil or 0.62 barrel, **a reduction of 0.34 barrels consumed** or 14.3 US gallons consumed, as compared to the two smaller tires in the dual set it replaces.

A study[62] of greenhouse gases emitted during the extraction and refining of one barrel of conventional crude oil not burned as fuel finds emissions of **CO2 totaling 48 kg per barrel**.

Therefore, the manufacture of one new-generation wide based single tire produces less CO2 in the amount of:

0.34 less barrels of oil consumed per tire x 48 kg CO2 per barrel consumed =

16.32 kg less CO2 per tire.

Using a neutralization cost of $30 per tonne of CO2 (**Section 2.2.4**), this reduction in emissions results in a savings to society in emissions neutralization costs of:

(16.32 kg/1000 kg per tonne) * $30/tonne =

$0.49 per tire.

The energy embodied in vehicle tires averages 85.80 Million Joules per kilogram of tire mass[63]. A new-generation wide base single tire has 18.9 kg less mass than the two dual tires it replaces. This equates to less embodied energy, as follows:

85.80 Million Joules/kg of tire x 18.9 kg difference in mass =

1,622 Million Joules of energy saved manufacturing each new-generation wide base single tire

Since the source of this embodied energy may be fossil fuels, nuclear, or renewable (e.g. hydro-electric) depending on manufacturing methods, location, and energy availability, it is impractical to consider either the consumption cost or the potential for emissions associated with this embodied energy. Accordingly, the authors have chosen to exclude this aspect of from further analysis.

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[62] http://tothetarsands.ca/wp-content/uploads/2007/09/kealans-greenhouse-gas-research.doc

[63] A Descriptive Analysis of Energy Consumption in the Agriculture and Food Sector in Canada, Final Report, CAEEDAC, February 2000.

Evidence – Recapping

The Rubber Manufacturer's Association[64] reports that a typical 11R22.5 conventional truck tire weighs 120 lbs when new, and 100 lbs when scrapped – a 17% loss of weight due to tire wear.

One new-generation wide base single tire has approximately the same contact area as two conventional tires which make up a dual set. It is therefore reasonable to conclude that the mass of the recap portion of one new-generation wide base single tire is equivalent to that of two conventional tires. On this basis, it is also reasonable to conclude that:

- No substantial difference exists in recap mass between one new-generation wide base single tire and two conventional dual tires;
- The embodied energy is substantially the same;
- The weight loss due to wear is substantially the same; and
- The remaining recap mass to be disposed of is equivalent.

On this basis, the authors conclude that recapping is neutral from an energy and resource consumption perspective.

Analysis

This benefit is associated with the lower mass of new-generation wide single tires, relative to conventional dual tires. The benefits assume equal durability and ability to be recapped between the two tire choices. The reductions in energy and resource consumption, although not quantified, are assumed to be reflected in the retail price of new-generation wide single tires, and thus are assumed to accrue to the operator. The benefit in reduced greenhouse gas emissions associated with the reduction in resources and energy embodied in new-generation wide single tires accrues to society as a whole, as the costs to mitigate environmental impacts are borne by society.

The scope of the benefit is avoidance of CO2 per new-generation wide single tire purchased as an alternative to a set of conventional dual tires, at a mitigation cost to society of $0.49 per tire. From **Table 16**, 92,200 tires are required annually.

92,200 tires * $0.49/tire = $ 46,100

The benefit to society is $46,100 in emissions mitigation costs avoided annually.

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[64] http://www.rma.org/scrap_tires/scrap_tire_markets/scrap_tire_characteristics/

2.2.11. Assumptions Regarding Reduction in Environmental Impact Associated with Tire Disposal

A paper from the Transportation Research Record, which may not be authoritative (i.e. not a TRB study, which would definitely be authoritative)[65] notes that the cost of properly disposing of scrap tires is estimated at $0.10 per 450g. An average dual tire assembly results in 72.5 kg of residual materials, where disposal of a new-generation wide single tire results in 53.6 kg of residual materials, a difference of 18.9 kg, or $4.20.

The Genivar study[66], conducted for Ministry of Transportation Quebec notes that savings from reduced tire disposal costs were based on the following masses:

- Wide single – 53.6 kg; and
- Conventional dual-pair – 72.5 kg.

Disposal cost was estimated at $0.19/kg, or $10 for a 50 kg tire.

Analysis

From **Table 16**, 92,200 tires are expected to be replaced annually. From **Section 2.2.10**, an average dual tire assembly (discounting rims) weights 72.5 kg, where a new-generation wide base single tire (again discounting the rim) weighs 53.6 kg, a difference of 18.9 kg or 36% less. At a disposal cost of $0.19 per kg., this represents an annual savings to operators, assuming 100% uptake of:

92,200 tires * 18.9 kg/tire * 0.19 $/kg = $331,100.

Operators would save $331,100 per year.

2.2.12. Anecdotal Benefits and Limitations Associated with New-generation Wide Single Tires

Perceived Limitation - Inability to Limp Home

The authors believe that this should not be considered a limitation, despite the industry's acceptance of the practice as a normal operating procedure.

One reservation that many truck operators and drivers have identified when discussing wide-base single tires is the issue of flat tires, and the lack of redundancy inherent in the

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[65] New Generation of Wide Base Tire and its Impacts on Trucking Operations, Environment, and Pavements, Imad L. Al-Qadi and Mostafa A. Elseifi, Paper No. 07-2432 Transportation Research Board, January 2007

[66] Economic Study: Use of Supersingle Tires by Heavy Vehicles Operating in Quebec, Final Report, Genivar for Ministry of Transportation Quebec, M08891, March 2005

use of single tires. The usual scenario is that one tire in a dual set goes flat while a vehicle is en-route, and rather than have the tire changed or repaired on-site, the driver “limps” into a repair facility on the remaining tire. The feeling is that, with wide-base single tires, this technique can not longer be employed and the resulting road-side down-time will adversely impact the driver, operator, and ultimately the customer.

While this attitude is very common in the industry and seems to be accepted as normal operating procedure by many operators and drivers, it must be pointed out that this practice is both dangerous and illegal in Ontario, and indeed in all of North America.

The first concern is the simple loss of load-bearing footprint area because of the flat tire, which will have serious effect on the braking ability and stability of the vehicle, or on the traction available in slippery conditions, in the case of a power unit. In some conditions or circumstances, a single flat tire could compromise a vehicle’s ability to stop or maneuver to avoid a collision, creating a very tangible safety hazard on Ontario’s roads.

Secondly, if a vehicle is loaded to the point where all its tires are heavily stressed by the weight, the loss of one tire in a dual set would dramatically overload the remaining tire, with the result that it will likely experience serious structural damage to the casing thus preventing it from being re-treaded, or worse yet it may self-destruct in a blow-out due to the excessive heat generated by the overload condition, resulting in dangerous road debris and an even more unsafe vehicle.

Also, although the term “limp home” implies a reduced speed for the vehicle until a repair facility is reached, in practice this may not be safe such as on high speed multi-lane highways, and drivers may be tempted to continue at a speed that further encourages the failure of the remaining tire in the dual set.

For these reasons, Ontario makes operation with a flat tire a violation of Highway Traffic Act, and the vehicle owner and driver are subject to severe penalties as a result.

Furthermore, all jurisdictions in the US, Mexico, and Canada are members of the Commercial Vehicle Safety Alliance which has established a uniform Out-of-Service criteria that all members follow.

This standard includes flat tires as an out-of-service item, which means that any truck found with a flat during a routine road-side inspection (such as those performed by MTO at its many Truck Inspection Stations province-wide), would immediately be detained and the tire would require replacement before the vehicle could continue.

Considering the serious implications of “limping home” with a flat tire, it does not seem logical to consider this characteristic of dual tires as an asset in determining the relative merits of second-generation wide single tires and dual tires, regardless of the apparent acceptance of this practice by the industry.

Perceived Limitation - Weight of Tire as it Effects Changing of the Tire

In the author’s discussions with carriers, there were no issues with the tire servicing process either at the roadside or in the shop.

Carriers interviewed all outsourced their roadside tire repairs to specialist firms who are properly equipped and trained in this technology, and if a wide-base single tire had to be replaced in the shop by the operator’s technicians, there were no issues with the procedure. This practice is widespread in the industry regardless of the type of tires used.

There were some comments in the industry journal articles reviewed regarding difficulties for a driver to change a heavy single tire at the roadside, compared to lighter and smaller single tires in a dual set. However, in practice this is not likely to be a significant factor in the choice of tires for most operators. The use of professional tire services to perform roadside tire repairs is almost universal, and even their involvement should lessen as wide-base single tires become more common, since flats and blowouts have been shown to be less frequent than with duals.

Obviously, changing a big heavy wide single tire is more difficult than changing a much lighter and smaller tire in a dual set, but only if the smaller tire is the outside one. The more common scenario is a flat inside tire in a dual set, usually the result of a lack of attention to its air pressure by a driver in the daily trip inspection. This was reported to be very common, and reflects “real world” experience. In the case of an inside flat, the driver has to remove and re-install both tire/wheel assemblies, which erases any advantage of using duals instead of wide singles. The advantage moves even further in favour of wide single tires when the ease of inspecting them for air pressure is considered.

Perceived Limitation – Availability

The Ontario operators surveyed generally had no problems obtaining new or re-treaded single tires, although one operator found they had to stockpile a few singles at some of their depots to ensure a steady supply in the event of flats or blowouts. In that case, a tire service had to pick the tires up first if a road service was required, but this didn’t seem to be a problem for either party. As wide single tires become better accepted by industry (as it is believed they will be) more tires will be available in more locations, and more tire manufacturers will become involved, with the same outcome.

Perceived Benefit - Ease of Inspection

The authors see this as a major advantage of single tires which should be emphasized. For several years MTO has been encouraging the trucking (and busing) industries to improve the thoroughness of daily trip inspections performed by drivers, and anything that makes this inspection process easier (and thus the vehicles more reliable and safer) should be considered a benefit to all road users.

A vehicle equipped with wide-base single tires is much easier to inspect simply because there are fewer tires involved and there is more room to do the inspection. Most importantly, tire pressures are much easier to inspect and adjust, which largely accounts for the noticeable drop in flats and blowouts with these tires. As well, these tires have a lot more elbow room around them for a driver to visually and physically inspect for casing damage and tread wear, and since there is no crevice for rocks or other debris to be wedged into, as with duals, there is no chance for damage to the tires from such debris nor any opportunity for it to fly out from centrifugal force and create a dangerous situation for following vehicles.

A less obvious benefit arises from the additional air space around a wide single tire compared to a set of duals. Because of this, a driver can more easily inspect other components required in the daily inspection, such as the chassis, suspension, brakes, etc. This is especially important on some trailers with extremely low floor and body heights where the sight lines for such inspections are limited because of the congested areas around the tires when duals are used.

Perceived Benefit – Handling

Several sources interviewed commented on the improved handling and traction with wide-base single tires in low-traction conditions, especially in snow. However, one operator surveyed commented that their drivers found the advantage lessened as the vehicle payload was reduced, possibly due to the plowing effect of the wider tires as they push their way through the snow compared to two smaller tires in a dual set.

In snow, the prevailing logic in the tire industry is that a wide tire will have less traction in snow than with narrower tires. For a given vehicle weight, the narrower tire will penetrate the snow cover due to its higher weight-per-footprint area, allowing the tire tread to contract the road surface below, while the wider tire will ride over the snow and compact it, reducing traction. The lighter the vehicle weight, the more pronounced this effect will be.

3. ECONOMIC ASSESSMENT SUMMARY

3.1. Net Costs and Benefits

The following Section summarizes the benefits and drawbacks of new-generation wide base single tires on an annual basis. The summary assumes 100% uptake amongst those configurations which would benefit from the regulatory change under consideration. It includes only those benefits and drawbacks directly attributable to the regulatory change, and only those benefits and drawbacks which could be quantified monetarily.

The expected reduction in cost of wheels and tires purchased as components of a new vehicle is $22,322,000 per year. This savings accrues to the operator, and is associated with the lower cost of each new-generation wide base single tire and rim, relative to the cost of two conventional tires and rims which make up a dual tire assembly.

The expected reduction in the time and associated cost to service and maintain new-generation wide base single tires is $5,927,000 per year. This benefit is derived from the shorter time required to service a vehicle equipped with new-generation wide single tires on all drive and trailer axles, relative to the to service an equivalent vehicle equipped with conventional dual tires. The benefit accrues to the vehicle operator.

Increased fuel economy is anticipated to reduce fuel consumption by 66,277,000 litres per year (1% savings per axle equipped with new-generation wide base single tires and aluminum rims) and 165,691,000 litres per year (2.5% savings), with 99,415,000 litres per year (1.5% saving) appearing most likely. This benefit is derived from the lower rolling resistance and aerodynamic drag of new-generation wide base single tires, relative to the rolling resistance and aerodynamic drag of conventional dual tires. The benefit accrues to the vehicle operator.

Monetary savings to the operator are dependent both fuel savings and fuel prices. A sensitivity analysis examined savings of between 1% and 2.5% per axle equipped with new-generation wide base single tires and aluminum rims, at diesel fuel prices between $0.80 and $1.20 per litre. Annual savings were found to potentially range between $53,022,000 (1% savings per axle, fuel cost $0.80) to $198,829,000 (2.5% savings per axle, fuel cost $1.20), with $99,415,000 (1.5% savings per axle, fuel cost $1.00) appearing most likely, and most representative of current fuel costs.

Fuel savings of 1.5% per axle equipped with new-generation wide base single tires and aluminum rims would annually avoid the production of 271,403 tonnes of CO2, at a savings of neutralization costs to society of $10,140,000. Given that this savings is tied to fuel economy expectations, this savings was also subjected to sensitivity analysis.

New-generation wide base single tires and rims are lighter, relative to the mass of two conventional tires and rims which make up a dual tire assembly. This serves to reduce the tare weight of vehicles so-equipped. A reduction in tare weight allows for an incremental addition of payload where bulk cargo is being transported. This increase in operational efficiency is estimated to be worth $974,000/year to operators.

The annual societal benefit of the increased stability of new-generation wide base single tires, leading to fewer tractor-trailer-involved crashes, and resultant casualties and congestion, is $9,970,000. A further $101,500/year in collision and congestion savings would accrue to society as a result of increased payload capacity amongst bulk carriers. Additional capacity would result in slightly fewer trips being required to move the same mass of cargo, reducing exposure, and thus collision risk.

One replacement new-generation wide base single tire costs less to purchase than two conventional replacement tires. The two tire types are assumed to have substantially the same durability and ability to be recapped. Retreading a new-generation wide base single tire is slightly more expensive than retreading two conventional tires. The net benefit to operators, based on whole-life cost-of-ownership of new-generation wide base single tires is $9,903,000/year.

One new-generation wide base single tire requires less materials and energy to produce than two conventional dual tires. A key component in tire manufacture is oil. Reducing the consumption of oil in tire manufacturing by substituting new-generation wide base single tires for conventional dual tires, where beneficial under the regulation being considered, saves society $46,100/year in emissions neutralization costs.

The reduced mass of a new-generation wide base single tire as compared to two conventional tires, assuming substantially equivalent durability and ability to be recapped, means less tire mass to be disposed of at the end of the tires' useful life. This reduction in disposal cost accrues to the operator, and is valued at $331,000/year.

Table 17 summarizes the annual benefits, while examining sensitivity around potential fuel savings (per benefiting axle), fuel pricing and emissions neutralization costs.

Table 17 – Annual Benefits (100% Uptake)

Benefit							
Reduction In New Vehicle Cost			$22,322,000	$22,322,000	$22,322,000	$22,322,000	$22,322,000
Reduction in Maintenance Cost			$5,927,000	$5,927,000	$5,927,000	$5,927,000	$5,927,000
Increased Fuel Economy	**Percentage Saved Per Axle**	**Fuel Price $/L**	**$0.80**	**$0.90**	**$1.00**	**$1.10**	**$1.20**
	1.00%		$53,022,000	$59,649,000	$66,277,000	$72,905,000	$79,532,000
	1.50%		$79,532,000	$89,474,000	$99,415,000	$109,357,000	$119,298,000
	2.00%		$106,042,000	$119,297,000	$132,552,000	$145,807,000	$159,062,000
	2.50%		$132,553,000	$149,122,000	$165,691,000	$182,260,000	$198,829,000
Decreased Emissions from Fuel Savings	**1.00%**		$6,760,000	$6,760,000	$6,760,000	$6,760,000	$6,760,000
	1.50%		$10,140,000	$10,140,000	$10,140,000	$10,140,000	$10,140,000
	2.00%		$13,520,000	$13,520,000	$13,520,000	$13,520,000	$13,520,000
	2.50%		$16,900,000	$16,900,000	$16,900,000	$16,900,000	$16,900,000
Operational Efficiency (Bulk Cargo)			$974,000	$974,000	$974,000	$974,000	$974,000
Collision Avoidance - Stability			$9,970,000	$9,970,000	$9,970,000	$9,970,000	$9,970,000
Collision Avoidance - Exposure Reduction			$101,500	$101,500	$101,500	$101,500	$101,500
Tire Ownership			$9,903,000	$9,903,000	$9,903,000	$9,903,000	$9,903,000
Tire Production Emissions			$46,100	$46,100	$46,100	$46,100	$46,100
Tire Disposal Costs			$331,000	$331,000	$331,000	$331,000	$331,000
Total Benefits Matrix - by Expected Fuel Savings and Fuel Price	**1.00%**		$109,356,600	$115,983,600	$122,611,600	$129,239,600	$135,866,600
	1.50%		$139,246,600	$149,188,600	$159,129,600	$169,071,600	$179,012,600
	2.00%		$169,136,600	$182,391,600	$195,646,600	$208,901,600	$222,156,600
	2.50%		$199,027,600	$215,596,600	$232,165,600	$248,734,600	$265,303,600

3.2. *Uptake Scenarios*

Table 18 through Table 21 illustrates the economic benefits of the proposed regulatory change under consideration, in the context of specific uptake scenarios for the industry as a whole.

Table 18 – Annual Benefits (5% Uptake) – No Change in Regulations

Uptake Assumption	**Percentage Fuel Savings per Axle**	**Fuel Price $/L**	**$0.80**	**$0.90**	**$1.00**	**$1.10**	**$1.20**
5.00%	**1.00%**		$5,467,830	$5,799,180	$6,130,580	$6,461,980	$6,793,330
	1.50%		**$6,962,330**	**$7,459,430**	**$7,956,480**	**$8,453,580**	**$8,950,630**
	2.00%		$8,456,830	$9,119,580	$9,782,330	$10,445,080	$11,107,830
	2.50%		$9,951,380	$10,779,830	$11,608,280	$12,436,730	$13,265,180

Table 19 – Annual Benefits (30% Uptake) Pessimistic

Uptake Assumption	**Percentage Fuel Savings per Axle**	**Fuel Price $/L**	**$0.80**	**$0.90**	**$1.00**	**$1.10**	**$1.20**
30.00%	**1.00%**		$32,806,980	$34,795,080	$36,783,480	$38,771,880	$40,759,980
	1.50%		**$41,773,980**	**$44,756,580**	**$47,738,880**	**$50,721,480**	**$53,703,780**
	2.00%		$50,740,980	$54,717,480	$58,693,980	$62,670,480	$66,646,980
	2.50%		$59,708,280	$64,678,980	$69,649,680	$74,620,380	$79,591,080

Table 20 – Annual Benefits (70% Uptake) Optimistic

Uptake Assumption	**Percentage Fuel Savings per Axle**	**Fuel Price $/L**	**$0.80**	**$0.90**	**$1.00**	**$1.10**	**$1.20**
70.00%	**1.00%**		$76,549,620	$81,188,520	$85,828,120	$90,467,720	$95,106,620
	1.50%		**$97,472,620**	**$104,432,020**	**$111,390,720**	**$118,350,120**	**$125,308,820**
	2.00%		$118,395,620	$127,674,120	$136,952,620	$146,231,120	$155,509,620
	2.50%		$139,319,320	$150,917,620	$162,515,920	$174,114,220	$185,712,520

Table 21 – Annual Benefits (50% Uptake) Most Likely

Uptake Assumption	**Percentage Fuel Savings per Axle**	**Fuel Price $/L**	**$0.80**	**$0.90**	**$1.00**	**$1.10**	**$1.20**
50.00%	**1.00%**		$54,678,300	$57,991,800	$61,305,800	$64,619,800	$67,933,300
	1.50%		**$69,623,300**	**$74,594,300**	**$79,564,800**	**$84,535,800**	**$89,506,300**
	2.00%		$84,568,300	$91,195,800	$97,823,300	$104,450,800	$111,078,300
	2.50%		$99,513,800	$107,798,300	$116,082,800	$124,367,300	$132,651,800

4.0 CONCLUSIONS

The broader application of new-generation wide base single tires offers substantial benefits to commercial vehicle operators and society. Based on expected fuel savings of 1.5% per axle so-equipped, and a fuel price of $1.00/L, the following outcomes are forecast:

- If no regulatory change occurs, uptake of new-generation wide base single tires is expected to reach no more than 5%. On that basis, annual benefits to society and the trucking industry from the net advantages of new-generation wide base single tires will be capped at slightly less than $10 million per year.

- If the regulations are amended to permit axles equipped with new-generation wide base single tires to operate at weights up to 9,000 kg, industry uptake is expected to be in the range of 50%, and annual benefits to society and the trucking industry from the net advantages of new-generation wide base single tires will be reach $79,564,800 per year.

- Of the $79.6 million savings, $69.3 million would go towards or benefit industry and the difference, $10.3 million, would benefit society (i.e., reduced emissions, collisions and tire disposal costs).

PART TWO

Impacts of Increasing the Ontario Weight Allowance for Wide-based Single Truck Tires on Vehicle Dynamic Performance and Collisions

Impacts of Increasing the Ontario Weight Allowance for Wide-based Single Truck Tires on Vehicle Dynamic Performance and Collisions

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In response to

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ABSTRACT

This work used computer simulation to assess the dynamic performance of certain tractor-semitrailer and B-train configurations if dual tires would be replaced by wide single tires, with the wide single tires allowed an increase in axle load from 8,000 to 9,000 kg (17,636 to 19,841 lb). The work has generated the dynamic performance of these configurations, and has used these results to estimate a change in the number of collisions that might be expected from greater use of wide single tires.

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Brian Rennie of Bridgestone Canada provided tire characteristics.

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EXECUTIVE SUMMARY

Tire manufacturers have recently introduced a new generation of 445/50R22.5 wide single tires that are a direct replacement for dual 11R22.5 tires. These were not practical in most provinces, where regulations reflected the 6,000 kg (13,227 lb) load limit for an axle with single tires from the national Memorandum of Understanding on Vehicle Weights and Dimensions ("the M.o.U."). This limit was imposed in Ontario in 1994, when semitrailer length was increased to 16.20 m (53 ft), and the overall length for double trailer combinations was increased to 25 m (82 ft). The limit was recently raised to 8,000 kg (17,636 lb) for "Safe, Productive and Infrastructure Friendly" (SPIF) tractor-semitrailer configurations. The 8,000 kg (17,636 lb) limit does not allow either a "standard spread" tandem axle, with a spread from 1.22 to 1.6 m (47 to 63 in), or a "wide spread" tridem axle, with a spread from 3.6 to 3.7 m (142 to 146 in), to reach the axle group load allowed when dual tires are used. The 8,000 kg (17,636 lb) limit could inhibit the introduction and use of these tires in Ontario.

Ontario Ministry of Transportation (MTO) is therefore evaluating the implications of increasing the allowable load on an axle with single tires to 9,000 kg (19,841 lb). This would allow wide single tires to replace dual tires at the same allowable gross weight on the following configurations:

1. Semitrailer with a "standard spread" tandem;
2. Semitrailer with a wide spread tridem;
3. Self-steer tri-axle semitrailer with a "standard spread" tandem;
4. Self-steer quad semitrailer with a wide spread tridem;
5. 7-axle B-train double trailer with "standard spread" tandem trailers; and
6. 8-axle B-train double trailer with a "standard spread" tandem pup trailer.

This work assessed the dynamic performance of these vehicle configurations when the tractor, the semitrailer or trailers, or both, were fitted with wide single tires instead of dual tires, and extended this to assess the impact this may have on collisions. This work is a contribution to a broad study of the costs and benefits of replacing wide single tires on these vehicles. MTO is assessing the pavement costs based on a series of tests it sponsored to compare the pavement impacts of wide single tires and dual tires.

Use of wide single tires increased the static roll threshold by about 2% on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This increase is accrued when wide single tires are fitted on the trailer only, or on both tractor and trailer. There is negligible benefit when wide single tires are fitted only on the tractor. A 2% increase in static roll threshold represents an increase of about 0.008 g for these vehicles in their most critical condition.

Use of wide single tires on the tractor only, trailer only, or both tractor and trailer decreased the high-speed offtracking by about 5%, 10% and 15% respectively, on average over all vehicle configurations considered, for the most critical case of a vehicle

loaded to its allowable gross weight, with a high payload height. This effect diminished as payload weight diminishes, and may actually increase high-speed offtracking at the lowest payload weight considered. However, the performance at this payload was well inside the performance standard, so would not be an issue.

Use of wide single tires decreased the load transfer ratio by up to 3.5%, on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This effect hardly changed as payload weight diminished.

Use of wide single tires on the tractor only or trailer only, or both tractor and trailer decreased the transient offtracking by about 10% and 18% respectively, on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This effect diminished as payload weight diminished, and may actually increase transient offtracking at the lowest payload weight considered. However, the performance at this payload was well inside the performance standard, so would not be an issue.

Complete replacement of dual tires by wide single tires on the vehicle configurations considered is estimated to result in a reduction in collisions by about 0.96%, which is estimated to result in an annual combined saving in direct collision costs and congestion costs of almost $10 million. A transition to wide single tires would take almost ten years to become substantially complete for tractors, and at least fifteen years for trailers.

A transition to wide single tires should provide a modest improvement in vehicle dynamic performance, a modest reduction in collisions, and a modest cost saving.

Use of wide single tires allows the frame rail spacing of a trailer to increase by about 0.15 m (6 in). This allows a tank to sit a bit lower on the chassis, which might increase the static roll threshold of a vehicle with a circular tank by 0.005 to 0.012 g, and a vehicle with a modified oval tank might increase its static roll threshold by no more than 0.005 g. Much greater increases in static roll threshold are available by other changes in design with the intention to maximize the static roll threshold.

If an existing vehicle would be modified to use wide single tires on rims without outset, this would result in a significant reduction in track width and a corresponding degradation of the static roll threshold and all dynamic performance measures. If an existing vehicle would be modified to use wide single tires on rims with outset, the gross axle weight ratings might be reduced. This work may not be straightforward, and it is evidently desirable that the work should be done either by the original manufacturer of the vehicle, or an entity that has the appropriate qualifications to design and make the changes. The work should involve discussions with the manufacturers of the hubs, axles and suspension on the vehicle, to ensure proper ratings are obtained for these components, or appropriate replacement components are selected. The entity that does the work should place a sticker on the vehicle that indicates the revised gross axle weight ratings, as already required for conversion of vehicles to SPIF configuration. It is clearly preferred that any vehicle that will use wide single tires should be built new for this purpose. This vehicle will have the maximum axle track width on tractor or trailer, and the suspension spacing will be appropriate so the vehicle achieves the maximum roll resistance.

The computer simulation used for this work depends on the vehicle configuration, payload weight and payload distribution, and also on the properties of steering, suspensions, tires and hitches. It was not possible to get sufficient data from tire manufacturers for the full non-linear tire characteristics file demanded by the simulation. The data provided were therefore blended with the complete characteristics of earlier generation wide single tires to produce composite characteristics for a generic 445/50R22.5 drive tire, and a generic trailer tire. The resulting generic files certainly are not the precise characteristics of the products of either manufacturer. A simulation run with these files would not be expected to match exactly the responses of a specific vehicle equipped with specific tires of one of the manufacturers. However, it is believed that the files should be somewhat representative of the mix of tires that might be in operation on the highway. The differences between vehicles with dual tires and vehicles with wide single tires are generally rather modest and in the expected direction. There would be greater confidence in the results if samples of the tires had been purchased and tested, and the test results would have been used directly in the simulations.

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1 INTRODUCTION

Tire manufacturers have recently introduced a new generation of 445/50R22.5 wide single tires that are a direct replacement for dual 11R22.5 tires. These were not practical in most provinces, where regulations reflected the 6,000 kg (13,227 lb) load limit for an axle with single tires from the national Memorandum of Understanding on Vehicle Weights and Dimensions ("the M.o.U.") [1]. This limit was imposed in Ontario in 1994, when semitrailer length was increased to 16.20 m (53 ft), and the overall length for double trailer combinations was increased to 25 m (82 ft). The limit was recently raised to 8,000 kg (17,636 lb) for "Safe, Productive and Infrastructure Friendly" (SPIF) tractor-semitrailer configurations [2]. The 8,000 kg (17,636 lb) limit does not allow either a "standard spread" tandem axle, with a spread from 1.22 to 1.6 m (47 to 63 in), or a "wide spread" tridem axle, with a spread from 3.6 to 3.7 m (142 to 146 in), to reach the axle group load allowed when dual tires are used. The 8,000 kg (17,636 lb) limit could inhibit the introduction and use of these tires in Ontario.

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This work assesses the dynamic performance of these vehicle configurations when the tractor, the semitrailer or trailers, or both, are fitted with wide single tires instead of dual tires, and extends this to assess the impact this may have on collisions. This is a contribution to a broad study of the costs and benefits of replacing wide single tires on these vehicles [3]. MTO is assessing the pavement costs based on a series of tests it sponsored to compare the pavement impacts of wide single tires and dual tires.

2 ASSESSMENT OF DYNAMIC PERFORMANCE

2.1 Performance Measures

This work used the same approach to assess vehicle dynamic performance as the CCMTA/RTAC Vehicle Weights and Dimensions Study [4], [5], [6]. This approach has served as the basis for all new vehicle weight and dimension regulations since 1985, and for evaluation of many special permit applications by most provinces.

A performance measure is some response of a system to a standardized input. The input is standardized so that responses of different systems can be compared to each other. The performance standard is the criterion or boundary between satisfactory and unsatisfactory performance. Evaluating vehicle performance consists of three steps:

1. Subject the vehicle to a standardized input;
2. Evaluate the performance measure; then
3. Compare the performance measure to the performance standard.

The evaluation process requires standardized inputs, performance measures and performance standards to be defined in a consistent and coherent manner.

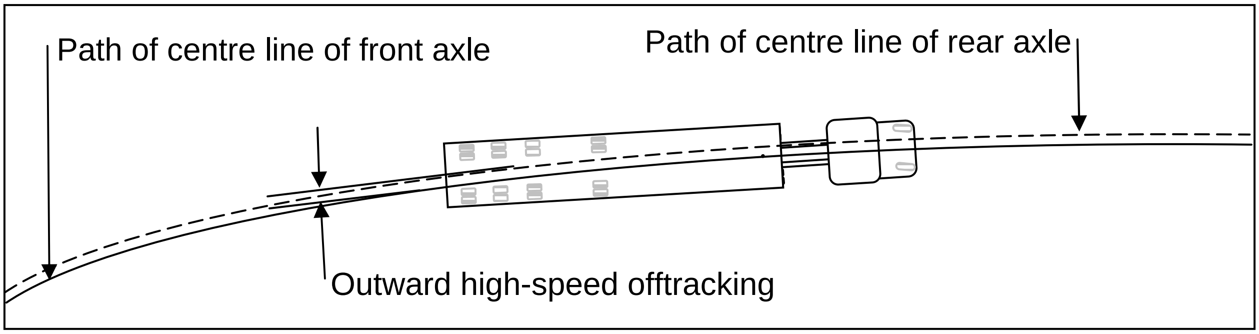
Dynamic performance was assessed using the so-called “RTAC” performance measures, developed during the CCMTA/RTAC Vehicle Weights and Dimensions Study [4], [6]. These are also consistent with performance measures proposed for vehicles that might operate North America-wide under possible future provisions of the North American Free Trade Agreement [7]. The CCMTA/RTAC Vehicle Weights and Dimensions Study principally examined the dynamic performance of trailers, so the RTAC performance measures were primarily aimed at characterizing the performance of the trailer within the whole vehicle. The performance measures can be determined by computer simulation using manoeuvres that produce the required responses to compute the performance measures, as described below.

Braking efficiency was one of the original RTAC performance measures, which assessed how effectively the braking system of a combination vehicle could use the available tire-road friction to stop a vehicle [4]. An antilock brake system (ABS) has been required on tractors since 1997, and trailers since 1998. An ABS automatically ensures the braking efficiency performance standard should be met over a much wider range of road and load conditions than the original RTAC performance measure. This performance measure is therefore no longer relevant, and was not evaluated.

2.1.1 High-speed Turn

A high-speed turn made on a high-friction surface at a speed of 100 km/h (62.1 mi/h) was used to evaluate the static rollover threshold and high-speed offtracking performance measures. This manoeuvre is shown in Figure 1. The turn started with a short tangent segment, and was followed by a spiral entry to a curve whose radius

Figure 1: High-speed Turn



corresponded to a lateral acceleration of 0.20 g at the specified speed. This curve was held until 15 s into the run, to allow steady state high-speed offtracking to be achieved. Steering wheel angle was then increased at 2 deg/s until the vehicle rolled over or became unstable in yaw.

The **Static Roll Threshold** performance measure is the lateral acceleration, in g, at which a vehicle just rolls over in a steady turn. This performance measure is known to correlate well with the incidence of single truck rollover crashes [8].

The CCMTA/RTAC Vehicle Weights and Dimensions Study set a target static roll threshold of 0.40 g [4]. This value was not used when vehicles were configured for the national M.o.U. [1], because it was recognized that certain commodities inherently have a high centre of gravity at the axle and gross weights allowed in Canada. So, vehicles that meet the M.o.U. may have a static roll threshold less than 0.40 g. However, provinces that use an assessment of dynamic performance as part of the review of a special permit application often do impose the 0.40 g static roll threshold.

New Zealand has narrow winding roads, and its regulations resulted in short, high vehicles. The outcome was a much higher rollover rate than common in North America. New Zealand therefore established a minimum static roll threshold of 0.35 g, for both new and existing vehicles [9]. Carriers could either reduce the payload on an existing vehicle that did not meet this roll threshold, modify the vehicle to improve its roll threshold, or replace it. Overall length was also increased for some configurations, which allowed new vehicles to be built that could carry the same payload weight as before, with a lower centre of gravity.

Australia is considering a minimum static roll threshold of 0.35 g for its proposed new regulation that would allow vehicles carrying general freight to be configured simply to performance standards [10].

Studies in the U.S. considered static roll thresholds of 0.35 and 0.38 g, and concluded that any roll threshold higher than 0.35 g would restrict commerce, and would require a considerable number of exemptions. This is a similar conclusion to that reached when vehicles were configured for the national M.o.U., as noted above. The static roll threshold is not considered in U.S. Federal regulations, nor is it known to be a factor in any state law, regulation or permit.

Tank trucks are prone to rollover. The Australian performance-based standards set a minimum static roll threshold of 0.35 g for vehicles carrying general freight, but set a minimum of 0.40 g for tank trucks [10]. The minimum static roll threshold for tank trucks in European countries is now 0.40 g based on a tilt test, or 0.42 g based on a specified calculation procedure [11]. New Zealand sets a minimum static roll threshold of 0.45 g for tank trucks, but its allowable axle weights and gross weight are modest by Canadian standards, so tank trucks have a low centre of gravity and meet this without difficulty.

This work will consider 0.35 g as the minimum static roll threshold that should be considered for vehicles that will carry general freight under a special permit, and 0.40 g as the minimum static roll threshold that should be considered for tank trucks. These values were adopted simply for presentation of this work, and should not preclude setting a higher limit when warranted for any configuration.

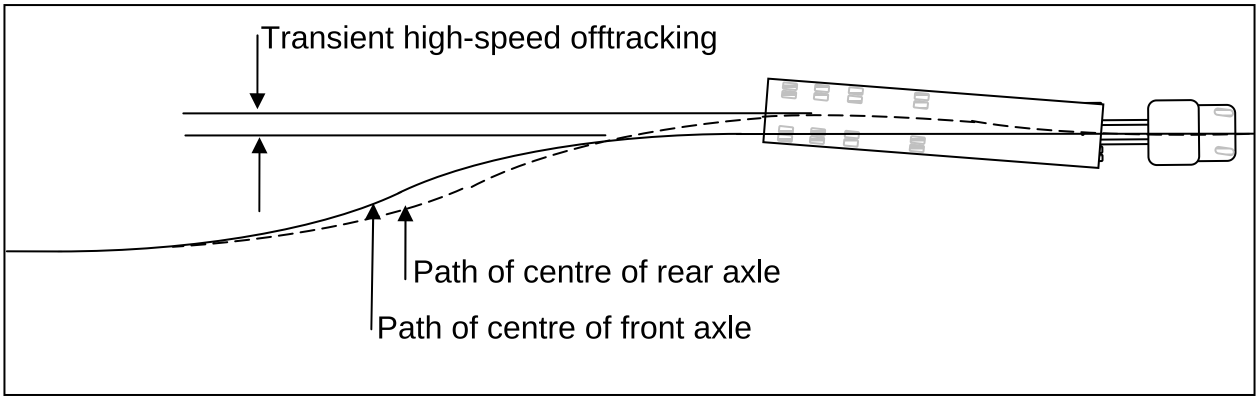
The **High-Speed Offtracking** performance measure is the lateral offset between the path of the steer axle of a tractor and the path of the last axle of the vehicle in a steady turn of 0.20 g lateral acceleration, as shown in Figure 1. Since the driver guides the tractor along a desired path, there is a clear safety hazard if the rearmost axle follows a more outboard path that might intersect a curb or other roadside obstacle, or intrude into an adjacent lane of traffic. This performance measure is a particularly significant for a long semitrailer equipped with self-steering axles, and double trailer combinations.

High-speed offtracking should not exceed 0.46 m (18 in) outboard of the path of the tractor. This allows the rearmost wheel of a vehicle with a 2.59 m (102 in) wide trailer whose tractor is centred in a 3.66 m (12 ft) wide lane within 0.08 m (3 in) of the edge of its lane.

2.1.2 High-speed Lane Change

A high-speed lane change made on a high-friction surface at a speed of 100 km/h (62.1 mi/h) was used to evaluate the load transfer ratio and transient high-speed offtracking performance measures. This manoeuvre is shown in Figure 2. The path was a side-step which corresponded to a single sinusoidal cycle of lateral acceleration of 0.15 g with a period of 3.0 s at the tractor front axle, and represented a manoeuvre made to avoid an obstacle in the path of the vehicle [6]. This manoeuvre was sufficiently gentle that it does not cause the rearmost trailer of a multi-trailer combination to roll over. The period corresponds to that at which the greatest response occurred for most trucks in the simulations for the CCMTA/RTAC Vehicle Weights and Dimensions Study [6], but is not necessarily the period at which greatest response would actually occur for any particular vehicle. The two performance measures do not depend strongly on steer period for tractor-semitrailers, whereas they usually do for double and triple trailer combinations, and truck-trailer combinations.

Figure 2: High-speed Lane Change



The **Load Transfer Ratio** performance measure is the fractional change in load between left- and right-hand side tires in an obstacle avoidance manoeuvre. It indicates how close all of the tires on one side of the rearmost roll-coupled unit came to lifting off, a precursor to rollover. The load transfer ratio should not exceed 0.60, which is equivalent to an 80% - 20% left-right division of wheel loads. This is a particularly significant performance measure for any vehicle with a high payload centre of gravity, double and triple trailer combinations, and truck-trailer combinations.

The **Transient High-Speed Offtracking** performance measure is the peak overshoot in the lateral position of the rearmost trailer axle from the path of the tractor front axle in an obstacle avoidance manoeuvre, as shown in Figure 2. It is an indication of potential for side-swipe of a vehicle in an adjacent lane, or for impact-induced rollover due to a curb strike. This measure quantifies the "tail-wagging" response to a rapid steer input. The transient high-speed offtracking should not exceed 0.80 m (31.5 in). This is a particularly significant performance measure for double and triple trailer combinations, and truck-trailer combinations.

2.2 Computer Simulations

The dynamic performance of vehicles has always been evaluated by computer simulation. While it is possible to determine some performance measures in a full-scale test, there is no practical way to measure others.

The simulation study was conducted using a version of the Yaw/roll model [12]. The Yaw/roll model is a dynamic simulation of moderate complexity that represents the combined lateral, yaw and roll response of heavy articulated vehicles as a result of either closed or open loop steering input with relatively simple input data. The model can represent vehicle combinations with up to six vehicle units and eleven axles, with up to eight axles on any vehicle unit. Up to five axles, other than the front steering axle, may be self-steering or forced steering. The model is structured so that any of these limits can easily be changed if necessary. Fifth wheel, turntable, pintle hook, C-dolly and other couplings allow representation of A-, B- and C-train combinations, and others.

The non-linear characteristics of these coupling devices are represented directly within the model. The non-linear characteristics of tires, suspensions and self-steering axles are represented by lookup tables from input data. The model does not represent longitudinal tire forces needed for drive and brake torque, so is restricted to travel at constant longitudinal velocity on a smooth, level road surface with uniform frictional characteristics. The model operates either in closed loop mode by defining a specific steer input, either at the steering wheel or the front steering axle, or in open loop mode, by defining a path that the vehicle should follow and using a driver model to steer the steering wheel to cause the vehicle to follow that path. The steer input is defined in the closed loop mode, and the vehicle does not follow any specific path on the ground, it goes where it wants to, depending on its own dynamic characteristics. Two different vehicles subjected to the same closed loop input may follow quite different paths on the ground. The path to be followed is defined in the open loop mode, and choice of parameters in a driver model determines how closely the specified path is actually followed. These parameters are normally chosen to represent an alert driver so that the vehicle follows the desired path closely.

The Yaw/roll simulation program has been used extensively in previous simulation studies [5], [13], and has been shown to provide reasonable agreement with test results for a large number of vehicle configurations [14], [15]. The absolute accuracy of a vehicle simulation depends critically both on how well the model represents the vehicle system, and how accurately the component data are known. The relative accuracy, for purposes of comparison of similar vehicles, is less dependent upon the accuracy of component data. The simulation can be expected to provide a proper ranking of vehicles in a comparison as long as the data are reasonably representative.

The performance measures were obtained from the two manoeuvres described in Section 2.1, which were designed to provide the necessary responses. This procedure is completely consistent with that used in the CCMTA/RTAC Vehicle Weights and Dimensions Study [5], and other studies conducted for a variety of purposes [13].

This work assumes the payload centre of gravity is on the centre-line of the vehicle. The static roll threshold deteriorates significantly as the payload centre of gravity moves laterally away from the centre-line of the vehicle, perhaps of the order of 0.10 g for each 0.30 m (12 in) of movement.

3 VEHICLE CONFIGURATIONS

3.1 Scope

This work will address the following six configurations:

1. Semitrailer with a “standard spread” tandem, as shown in Figure 3;
2. Semitrailer with a wide spread, as shown in Figure 4;
3. Self-steer tri-axle semitrailer with a “standard spread” tandem, as shown in Figure 5;
4. Self-steer quad semitrailer with a wide spread tridem, as shown in Figure 6;
5. 7-axle B-train double with “standard spread” tandem trailers, as shown in Figure 7; and
6. 8-axle B-train double with a “standard spread” tandem pup trailer, as shown in Figure 8.

3.2 Tractor

This work used a generic tandem drive tractor, with a front axle setback of 0.91 m (36 in), a 4.83 m (190 in) wheelbase, a tandem drive axle with a spread of 1.37 m (54 in), and a fifth wheel placed 0.20 m (8 in) forward of the centre of the drive tandem. The tractor had a tare weight of 8,164 kg (18,000 lb) with dual tires. The front axle was assumed to weigh 544 kg (1,200 lb), with a rating of at least 5,500 kg (12,125 lb), and a tare load of 4,762 kg (10,500 lb). Each drive axle was assumed to weigh 1,134 kg (2,500 lb) with dual tires, or 1,043 kg (2,300 lb) with single tires. Moments of inertia were generated in the same way as during the CCMTA/RTAC Vehicle Weights and Dimensions Study [6].

3.3 Trailers

This work used generic 14.65 and 16.2 m (48 and 53 ft) van semitrailers, as shown in Figure 3 through Figure 6. The semitrailer wheelbase was chosen to balance a uniformly distributed load, but not more than 12.50 m (492 in), nor less than that which arises from 35% effective rear overhang. The tare weight of a tandem, three-axle and quad semitrailer with dual tires was 6,350, 7,484 and 8,618 kg (14,000, 16,500 and 19,000 lb) respectively.

This work used generic B-train double trailer combinations, with two equal length semitrailers and a box length of 20 m (65 ft 7 in), as shown in Figure 7 and Figure 8. The lead trailer kingpin setback was 1.22 m (48 in), and the pup trailer kingpin setback was 0.46 m (18 in). The lead semitrailer was fitted with either a “standard spread” tandem or a 3.05 m (120 in) spread tridem axle, and the pup semitrailer was fitted with a “standard spread” tandem axle. The tare weight of 7-axle and 8-axle B-trains were 9,525 and 10,205 kg (21,000 and 22,500 lb) respectively, with dual tires.

Figure 3: Tandem Semitrailer

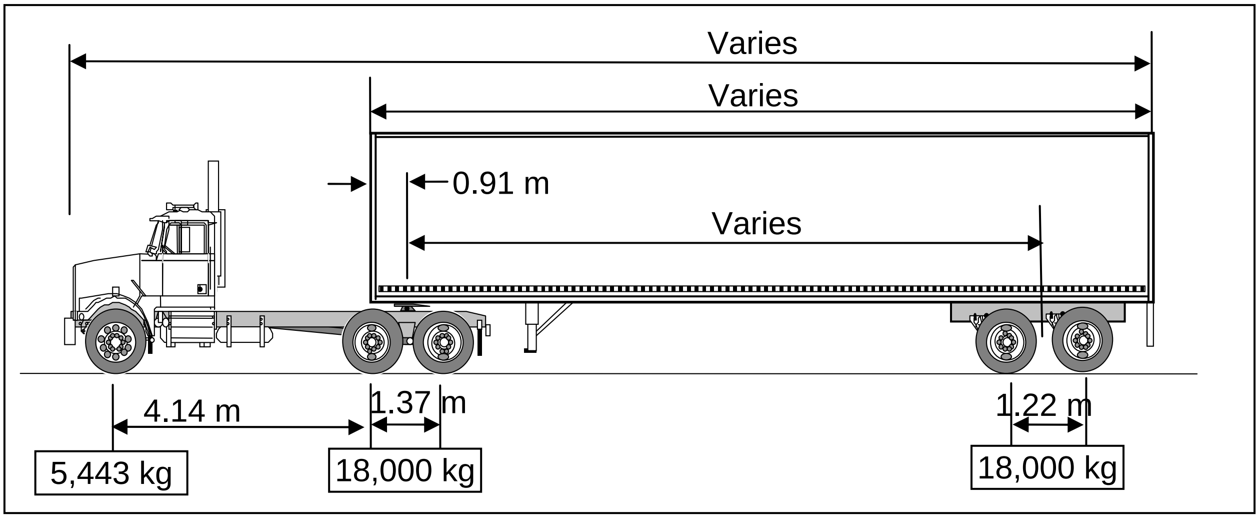


Figure 4: Tridem Semitrailer

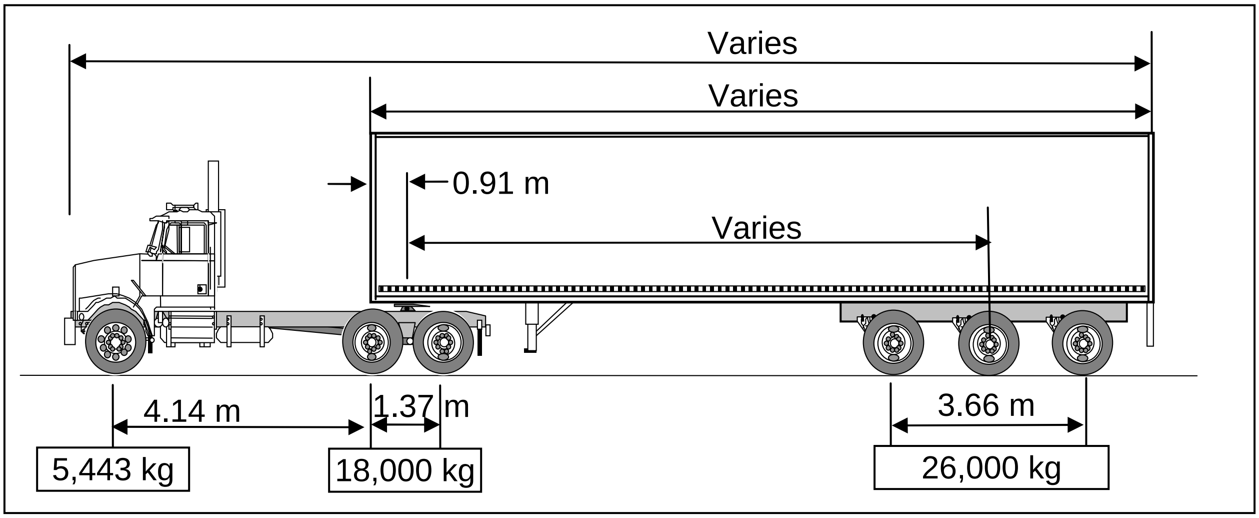


Figure 5: Self-steer Tri-axle Semitrailer

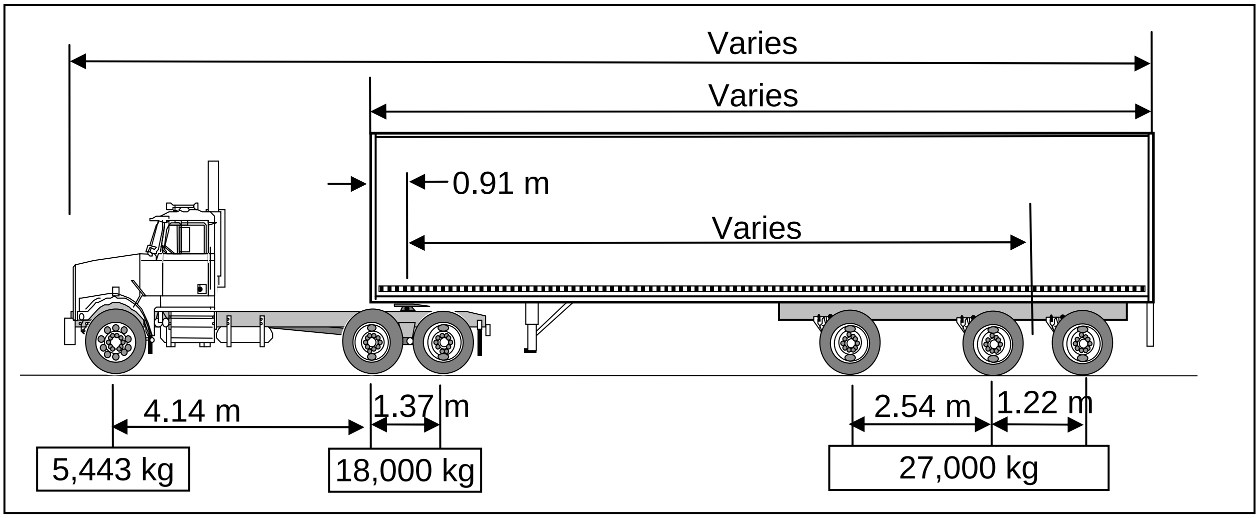


Figure 6: Self-steer Quad Semitrailer

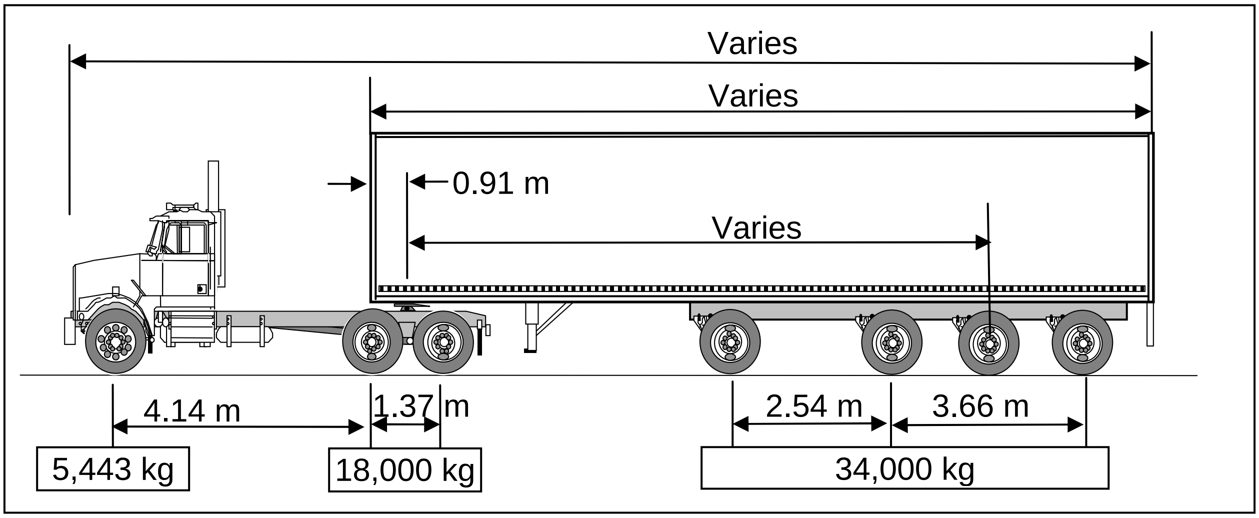


Figure 7: 7-axle B-train

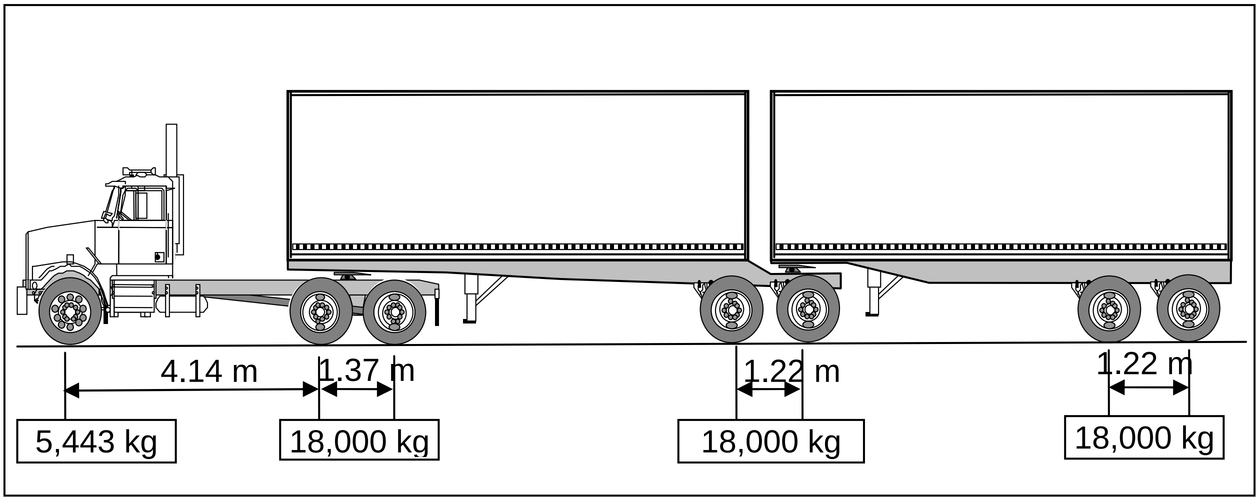
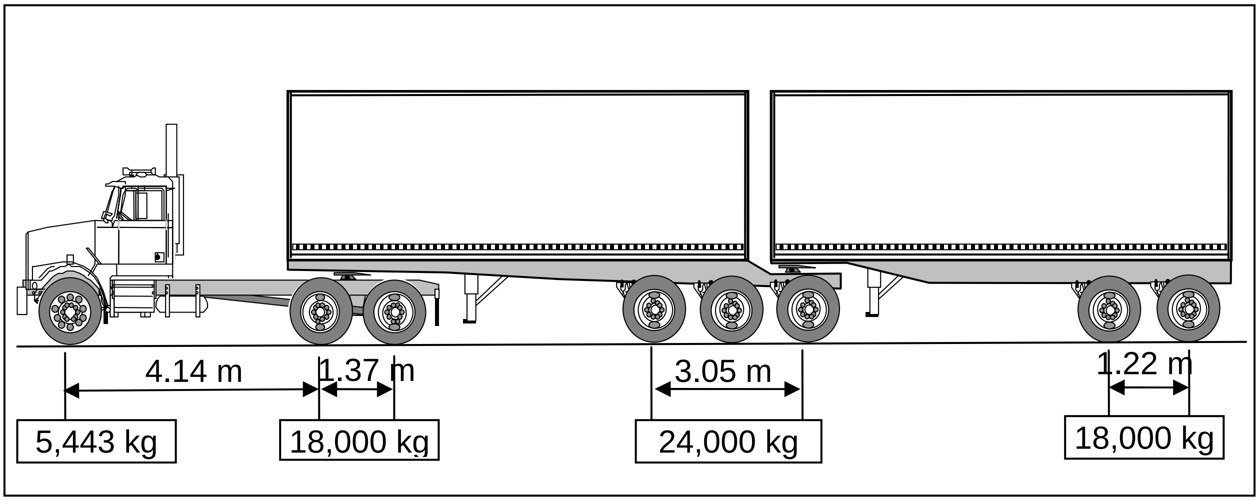


Figure 8: 8-axle B-train



Each fixed axle was assumed to weigh 680 kg (1,500 lb) with dual tires, and 590 kg (1,300 lb) with single tires, and each self-steering axle was assumed to weigh 907 kg (2,000 lb). Moments of inertia for all semitrailers were generated in the same way as during the CCMTA/RTAC Vehicle Weights and Dimensions Study [6].

3.4 Axle Dimensions

Nominal axle dimensions are shown in Table 1. Narrow track axles are generally used for vehicles with dual tires and an overall width of 2.44 m (96 in), while wide track axles are generally used for vehicles with dual tires and an overall width of 2.59 m (102 in). The wide single track axle has been developed for vehicles with wide single tires and an overall width of 2.59 m (102 in). The spring spacing shown is a nominal spacing for an air suspension on a trailer. The overall width assumes a nominal spacing of 0.32 m (12.5 in) for dual tires with a nominal tire width of 0.30 m (12 in), and a nominal tire width of 0.445 m (17.5 in) for wide single tires.

This work assumes that all vehicles fitted with wide single tires are newly constructed or converted with wide track for the tractor drive axles and wide single track for the trailer axles. This work also assumes that all vehicles fitted with dual tires have narrow track for the tractor drive axles and wide track for the trailer axles. Some of the issues that arise if wide single tires are installed on narrower axles than assumed are addressed in Chapter 7.

Table 1: Axle Dimensions

Axle Track	Track Width	Spring Spacing	Overall Width	
			Dual 11R22.5	Single 445/50R22.5
Narrow	1.82 m (71.5 in)	0.79 m (31 in)	2.44 m (96.0 in)	2.26 m (89.0 in)
Wide	1.97 m (77.5 in)	0.94 m (37 in)	2.59 m (102.0 in)	2.41 m (95.0 in)
Wide Single	2.12 m (83.5 in)	1.09 m (43 in)		2.57 m (101.0 in)

3.5 Payload Weight

Vehicle configurations were created using the generic tractor described above. The allowable front axle weight was 5,443 kg (12,000 lb). The allowable weight on a tandem axle group was 18,000 kg (39,682 lb). The allowable weight on a tridem axle group was 24,000 or 26,000 kg (52,910 or 57,319 lb), for a 3.05 or 3.66 m (120 or 144 in) spread. The allowable gross weight was determined according to Ontario regulations. The maximum payload weight was the difference between the allowable gross weight, and the tare weight of the vehicle, with the result rounded down to the nearest thousand pounds, as shown in Table 2. The maximum payload was not increased when the tare weight diminished when vehicles were fitted with wide single tires. There were two reasons for this. First, the results allow a direct comparison of vehicles with different tires and exactly the same payload. Second, in most cases, the additional potential payload will not generally be available to van trailers that carry unitized payloads like pallets. It will be available to vehicles with some other body styles, such as those carrying loose bulk commodities like aggregates and liquids.

The five load cases in Table 3 were considered for each combination. Load Case 1 used the maximum payload weight on the semitrailer, from Table 2. The typical maximum tandem semitrailer payload weight for shipment to the U.S. is 20,411 kg (45,000 lb), and the average tandem semitrailer payload is about 15,875 kg (35,000 lb). Tridem and self-steer semitrailers were run at tandem weights because they often operate at these weights. Other weights simply provide reasonable steps. B-train payloads were split equally between the two trailers.

Table 2: Payload Capacity of Semitrailers

Semitrailer	Gross Weight (lb)	Tare Weight (lb)	Payload Weight (lb)
Tandem	41,443 kg (91,365 lb)	32,000	58,000
Tridem	49,443 kg (109,002 lb)	34,500	74,000
Self-steer tri-axle	50,443 kg (111,206 lb)	35,000	75,000
Self-steer quad	57,443 kg (126,638 lb)	38,000	88,000
7-axle B-train	59,443 kg (131,092 lb)	39,000	91,000
8-axle B-train	63,500 kg (139,992 lb)	40,500	99,000

Table 3: Payload Weights for Load Cases

Semitrailer	Payload Weight for Load Case (lb)				
	1	2	3	4	5
Tandem	58,000	53,000	45,000	35,000	25,000
Tridem	74,000	59,500	45,000	35,000	25,000
Self-steer tri-axle	75,000	60,000	45,000	35,000	25,000
Self-steer quad	88,000	81,000	74,000	59,500	45,000
7-axle B-train	91,000	81,000	71,000	61,000	51,000
8-axle B-train	99,000	89,000	79,000	69,000	59,000

3.6 Load Distribution

Vehicles were loaded with the specified payload weight in a solid block of uniform density, with a height of 1.22, 1.83 or 2.44 m (48, 72 or 96 in), over a width of 2.44 m (96 in), and from the nose of a trailer rearward to 0.30 m (12 in) from the rear of a trailer. The trailer wheelbase was adjusted to ensure no axle group was overloaded.

This procedure for load distribution meant that the density of the payload varied, depending on the payload weight, height and load length. However, it did result in a consistent height for the payload centre of gravity, which can be helpful when assessing an actual vehicle against the simulation results. The CCMTA/RTAC Vehicle Weights and Dimensions Study used a constant payload density of 545 kg/cu m (34 lb/cu ft) [6]. This density represents a payload like dressed lumber, products packed 1.52-1.83 m (60-72 in) high on a pallet and weighing 1,000-1,500 kg (2,204-3,306 lb), and many other commodities of moderate density. A constant density payload results in a different payload height depending on the payload weight and length, which means for example that payloads of the same weight but different length, as necessary to balance the axle loads, will have different roll thresholds.

3.7 Scope

Each configuration was evaluated for the four tire fitments shown in Table 4. **DD**, dual tires on both tractor and trailer(s), represents the status quo. The other three cases are possible combinations that may arise. The same tire was used on both trailers of a B-train.

Table 4: Tire Fitment

Code	Tractor Tires	Trailer Tires
DD	Dual	Dual
DS	Dual	Wide single
SD	Wide single	Dual
SS	Wide single	Wide single

3.8 Computer Simulation

The computer simulation depends on the vehicle configuration, payload weight and payload distribution, and also on the properties of steering, suspensions, tires and hitches. Representative data were available on file for all components except the new generation of wide single tires. Ideally, sample tires would have been purchased and tested to determine the lateral force and aligning moment as functions of slip angle and vertical load, but this was not possible within the scope or budget of the project. These data were therefore requested from the two principal manufacturers of these tires.

Bridgestone graciously provided data available from tests they had conducted. Michelin declined to provide data, as these data were considered proprietary, but they did provide a published reference which included linearized characteristics of their tires [16]. Neither offering was sufficient to generate the complete file of non-linear tire characteristics demanded by the simulation. It was evident from the data provided that the drive and trailer tires of each manufacturer have distinctly different characteristics, the drive tires of each manufacturer have somewhat similar characteristics, and the trailer tires of each manufacturer also have somewhat similar characteristics. The data provided were therefore blended with the complete characteristics of earlier generation 445/65R22.5 tires from each of these manufacturers to produce composite characteristics for a generic 445/50R22.5 drive tire, and a generic 445/50R22.5 trailer tire.

MTO effectively restricts wide single tires to a load of 10 kg/mm (560 lb/in) of tire width, which limits the 445/50R22.5 to an axle load of 8,900 kg (19,620 lb). It requires a 455/55R22.5 tire to reach the full axle load of 9,000 kg (19,841 lb). The only data provided related to 445/50R22.5 tires. There is no way to quantify the difference in tire characteristics between 445/50R22.5 and 455/55R22.5 tires, nor between actual 445/50R22.5 tires and the generic tire data developed as described above. It is assumed that all these differences are small.

The generic files tire data developed as described above are certainly not the precise characteristics of the products of either manufacturer. A simulation run with these files would not be expected to match exactly the responses of a specific vehicle equipped with specific tires of either of the manufacturers. However, it is believed that the files should be somewhat representative of the mix of tires that might be in operation on the highway. At the end of the work, if there is little difference between vehicles with dual tires and vehicles with wide single tires, then safety considerations might not be a significant factor in the Ministry’s policy decision. If there is a significant difference, and that difference would be the principal factor in the decision, it might be prudent to conduct the tests outlined above to how representative the composite tire characteristics used here actually were.

This work evaluated the customary high-speed performance measures:

- Static roll threshold;
- High-speed offtracking;
- Load transfer ratio; and
- Transient offtracking.

The performance measures were evaluated for a vehicle traveling at 100 km/h (62.1 mi/h).

There was no need to evaluate the low-speed performance measures, as all vehicles were within allowable dimensions. These performance measures are not affected by the type of tire fitted to a vehicle.

4 RESULTS AND DISCUSSION

4.1 Static Roll Threshold

The static roll thresholds are presented in Table 5 through Table 10 for tandem, tridem, self-steer tri-axle and self-steer quad semitrailers, and 7- and 8-axle B-trains, respectively. **LC** in the first column indicates the load case, as given in Table 3. The column headings **DD**, **DS**, **SD** and **SS** indicate the tire fitment, as given in Table 4. There is little variation with semitrailer length or B-train box length, so values for each tire fitment, load case and payload height were averaged for short and long vehicles for each load case, payload height and tire condition. Blank fields in these tables indicate cases where a vehicle became unstable in yaw before it rolled over. These all occur for a low payload height, and a lateral acceleration that would, in most cases, be above 0.50 g. Performance at a lateral acceleration in this range is highly non-linear, and whether the outcome is a rollover or yaw instability depends on which of two rapidly changing variables reaches a defined threshold first. The outcome really is only of academic interest. It is rather unlikely any driver would be able to control a vehicle in such a manoeuvre, so a crash would be inevitable anyway. In the instances where yaw instability occurs before rollover, a vehicle would be likely to depart from the highway when a rollover would likely follow.

The static roll threshold increased modestly as payload weight diminished, and increased significantly as payload height diminished. All semitrailers met the static rollover performance standard of 0.35 g for all payload weights and payload heights considered. All B-trains also met the static rollover performance standard of 0.35 g, except for the highest payload weights and highest payload height when the trailers were fitted with dual tires.

The static roll threshold was not significantly different for a vehicle with dual or single tires on the drive axles, as the track width (outside to outside of tires) was unchanged. The static roll threshold increased slightly when wide single tires were used on a semitrailer or B-train trailers, for all load cases and payload heights. Wide single tires increased the roll threshold between 2 and 5% for most load cases, payload heights and tire fitments for most vehicles. The average increase over all vehicles considered was about 3%.

The results show there was no significant difference in static rollover threshold between semitrailers of different length, or B-trains of different box length, when each is loaded with the same payload weight having the same payload height. As noted above, these payloads would have different densities. There would be differences to the extent that semitrailers of different length could be loaded full with the same commodity, when vehicles would have the same payload weight, but the payload height in the shorter semitrailer would be greater than for the longer one, so would have a correspondingly lower static roll threshold. The actual difference may be estimated by interpolation within Table 5 through Table 10 for any particular case.

Table 5: Static Roll Threshold for Tandem Semitrailers

LC	Payload Height											
	2.44 m (96 in)				1.83 m (72 in)				1.22 m (48 in)			
	DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
1	0.358	0.370	0.355	0.370	0.422	0.431	0.425	0.432	0.488	0.497	0.506	0.515
2	0.367	0.378	0.367	0.381	0.426	0.439	0.428	0.440	0.492	0.502	0.513	0.523
3	0.383	0.394	0.389	0.401	0.441	0.453	0.437	0.450	0.501	0.510	0.526	0.536
4	0.407	0.418	0.414	0.423	0.456	0.474	0.462	0.476	0.514	0.530	0.529	0.568
5	0.447	0.459	0.456	0.470	0.489	0.504	0.495	0.511	0.546	0.563	0.572	0.580

Table 6: Static Roll Threshold for Tridem Semitrailers

LC	Payload Height											
	2.44 m (96 in)				1.83 m (72 in)				1.22 m (48 in)			
	DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
1	0.361	0.374	0.360	0.377	0.428	0.433	0.435	0.436	0.504	0.514	0.541	0.556
2	0.382	0.395	0.385	0.401	0.439	0.450	0.449	0.457	0.512	0.528	0.555	0.566
3	0.408	0.423	0.412	0.425	0.461	0.474	0.469	0.484	0.521	0.543	0.548	0.593
4	0.436	0.450	0.441	0.457	0.487	0.499	0.497	0.517	0.544	0.561	0.571	0.611
5	0.479	0.489	0.480	0.495	0.522	0.536	0.535	0.555	0.580	0.601	0.625	0.649

Table 7: Static Roll Threshold for Self-steer Tri-axle Semitrailers

LC	Payload Height											
	2.44 m (96 in)				1.83 m (72 in)				1.22 m (48 in)			
	DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
1	0.380	0.385	0.375	0.380	0.439	0.441	0.447	0.452	0.501	0.528	0.548	
2	0.395	0.409	0.395	0.399	0.448	0.462	0.465	0.479	0.517	0.535	0.580	
3	0.416	0.433	0.420	0.430	0.471	0.494	0.487	0.498	0.533	0.554	0.508	
4	0.445	0.454	0.449	0.467	0.496	0.502	0.515	0.537	0.561	0.579	0.605	
5	0.487	0.495	0.490	0.501	0.537	0.548	0.566	0.581	0.591	0.614	0.636	

Table 8: Static Roll Threshold for Self-steer Quad Semitrailers

L C	Payload Height											
	2.44 m (96 in)				1.83 m (72 in)				1.22 m (48 in)			
	DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
1	0.382	0.391	0.387	0.390	0.446	0.457	0.469	0.489	0.532	0.552	0.557	0.568
2	0.387	0.393	0.392	0.398	0.457	0.466	0.479	0.567	0.540	0.544	0.566	0.569
3	0.399	0.401	0.394	0.405	0.461	0.464	0.499	0.510	0.536	0.543	0.590	0.586
4	0.409	0.425	0.415	0.425	0.472	0.486	0.497	0.529	0.550	0.570		
5	0.442	0.454	0.453	0.460	0.495	0.509	0.527	0.543	0.563	0.584		

Table 9: Static Roll Threshold for 7-axle B-trains

L C	Payload Height											
	2.44 m (96 in)				1.83 m (72 in)				1.22 m (48 in)			
	DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
1	**0.342**	0.352	**0.336**	0.347	0.406	0.419	0.400	0.410	0.497	0.492		
2	0.353	0.364	**0.347**	0.360	0.414	0.429	0.409	0.421	0.504	0.501		
3	0.366	0.378	0.359	0.375	0.425	0.442	0.418	0.433	0.509	0.510		
4	0.380	0.397	0.375	0.394	0.437	0.458	0.429	0.449	0.515	0.523		
5	0.398	0.418	0.396	0.418	0.449	0.476	0.442	0.467	0.517	0.539		

Table 10: Static Roll Threshold for 8-axle B-trains

L C	Payload Height											
	2.44 m (96 in)				1.83 m (72 in)				1.22 m (48 in)			
	DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
1	**0.347**	0.357	**0.340**	0.353	0.413	0.425	0.402	0.413	0.497	0.500		
2	0.356	0.368	**0.350**	0.365	0.420	0.435	0.410	0.421	0.502	0.507		
3	0.366	0.381	0.360	0.378	0.427	0.446	0.417	0.432	0.506	0.516		
4	0.378	0.397	0.374	0.395	0.435	0.461	0.424	0.447	0.509	0.529		
5	0.395	0.414	0.394	0.414	0.450	0.476	0.438	0.461	0.518	0.543		

4.2 High-speed Performance Measures

High-speed offtracking, load transfer ratio and transient offtracking are collectively considered the high-speed performance measures. They are presented in Table 11 through Table 16 for tandem, tridem, self-steer tri-axle and self-steer quad semitrailers, and 7- and 8-axle B-trains, respectively. In these tables, the first column labeled **L** indicates the length in feet for a semitrailer, or box length for a B-train, where **S** or **L** indicates 18.5 or 20 m (728 or 787 in) box length respectively. The second column labeled **LC** indicates the load case as shown in Table 3, and the third column labeled **PH** indicates the payload height, where **L**, **M** and **H** correspond to a payload height of 1.22, 1.83 and 2.44 m (48, 72 and 96 in), respectively. The value of each performance measure is presented for the tire fitment indicated, as given in Table 4. In each table, any performance measure that exceeds its performance standard is highlighted in bold.

A comparison of corresponding entries between Table 11 through Table 16 show that high-speed offtracking, load transfer ratio and transient offtracking all increased with an increase in payload weight and payload height for all vehicle configurations and tire fitments. High-speed offtracking was similar for 14.65 and 16.20 m (48 and 53 ft) long semitrailers, and for 18.5 and 20 m (728 and 787 in) box length B-trains with the same payload weight, payload height and tire fitment. The load transfer ratio and transient offtracking performance measures were slightly lower for the longer vehicles, due to their longer wheelbase.

Tire fitment resulted in a number of other patterns in the results in Table 11 through Table 16 that were consistent across all vehicle configurations, and are summarized in Table 17 through Table 19 for the high-speed offtracking, load transfer ratio and transient offtracking performance measures, respectively. The **Load Case** is as given in Table 3. The tire fitment columns show the percentage that the numerator performance measure is of the denominator performance measure for the tire fitment codes given in Table 4, averaged over all payload heights and vehicle lengths for all vehicles. Thus, the first entry in the column headed **DS/DD** is the percentage that high-speed offtracking for a vehicle with dual tires on the tractor and wide single tires on the trailer was of the same vehicle with dual tires on both drive and trailer axles, averaged over all payload heights and vehicle lengths for all vehicles. Averaging was feasible because each individual percentage for a particular payload height, vehicle length and vehicle differed by no more than a couple of percentage points from the overall average, and had the same trend with load case.

High-speed offtracking is summarized in Table 17. For all tire fitments, use of single tires on any axle reduces high-speed offtracking at the highest payload weight, but may result in an increase in high-speed offtracking at the lowest payload weight. However, high-speed offtracking is well inside its performance standard of 0.46 m (18 in) for the lowest payload weight for all payload heights, vehicle lengths and all vehicles, so a modest increase in high-speed offtracking could be tolerated without any likelihood of exceeding the performance standard. Wide single tires on the drive axles (tire fitments **SD/DD** and **SS/DS**) resulted in a reduction of about 5% in high-speed offtracking for the highest payload weight if the trailer tires were unchanged. Wide single tires on the trailer axles (tire fitments **DS/DD** and **SS/SD**) resulted in a reduction of about 10% in high-speed offtracking for the highest payload weight if the drive tires were unchanged. These changes were cumulative (tire fitment **SS/DD**), so there was about 15% reduction in high-speed offtracking for wide single tires on both drive and trailer axles compared to dual tires on drive and trailer axles. These reductions all diminished as payload weight diminished, as noted above, with no change for Load Case 4, and a modest increase for Load Case 5.

Load transfer ratio is summarized in Table 18. Wide single tires on the drive axles (tire fitments **SD/DD** and **SS/DS**) resulted in a reduction of about 2-4% in load transfer ratio for all payload weights if the trailer tires were unchanged. Wide single tires on the trailer axles (tire fitments **DS/DD** and **SS/SD**) resulted in an increase of about 1% in load transfer ratio for the highest payload weight if the drive tires were unchanged. This is the most critical condition, especially for a high payload height. These changes were cumulative (tire fitment **SS/DD**), so there was about 4% reduction in load transfer ratio for wide single tires on both drive and trailer axles compared to dual tires on drive and trailer axles.

Transient offtracking is summarized in Table 19. For all tire fitments, wide single tires on any axle reduced transient offtracking at the highest payload weight, but resulted in an increase in transient offtracking at the lowest payload weight for some vehicles. However, transient offtracking was well inside its performance standard of 0.80 m (31.5 in) for the lowest payload weight for all payload heights, vehicle lengths and all vehicles, so a modest increase in transient offtracking could be tolerated without any likelihood of exceeding the performance standard. Wide single tires on the drive axles (tire fitments **SD/DD** and **SS/DS**) resulted in a reduction of about 9% in transient offtracking for the highest payload weight if the trailer tires were unchanged. Wide single tires on the trailer axles (tire fitments **DS/DD** and **SS/SD**) resulted in a reduction of about 10% in transient offtracking for the highest payload weight if the drive tires were unchanged. These changes were cumulative (tire fitment **SS/DD**), so there was about 19% reduction in transient offtracking for wide single tires on both drive and trailer axles compared to dual tires on drive and trailer axles. These reductions all diminished as payload weight diminished, as noted above, with no change for Load Case 4, and a modest increase for Load Case 5.

At modest axle loads, one wide single and two dual tires provided comparable side force at the same slip angle. However, as vertical load was increased, the side force provided by two dual tires dropped increasingly below that of a wide single tire. This difference in side force characteristics between wide single and dual tires largely accounts for the trends of performance measures against payload weight seen in Table 17 through Table 19.

Table 11: High-speed Performance Measures for Tandem Semitrailers

L	L C	P H	High-speed Offtracking (<0.46 m)				Load Transfer Ratio (<0.60)				Transient Offtracking (<0.80 m)			
			DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
48	1	H	0.406	0.345	0.381	0.320	**0.600**	**0.611**	0.575	0.585	0.537	0.478	0.484	0.430
48	2	H	0.377	0.331	0.359	0.312	0.576	0.583	0.548	0.554	0.499	0.455	0.452	0.412
48	3	H	0.331	0.308	0.322	0.298	0.549	0.549	0.517	0.515	0.438	0.417	0.400	0.382
48	4	H	0.297	0.292	0.294	0.289	0.498	0.492	0.470	0.463	0.376	0.374	0.352	0.351
48	5	H	0.271	0.276	0.276	0.281	0.437	0.432	0.417	0.412	0.319	0.329	0.314	0.323
48	1	M	0.379	0.331	0.355	0.306	0.499	0.503	0.471	0.474	0.479	0.437	0.426	0.385
48	2	M	0.353	0.318	0.336	0.300	0.484	0.484	0.456	0.454	0.447	0.417	0.400	0.371
48	3	M	0.316	0.300	0.306	0.290	0.465	0.460	0.437	0.431	0.399	0.386	0.361	0.350
48	4	M	0.288	0.288	0.286	0.285	0.431	0.423	0.405	0.397	0.353	0.354	0.329	0.330
48	5	M	0.266	0.275	0.272	0.280	0.385	0.380	0.368	0.363	0.305	0.318	0.300	0.313
48	1	L	0.357	0.317	0.335	0.294	0.411	0.411	0.387	0.385	0.435	0.400	0.381	0.347
48	2	L	0.334	0.306	0.316	0.288	0.405	0.401	0.380	0.377	0.407	0.383	0.360	0.336
48	3	L	0.304	0.293	0.293	0.283	0.394	0.387	0.369	0.363	0.371	0.362	0.333	0.325
48	4	L	0.283	0.284	0.280	0.281	0.369	0.362	0.348	0.340	0.335	0.337	0.311	0.313
48	5	L	0.260	0.273	0.267	0.280	0.338	0.332	0.323	0.317	0.294	0.309	0.289	0.304
53	1	H	0.406	0.345	0.381	0.319	0.595	**0.605**	0.570	0.580	0.531	0.472	0.477	0.425
53	2	H	0.377	0.330	0.359	0.311	0.572	0.578	0.544	0.549	0.492	0.450	0.446	0.407
53	3	H	0.331	0.308	0.321	0.297	0.545	0.544	0.512	0.511	0.433	0.412	0.395	0.377
53	4	H	0.295	0.291	0.293	0.288	0.494	0.488	0.466	0.460	0.371	0.370	0.348	0.347
53	5	H	0.270	0.275	0.275	0.280	0.433	0.428	0.414	0.409	0.315	0.325	0.311	0.320
53	1	M	0.379	0.330	0.355	0.305	0.495	0.499	0.468	0.470	0.472	0.431	0.419	0.379
53	2	M	0.353	0.317	0.335	0.299	0.480	0.480	0.452	0.450	0.441	0.412	0.393	0.365
53	3	M	0.315	0.299	0.305	0.288	0.462	0.456	0.434	0.428	0.393	0.382	0.357	0.345
53	4	M	0.287	0.286	0.285	0.284	0.427	0.420	0.401	0.394	0.349	0.350	0.326	0.327
53	5	M	0.264	0.273	0.270	0.279	0.382	0.376	0.366	0.361	0.301	0.314	0.298	0.311
53	1	L	0.357	0.316	0.334	0.293	0.408	0.408	0.385	0.382	0.429	0.395	0.375	0.342
53	2	L	0.333	0.305	0.315	0.287	0.402	0.398	0.377	0.374	0.402	0.379	0.355	0.332
53	3	L	0.302	0.292	0.292	0.281	0.390	0.384	0.366	0.360	0.366	0.357	0.329	0.320
53	4	L	0.282	0.283	0.279	0.280	0.366	0.359	0.345	0.338	0.331	0.333	0.308	0.309
53	5	L	0.258	0.271	0.265	0.279	0.334	0.328	0.321	0.315	0.289	0.305	0.287	0.302

Table 12: High-speed Performance Measures for Tridem Semitrailers

L	LC	PH	High-speed Offtracking (<0.46 m)				Load Transfer Ratio (<0.60)				Transient Offtracking (<0.80 m)			
			DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
48	1	H	0.429	0.380	0.403	0.354	**0.641**	**0.656**	**0.613**	**0.626**	0.646	0.579	0.588	0.525
48	2	H	0.367	0.348	0.355	0.335	0.596	**0.600**	0.567	0.567	0.554	0.523	0.508	0.481
48	3	H	0.333	0.329	0.331	0.328	0.542	0.534	0.517	0.508	0.472	0.469	0.447	0.445
48	4	H	0.313	0.317	0.319	0.322	0.488	0.483	0.473	0.468	0.426	0.432	0.418	0.424
48	5	H	0.292	0.312	0.304	0.324	0.431	0.425	0.425	0.422	0.378	0.402	0.392	0.415
48	1	M	0.405	0.367	0.380	0.342	0.533	0.538	0.509	0.510	0.589	0.541	0.527	0.481
48	2	M	0.353	0.340	0.341	0.328	0.507	0.501	0.483	0.475	0.507	0.491	0.463	0.448
48	3	M	0.325	0.326	0.323	0.324	0.468	0.459	0.445	0.436	0.447	0.449	0.423	0.425
48	4	M	0.307	0.314	0.313	0.320	0.427	0.421	0.414	0.408	0.409	0.420	0.402	0.412
48	5	M	0.287	0.310	0.301	0.324	0.385	0.380	0.379	0.375	0.366	0.394	0.383	0.409
48	1	L	0.386	0.354	0.362	0.330	0.445	0.443	0.424	0.420	0.541	0.504	0.478	0.442
48	2	L	0.342	0.333	0.330	0.321	0.432	0.422	0.408	0.398	0.474	0.464	0.430	0.422
48	3	L	0.319	0.322	0.317	0.320	0.399	0.390	0.381	0.371	0.429	0.434	0.404	0.409
48	4	L	0.301	0.312	0.308	0.319	0.372	0.365	0.359	0.353	0.394	0.409	0.389	0.403
48	5	L	0.282	0.309	0.297	0.324	0.343	0.338	0.336	0.331	0.356	0.387	0.374	0.404
53	1	H	0.434	0.380	0.408	0.354	**0.604**	**0.616**	0.578	0.588	0.597	0.536	0.536	0.480
53	2	H	0.368	0.346	0.355	0.333	0.563	0.563	0.535	0.533	0.503	0.480	0.461	0.441
53	3	H	0.330	0.327	0.329	0.325	0.510	0.502	0.486	0.479	0.434	0.433	0.410	0.409
53	4	H	0.309	0.314	0.315	0.319	0.460	0.454	0.445	0.439	0.389	0.397	0.382	0.390
53	5	H	0.286	0.308	0.299	0.320	0.405	0.399	0.402	0.397	0.341	0.368	0.356	0.382
53	1	M	0.408	0.365	0.383	0.340	0.503	0.505	0.479	0.480	0.538	0.495	0.479	0.440
53	2	M	0.352	0.337	0.340	0.325	0.478	0.472	0.455	0.447	0.465	0.452	0.423	0.411
53	3	M	0.322	0.322	0.320	0.320	0.439	0.431	0.419	0.410	0.411	0.415	0.387	0.390
53	4	M	0.302	0.311	0.308	0.317	0.402	0.396	0.390	0.384	0.372	0.385	0.366	0.378
53	5	M	0.281	0.307	0.295	0.320	0.363	0.356	0.358	0.352	0.329	0.360	0.347	0.376
53	1	L	0.387	0.351	0.363	0.328	0.420	0.417	0.399	0.396	0.493	0.462	0.436	0.405
53	2	L	0.339	0.330	0.327	0.318	0.406	0.397	0.384	0.375	0.436	0.428	0.394	0.386
53	3	L	0.315	0.319	0.313	0.316	0.376	0.366	0.359	0.349	0.393	0.398	0.369	0.374
53	4	L	0.296	0.309	0.302	0.315	0.350	0.343	0.339	0.332	0.358	0.375	0.353	0.368
53	5	L	0.276	0.306	0.291	0.320	0.324	0.317	0.318	0.312	0.320	0.353	0.338	0.370

Table 13: High-speed Performance Measures for Self-steer Tri-axle Semitrailers

L	LC	PH	High-speed Offtracking (<0.46 m)				Load Transfer Ratio (<0.60)				Transient Offtracking (<0.80 m)			
			DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
48	1	H	**0.525**	0.433	**0.482**	0.417	0.579	**0.603**	0.549	0.578	0.681	0.621	0.627	0.553
48	2	H	0.422	0.392	0.401	0.383	0.556	0.567	0.530	0.533	0.581	0.553	0.530	0.511
48	3	H	0.357	0.353	0.357	0.354	0.519	0.510	0.499	0.488	0.490	0.490	0.470	0.469
48	4	H	0.318	0.323	0.326	0.331	0.484	0.476	0.469	0.463	0.438	0.450	0.435	0.445
48	5	H	0.293	0.307	0.306	0.320	0.427	0.426	0.424	0.423	0.386	0.408	0.404	0.424
48	1	M	**0.491**	**0.478**	**0.471**	0.404	0.498	0.492	0.474	0.472	0.636	0.572	0.541	0.515
48	2	M	0.401	0.383	0.393	0.390	0.470	0.469	0.462	0.458	0.531	0.518	0.504	0.485
48	3	M	0.349	0.350	0.349	0.350	0.455	0.444	0.436	0.424	0.454	0.470	0.441	0.451
48	4	M	0.312	0.320	0.322	0.331	0.423	0.418	0.412	0.407	0.423	0.434	0.418	0.430
48	5	M	0.289	0.305	0.304	0.319	0.381	0.379	0.378	0.376	0.376	0.400	0.395	0.418
48	1	L	**0.461**	0.422	0.441	0.392	0.404	0.405	0.386	0.387	0.569	0.533	0.525	0.476
48	2	L	0.385	0.375	0.378	0.369	0.398	0.397	0.390	0.377	0.505	0.486	0.443	0.451
48	3	L	0.341	0.347	0.340	0.348	0.390	0.379	0.372	0.365	0.440	0.452	0.429	0.424
48	4	L	0.304	0.317	0.315	0.327	0.369	0.364	0.357	0.350	0.408	0.424	0.405	0.418
48	5	L	0.285	0.303	0.301	0.319	0.340	0.337	0.335	0.334	0.366	0.392	0.387	0.411
53	1	H	**0.521**	0.442	**0.507**	0.418	0.576	0.597	0.553	0.576	0.682	0.621	0.624	0.561
53	2	H	0.426	0.402	0.420	0.395	0.552	0.566	0.528	0.551	0.577	0.552	0.537	0.530
53	3	H	0.357	0.356	0.359	0.358	0.520	0.517	0.495	0.499	0.486	0.484	0.473	0.463
53	4	H	0.320	0.325	0.328	0.333	0.484	0.478	0.473	0.468	0.445	0.455	0.445	0.452
53	5	H	0.293	0.307	0.307	0.320	0.429	0.428	0.428	0.427	0.392	0.415	0.414	0.436
53	1	M	0.431	0.429	**0.473**	0.404	0.492	0.489	0.457	0.459	0.634	0.573	0.564	0.524
53	2	M	0.404	0.384	0.396	0.377	0.491	0.470	0.449	0.440	0.545	0.523	0.484	0.479
53	3	M	0.348	0.353	0.355	0.356	0.450	0.444	0.436	0.425	0.474	0.468	0.453	0.459
53	4	M	0.314	0.321	0.322	0.333	0.424	0.418	0.414	0.406	0.426	0.435	0.426	0.441
53	5	M	0.289	0.305	0.304	0.320	0.383	0.381	0.381	0.380	0.381	0.406	0.405	0.429
53	1	L	**0.482**	0.413	0.391	0.410	0.400	0.408	0.396	0.400	0.580	0.535	0.495	0.493
53	2	L	0.388	0.377	0.380	0.369	0.408	0.407	0.379	0.376	0.482	0.470	0.461	0.453
53	3	L	0.343	0.348	0.343	0.350	0.387	0.378	0.371	0.364	0.450	0.460	0.436	0.440
53	4	L	0.308	0.319	0.318	0.333	0.369	0.364	0.360	0.355	0.412	0.427	0.413	0.426
53	5	L	0.285	0.303	0.302	0.319	0.340	0.337	0.338	0.337	0.371	0.399	0.397	0.423

Table 14: High-speed Performance Measures for Self-steer Quad Semitrailers

L	**LC**	**PH**	**High-speed Offtracking** (<0.46 m)				**Load Transfer Ratio (<0.60)**				**Transient Offtracking (<0.80 m)**			
			DD	**DS**	**SD**	**SS**	**DD**	**DS**	**SD**	**SS**	**DD**	**DS**	**SD**	**SS**
48	1	H	**0.507**	0.447	**0.487**	0.426	**0.641**	**0.678**	**0.608**	**0.633**	0.771	0.724	0.709	0.646
48	2	H	**0.471**	0.427	0.459	0.415	**0.633**	**0.645**	**0.605**	**0.616**	0.738	0.678	0.683	0.632
48	3	H	0.437	0.408	0.420	0.401	**0.624**	**0.644**	0.594	**0.603**	0.697	0.670	0.651	0.619
48	4	H	0.386	0.381	0.389	0.384	0.592	0.593	0.574	0.568	0.618	0.623	0.602	0.600
48	5	H	0.361	0.362	0.370	0.372	0.540	0.535	0.528	0.523	0.567	0.573	0.569	0.574
48	1	M	**0.477**	0.430	0.458	0.413	0.539	0.550	0.514	0.521	0.719	0.662	0.652	0.613
48	2	M	0.443	0.414	0.434	0.401	0.533	0.542	0.508	0.522	0.682	0.651	0.628	0.614
48	3	M	0.411	0.399	0.409	0.391	0.543	0.542	0.509	0.505	0.647	0.642	0.609	0.586
48	4	M	0.378	0.377	0.381	0.380	0.516	0.506	0.497	0.487	0.603	0.603	0.579	0.579
48	5	M	0.352	0.358	0.364	0.369	0.471	0.466	0.460	0.456	0.545	0.556	0.547	0.557
48	1	L	0.454	0.418	0.436	0.399	0.454	0.468	0.431	0.438	0.668	0.650	0.605	0.567
48	2	L	0.425	0.404	0.413	0.390	0.455	0.448	0.439	0.436	0.644	0.620	0.600	0.580
48	3	L	0.403	0.393	0.396	0.386	0.450	0.450	0.434	0.431	0.614	0.604	0.571	0.571
48	4	L	0.371	0.374	0.372	0.374	0.442	0.433	0.421	0.413	0.580	0.584	0.555	0.556
48	5	L	0.347	0.355	0.358	0.366	0.409	0.405	0.398	0.394	0.525	0.542	0.529	0.544
53	1	H	**0.511**	0.447	**0.494**	0.425	**0.603**	**0.620**	0.582	0.599	0.704	0.648	0.658	0.603
53	2	H	**0.480**	0.429	**0.462**	0.413	0.597	**0.612**	0.576	0.589	0.681	0.636	0.636	0.591
53	3	H	0.433	0.409	0.426	0.399	0.592	0.596	0.563	0.571	0.644	0.610	0.597	0.570
53	4	H	0.385	0.381	0.385	0.380	0.564	0.559	0.541	0.534	0.581	0.576	0.550	0.549
53	5	H	0.357	0.361	0.365	0.368	0.507	0.503	0.494	0.490	0.519	0.528	0.517	0.524
53	1	M	**0.480**	0.432	**0.461**	0.412	0.515	0.521	0.490	0.494	0.664	0.621	0.603	0.559
53	2	M	0.459	0.416	0.433	0.401	0.508	0.521	0.483	0.485	0.629	0.609	0.575	0.552
53	3	M	0.416	0.400	0.407	0.390	0.504	0.504	0.488	0.476	0.596	0.582	0.545	0.535
53	4	M	0.379	0.378	0.377	0.377	0.487	0.479	0.467	0.459	0.555	0.551	0.525	0.526
53	5	M	0.351	0.357	0.358	0.365	0.441	0.437	0.431	0.426	0.500	0.512	0.499	0.510
53	1	L	0.455	0.418	0.436	0.400	0.441	0.443	0.423	0.410	0.637	0.590	0.546	0.526
53	2	L	0.426	0.404	0.411	0.391	0.435	0.435	0.415	0.410	0.581	0.579	0.550	0.514
53	3	L	0.405	0.394	0.394	0.383	0.431	0.426	0.409	0.400	0.568	0.564	0.518	0.512
53	4	L	0.370	0.372	0.368	0.372	0.413	0.405	0.397	0.389	0.532	0.534	0.506	0.508
53	5	L	0.344	0.354	0.353	0.362	0.383	0.378	0.373	0.369	0.483	0.499	0.482	0.497

Table 15: High-speed Performance Measures for 7-axle B-trains

L	LC	PH	High-speed Offtracking (<0.46 m)				Load Transfer Ratio (<0.60)				Transient Offtracking (<0.80 m)			
			DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
S	1	H	**0.547**	**0.478**	**0.522**	0.452	**0.669**	**0.700**	**0.650**	**0.670**	**0.944**	**0.813**	**0.873**	0.742
S	2	H	**0.504**	0.458	**0.487**	0.440	**0.643**	**0.661**	**0.621**	**0.636**	**0.877**	0.778	**0.810**	0.716
S	3	H	**0.461**	0.438	0.451	0.427	**0.618**	**0.628**	0.599	**0.605**	**0.803**	0.742	0.743	0.691
S	4	H	0.432	0.426	0.427	0.420	0.592	0.591	0.574	0.572	0.732	0.710	0.689	0.668
S	5	H	0.415	0.415	0.416	0.416	0.555	0.546	0.542	0.534	0.681	0.682	0.653	0.654
S	1	M	**0.517**	**0.461**	**0.493**	0.436	0.562	0.573	0.543	0.549	**0.876**	0.767	0.798	0.698
S	2	M	**0.478**	0.443	**0.461**	0.426	0.544	0.548	0.524	0.525	**0.810**	0.737	0.739	0.676
S	3	M	0.445	0.428	0.434	0.417	0.530	0.525	0.513	0.506	0.744	0.710	0.690	0.657
S	4	M	0.423	0.420	0.418	0.415	0.511	0.500	0.496	0.483	0.695	0.685	0.652	0.643
S	5	M	0.406	0.410	0.408	0.411	0.481	0.471	0.471	0.461	0.654	0.662	0.626	0.634
S	1	L	**0.493**	0.445	**0.470**	0.422	0.470	0.469	0.451	0.449	**0.812**	0.725	0.732	0.654
S	2	L	0.458	0.429	0.441	0.412	0.458	0.453	0.442	0.435	0.752	0.702	0.688	0.639
S	3	L	0.431	0.419	0.420	0.408	0.452	0.441	0.436	0.424	0.704	0.681	0.650	0.627
S	4	L	0.415	0.413	0.410	0.408	0.438	0.423	0.424	0.409	0.665	0.664	0.622	0.621
S	5	L	0.399	0.406	0.400	0.407	0.415	0.403	0.405	0.393	0.631	0.645	0.604	0.617
L	1	H	**0.561**	**0.486**	**0.535**	**0.460**	**0.636**	**0.661**	**0.614**	**0.633**	**0.923**	0.793	**0.845**	0.728
L	2	H	**0.515**	**0.465**	**0.497**	0.447	**0.609**	**0.626**	0.591	**0.601**	**0.849**	0.762	0.784	0.702
L	3	H	**0.469**	0.444	0.459	0.433	0.589	0.595	0.572	0.574	0.779	0.729	0.724	0.676
L	4	H	0.438	0.431	0.433	0.426	0.563	0.559	0.547	0.542	0.716	0.696	0.671	0.653
L	5	H	0.421	0.420	0.421	0.421	0.525	0.517	0.516	0.508	0.664	0.668	0.636	0.640
L	1	M	**0.528**	**0.468**	**0.503**	0.443	0.535	0.542	0.517	0.521	**0.850**	0.752	0.776	0.682
L	2	M	**0.487**	0.449	**0.470**	0.432	0.518	0.520	0.501	0.499	0.787	0.723	0.722	0.660
L	3	M	0.451	0.433	0.441	0.422	0.505	0.499	0.488	0.479	0.728	0.695	0.671	0.639
L	4	M	0.429	0.426	0.423	0.420	0.485	0.473	0.472	0.459	0.677	0.671	0.633	0.627
L	5	M	0.411	0.415	0.412	0.416	0.455	0.445	0.445	0.435	0.636	0.647	0.609	0.619
L	1	L	**0.502**	0.451	**0.479**	0.427	0.448	0.447	0.430	0.426	0.791	0.710	0.716	0.636
L	2	L	**0.465**	0.435	0.448	0.418	0.437	0.431	0.420	0.412	0.737	0.686	0.670	0.620
L	3	L	0.436	0.424	0.426	0.413	0.429	0.417	0.413	0.402	0.688	0.665	0.631	0.609
L	4	L	0.420	0.418	0.414	0.412	0.413	0.400	0.400	0.387	0.649	0.649	0.605	0.604
L	5	L	0.403	0.411	0.404	0.411	0.393	0.381	0.384	0.372	0.614	0.630	0.588	0.601

Table 16: High-speed Performance Measures for 8-axle B-trains

L	**L C**	**P H**	**High-speed Offtracking** (<0.46 m)				**Load Transfer Ratio (<0.60)**				**Transient Offtracking (<0.80 m)**			
			DD	**DS**	**SD**	**SS**	**DD**	**DS**	**SD**	**SS**	**DD**	**DS**	**SD**	**SS**
S	1	H	**0.527**	**0.481**	**0.500**	0.457	**0.666**	**0.687**	**0.646**	**0.661**	**0.944**	**0.842**	**0.870**	0.773
S	2	H	**0.488**	**0.461**	**0.469**	0.444	**0.647**	**0.659**	**0.625**	**0.634**	**0.881**	**0.811**	**0.815**	0.748
S	3	H	0.459	0.447	0.447	0.436	**0.630**	**0.633**	**0.609**	**0.610**	**0.819**	0.779	0.760	0.723
S	4	H	0.442	0.437	0.437	0.433	**0.601**	0.596	0.584	0.577	0.761	0.747	0.715	0.703
S	5	H	0.426	0.427	0.427	0.428	0.566	0.558	0.553	0.546	0.713	0.717	0.684	0.689
S	1	M	**0.499**	**0.465**	**0.474**	0.442	0.566	0.570	0.545	0.547	**0.875**	**0.800**	0.798	0.725
S	2	M	**0.468**	0.449	0.451	0.433	0.554	0.552	0.533	0.528	**0.818**	0.772	0.749	0.705
S	3	M	0.446	0.440	0.436	0.430	0.538	0.531	0.520	0.510	0.766	0.745	0.707	0.689
S	4	M	0.432	0.433	0.426	0.427	0.517	0.506	0.501	0.489	0.721	0.721	0.678	0.679
S	5	M	0.417	0.423	0.417	0.423	0.491	0.482	0.479	0.469	0.686	0.700	0.658	0.671
S	1	L	**0.476**	0.449	0.454	0.427	0.477	0.470	0.457	0.449	**0.816**	0.760	0.735	0.684
S	2	L	0.451	0.439	0.436	0.423	0.469	0.458	0.451	0.439	0.766	0.737	0.697	0.672
S	3	L	0.436	0.433	0.426	0.422	0.458	0.443	0.442	0.427	0.725	0.718	0.671	0.664
S	4	L	0.424	0.427	0.418	0.421	0.442	0.428	0.428	0.414	0.694	0.701	0.652	0.658
S	5	L	0.408	0.419	0.409	0.419	0.422	0.412	0.412	0.402	0.663	0.683	0.635	0.654
L	1	H	**0.542**	**0.491**	**0.517**	**0.469**	**0.651**	**0.671**	**0.630**	**0.646**	**0.960**	**0.849**	**0.885**	0.784
L	2	H	**0.502**	**0.471**	**0.484**	0.455	**0.631**	**0.641**	**0.612**	**0.618**	**0.894**	**0.819**	**0.825**	0.762
L	3	H	**0.470**	0.456	0.459	0.447	**0.614**	**0.615**	0.596	0.595	**0.828**	0.790	0.776	0.740
L	4	H	0.451	0.447	0.445	0.440	0.587	0.581	0.572	0.565	0.774	0.760	0.734	0.721
L	5	H	0.435	0.436	0.434	0.436	0.552	0.544	0.543	0.536	0.726	0.732	0.703	0.710
L	1	M	**0.513**	**0.474**	**0.489**	0.453	0.550	0.555	0.532	0.534	**0.888**	**0.809**	**0.811**	0.741
L	2	M	**0.480**	0.458	**0.463**	0.444	0.540	0.538	0.522	0.517	**0.829**	0.784	0.767	0.723
L	3	M	0.457	0.449	0.445	0.440	0.526	0.518	0.510	0.500	0.780	0.759	0.726	0.707
L	4	M	0.441	0.441	0.437	0.434	0.505	0.493	0.492	0.480	0.736	0.736	0.696	0.697
L	5	M	0.425	0.431	0.425	0.431	0.476	0.467	0.470	0.460	0.698	0.713	0.675	0.690
L	1	L	**0.489**	0.457	**0.469**	0.437	0.464	0.459	0.446	0.439	**0.828**	0.771	0.755	0.700
L	2	L	**0.462**	0.447	0.448	0.432	0.458	0.448	0.441	0.430	0.783	0.751	0.718	0.688
L	3	L	0.446	0.441	0.436	0.431	0.447	0.432	0.433	0.418	0.742	0.733	0.689	0.680
L	4	L	0.432	0.435	0.428	0.430	0.429	0.416	0.418	0.404	0.707	0.715	0.667	0.675
L	5	L	0.416	0.427	0.416	0.426	0.411	0.400	0.402	0.392	0.673	0.696	0.650	0.672

Table 17: High-speed Offtracking Overall Summary

Load Case	Tire Fitment				
	SD/DD	SS/DS	DS/DD	SS/SD	SS/DD
1	94.94%	94.15%	89.68%	88.99%	84.42%
2	96.45%	96.44%	93.54%	93.54%	90.23%
3	98.31%	98.22%	97.63%	97.54%	95.91%
4	100.30%	100.28%	100.61%	100.60%	100.92%
5	102.55%	102.34%	103.62%	103.40%	106.08%

Table 18: Load Transfer Ratio Overall Summary

Load Case	Tire Fitment				
	SD/DD	SS/DS	DS/DD	SS/SD	SS/DD
1	95.70%	95.26%	101.39%	100.92%	96.59%
2	95.56%	95.21%	100.08%	99.72%	95.29%
3	95.67%	95.37%	98.89%	98.58%	94.31%
4	96.44%	96.28%	98.34%	98.16%	94.67%
5	97.80%	97.88%	98.54%	98.62%	96.45%

Table 19: Transient Offtracking Overall Summary

Load Case	Tire Fitment				
	SD/DD	SS/DS	DS/DD	SS/SD	SS/DD
1	90.07%	89.95%	91.06%	90.96%	81.89%
2	91.49%	91.60%	94.49%	94.61%	86.55%
3	93.26%	93.06%	97.99%	97.78%	91.22%
4	95.80%	95.77%	100.75%	100.71%	96.52%
5	100.24%	99.93%	104.15%	103.83%	104.16%

5 ASSESSMENT OF SAFETY EFFECTS

5.1 Introduction

MTO provided a spreadsheet that allowed collision rates to be estimated from dynamic performance measures. The spreadsheet was based on prior work done by MTO to correlate the collision rates of various configurations with their dynamic performance and vehicle kilometres of travel (VKT) on the Ontario provincial highway system [17]. MTO had previously used this methodology to estimate the safety impact of a transition to SPIF vehicles [18]. That work included specific collision data and costs that were also appropriate for this work. MTO also provided an estimate of the daily axle-kilometres of travel on all roads in Ontario for the vehicle configurations considered in this study [19]. These estimates were transformed into annual vehicle-kilometres of travel (VKT), as shown in Table 20. The top row shows the estimated travel of tractors with wide single tires pulling trailers with dual tires. The remaining rows show the estimated travel of the various trailers considered here with wide single tires.

Table 20: Annual Vehicle Kilometres of Travel (millions)

Trailer	**VKT**
None	5,616
Tandem	3,175
Tridem	184
SS Tri-axle	28
SS Quad	206
B-train	275
Trailer total	3,868

5.2 Collision Estimates

The MTO spreadsheet contained baseline data for the configurations of interest to this study, which included baseline values for the static rollover, high-speed offtracking, load transfer ratio and transient offtracking performance measures, and a calculation process to determine the crash rate of a vehicle configuration based on the values of those performance measures. The methodology was calibrated to the overall collision and traffic data using these baseline performance measures [17], [18]. The performance measures in the spreadsheet were drawn from a variety of sources, and were for vehicles and load conditions that were not necessarily the same as those used here. It was therefore considered inappropriate to use the performance measures developed here directly in the spreadsheet. The baseline performance measures were all developed for vehicles with dual tires. This work has shown that the actual change in most performance measures due to any of the wide single tire fitments was generally not more than 5%, though some were as large as 15-20%, and the changes were rather consistent over vehicle configuration and payload height. It was therefore assumed that these same percentage changes in performance could be applied to the baseline vehicles included in the MTO spreadsheet. The spreadsheet was therefore modified to multiply each performance measure by a weighting factor such as those presented in Table 17 through Table 19, and a collision rate was calculated for each vehicle configuration with the weighted performance measures. The difference between collision rates calculated from baseline and weighted performance measures, multiplied by the vehicle kilometres of travel for the configuration, gave an estimate of the change in the number of collisions if vehicle dynamic performance changed in the manner predicted from the introduction of wide single tires.

Three separate cases were considered:

- Trailers with wide single tires and an axle load over 8,000 kg (17,636 lb);
- Trailers with wide single tires and no axle load over 8,000 kg (17,636 lb); and
- Tractors with wide single tires and trailers with dual tires.

Trailers with wide single tires and an axle load over 8,000 kg (17,636 lb) represent 11.3% of the VKT for trailers in Table 20 [19]. The collision rate for this group of vehicles was estimated using the performance measures for Load Case 1 with a high payload for loaded vehicles, and Load Case 5 with a low payload for empty vehicles. Table 21 presents a summary of the collisions that would be expected for the vehicle configurations considered here. The second column contains the collision rates for the vehicle configurations with dual tires, and the third column contains the collision rates for the vehicle configurations fitted with wide single tires on both drive and trailer axles. The fourth column contains the annual VKT, in millions, which is 11.3% of the trailer values from Table 20. The two subsequent columns estimate the numbers of collisions for baseline vehicles, and those for the same vehicles with wide single tires. The next column is the reduction in numbers of collisions per year due to a change to wide single tires, and the final column is the percentage reduction relative to the baseline. A change to wide single tires by this group of vehicles was estimated to reduce collisions by 2.06%, which is equivalent to 5 collisions per year.

Trailers with wide single tires and an axle load up to 8,000 kg (17,636 lb) represent the remaining 88.7% of the trailer VKT in Table 20. The collision rate for this group of vehicles was estimated using the performance measures for Load Case 2 with a high payload for loaded vehicles, except for tandem trailers, when Load Case 4 was used, and Load Case 5 with a low payload for empty vehicles. Table 22 presents a summary of the collisions that would be expected for the vehicle configurations considered here fitted with wide single tires on both drive and trailer axles. A change to wide single tires by this group of vehicles was estimated to reduce collisions by 1.78%, which is equivalent to 33.8 collisions per year.

The collision rate for trucks with wide single tires only on the tractor drive axles was estimated using the performance measures for Load Case 2 with a high payload for loaded vehicles, except for tandem trailers, when Load Case 4 was used, and Load

Case 5 with a low payload for empty vehicles, with the tractor VKT allocated to trailers in the same proportions as in Table 20. Table 23 presents a summary of the collisions that would be expected for the vehicle configurations considered here fitted with wide single tires on only the drive axles. A change to wide single tires by this group of vehicles was estimated to reduce collisions by 0.74%, which would eliminate 22.9 collisions per year. However, the estimation procedure addressed only SPIF trailers, and some of the tractors may pull non-SPIF trailers. While SPIF trailers are a majority of the fleet, non-SPIF trailers have poorer dynamic performance. The collision estimate for this group of vehicles was arbitrarily reduced by half, to 0.37%, which is equivalent to 11.5 collisions per year.

There are a total of (241.4 + 1,894.9 + 3,101.9) = 5,238.2 collisions for the baseline condition of dual tires from Table 21, Table 22 and Table 23. Use of wide single tires according to the above assumptions is estimated to save (5.0 + 33.8 + 11.5) = 50.2 collisions per year, or 0.96% of the baseline number of collisions. This composite number was used to estimate the cost saving from use of wide single tires.

Table 21: Collision Estimate for Trailers with Wide Single Tires over 8,000 kg

Vehicle	Baseline Collision Rate	WS Tire Collision Rate	VKT	Baseline Collisions	WBS Collisions	Change	% Change
Tandem	0.551	0.543	358.7	197.6	194.6	3.0	1.52%
Tridem	0.636	0.626	20.8	13.2	13.0	0.2	1.58%
SS Tri-axle	0.751	0.714	3.2	2.4	2.3	0.1	4.90%
SS Quad	0.674	0.652	23.3	15.7	15.2	0.5	3.34%
B-train	0.401	0.365	31.1	12.4	11.3	1.1	9.01%
Total			437.1	241.4	236.4	5.0	2.06%

Table 22: Collision Estimate for Trailers with Wide Single Tires up to 8,000 kg

Vehicle	Baseline Collision Rate	WS Tire Collision Rate	VKT	Baseline Collisions	WBS Collisions	Change	% Change
Tandem	0.551	0.543	2,816.0	1,551.4	1,529.7	21.7	1.40%
Tridem	0.636	0.627	163.5	103.9	102.5	1.4	1.39%
SS Tri-axle	0.751	0.735	24.9	18.7	18.3	0.4	2.08%
SS Quad	0.674	0.656	182.6	123.1	119.8	3.2	2.64%
B-train	0.401	0.372	243.8	97.7	90.8	6.9	7.10%
Total			3,430.8	1,894.9	1,861.2	33.8	1.78%

Table 23: Collision Estimate for Tractors with Wide Single Tires

Vehicle	Baseline Collision Rate	WS Tire Collision Rate	VKT	Baseline Collisions	WBS Collisions	Change	% Change
Tandem	0.551	0.548	4,609.8	2,539.7	2,524.1	15.5	0.61%
Tridem	0.636	0.632	267.6	170.2	169.2	1.0	0.59%
SS Tri-axle	0.751	0.743	40.8	30.7	30.3	0.3	1.08%
SS Quad	0.674	0.666	298.9	201.5	199.2	2.3	1.14%
B-train	0.401	0.391	399.1	160.0	156.2	3.8	2.35%
Total			5,616.3	3,101.9	3,079.0	22.9	0.74%

5.3 Cost Estimates

The direct costs of collisions, and ensuing congestion costs, were calculated using the same method as used previously by MTO [18], except that the unit costs of collisions and congestion were increased by 6.3% to reflect inflation in the Consumer Price Index from 2004 to 2007.

Table 24 shows the reduction in the direct cost of collisions to a complete conversion to wide single tires. The baseline numbers of casualties and unit costs were from MTO [18]. Table 25 shows the reduction in the cost of congestion caused by collisions for a complete conversion to wide single tires. The allocation of casualties to road type and the unit costs were from MTO [18]. The combined estimated cost saving was $9,970,000, almost $10 million.

Table 24 and Table 25 assume there would be complete conversion of all vehicles of these configurations to wide single tires. These projected cost savings therefore represent the ultimate condition once a transition to wide single tires had been completed. This transition would take almost ten years to become substantially complete for tractors, and at least fifteen years for trailers.

MTO's methodology for assessing the changes in collisions due to changes in dynamic performance of vehicle configurations was specifically developed to assess the effect of adoption of SPIF configurations, and was calibrated to that end. The vehicle mix considered here is somewhat different than that for which the MTO methodology was calibrated. MTO expressed concern during this work that the extension of the methodology used here may be "taking us to soft grounds for the estimates". The author concurs with this concern. The estimates of changes in performance are also based on less than complete data for the tire characteristics, as discussed above in Section 3.8. This is further cause for concern. However, this work found wide single tires could provide modest improvements in vehicle dynamic performance, which is consistent with the findings of others. The safety analysis suggests these modest improvements in vehicle dynamic performance translate into a small reduction in collisions, and this translates further into a small saving in collision costs. These are both plausible. So, while the process may be "soft", the outcome on all counts is modestly positive, and may not be greatly out of line with what would be expected.

Table 24: Reduction in Direct Cost of Collisions for a Fleet with Wide Single Tires

Collision Type	Casualties	Reduction	Change	Unit Cost	Cost Saving
Fatal	88.9	0.96%	0.9	$7,547,000	$6,431,000
Injury	1885.2	0.96%	18.1	$69,000	$1,246,000
Property Damage	4175.0	0.96%	40.0	$10,000	$400,000
Total					$8,077,000

Table 25: Reduction in Congestion Cost for a Fleet with Wide Single Tires

Road Class	Collision Type	Proportion of Total	Estimated Reduction	Average Cost	Cost Saving
GTA Freeways	**Fatal**	28.4%	0.2	$440,000	$95,000
	Injury	28.4%	2.7	$149,000	$399,000
	PDO	28.4%	11.4	$46,000	$523,000
Non-GTA Freeways	**Fatal**	43.6%	0.3	$188,000	$62,000
	Injury	43.6%	4.1	$64,000	$263,000
	PDO	43.6%	17.4	$19,000	$331,000
Other Provincial Hwys	**Fatal**	28.0%	0.2	$97,000	$21,000
	Injury	28.0%	2.6	$33,000	$87,000
	PDO	28.0%	11.2	$10,000	$112,000
Total			50.2		$1,893,000

6 POTENTIAL TO IMPROVE THE ROLL STABILITY OF TANKERS

When a trailer is fitted with wide single tires, the frame rail spacing can be increased from about 1.18 (44 in) to 1.27 m (50 in). This does two things. First, it allows a corresponding increase in suspension spring spacing, which increases the roll resistance of the trailer suspension, and should produce an increase in static roll threshold roughly as given in Section 4.1, depending on the vehicle configuration. Second, it allows a tank with a curved bottom to be dropped a little further between the frame rails.

The amount by which the tank can be dropped between the frame rails, for a given frame rail spacing, depends on the shape of the bottom of the tank. By geometry, the amount a tank with a circular radius can be dropped is shown in Table 26, for an increase in frame rail spacing from 1.18 (44 in) to 1.27 m (50 in). A circular tank may have a radius up to 1.22 m (48 in). A modified oval tank, such as those used for fuel tankers, may have a much larger radius, and an entry lower down the table may be appropriate for these tanks. The fifth wheel should not change in elevation if the frame rail spacing is increased, so an increase in frame rail spacing will allow a tank to be sloped down slightly to the rear. The centre of the tank would therefore drop by about half the value shown in the second column of Table 26. However, the contents of a tank sloped down towards the rear will settle towards the rear, which will actually result in a fluid centre of gravity height between half and the full amount shown in Table 26. The actual calculations for this are complex, and are beyond the scope of this work.

Table 26: Tank Drop from an Increase in Frame Rail Spacing

Tank Radius	Tank Drop
0.76 m (30 in)	97mm (3.8 in)
0.91 m (36 in)	66mm (2.6 in)
1.07 m (42 in)	52mm (2.0 in)
1.22 m (48 in)	43mm (1.7 in)
1.52 m (60 in)	32mm (1.3 in)
1.83 m (72 in)	26mm (1.0 in)
2.13 m (84 in)	22mm (0.9 in)
2.44 m (96 in)	19mm (0.8 in)
3.05 m (120 in)	15mm (0.6 in)

There would be roughly 0.25 g change in roll threshold for each metre of change in sprung mass (trailer body plus payload) centre of gravity height for a full cargo tank [20]. Applying this to the table above, a vehicle with a circular tank might increase its static roll threshold by 0.005 to 0.012 g as a consequence of the increase in frame rail spacing, and a vehicle with a modified oval tank might increase its static roll threshold by no more than 0.005 g.

Tanks in North America appear generally to be designed for ease of construction, which results in a modest static roll threshold for many tank trucks [21]. In contrast, tank trucks in Australia are evidently designed with great attention to detail to achieve a high static roll threshold [21], and most reportedly have a static roll threshold over 0.50 g. The allowable gross weight of legal vehicles in Australia approaches that under the M.o.U., and the allowable gross weight of certain permitted vehicles may exceed that of Ontario. Greater use of wide single tires would have a modestly beneficial effect on the static roll threshold of tank trucks. However, there are many other design changes commonly used in Australia that North American tank truck manufacturers could implement that would provide a much greater increase in the static roll threshold of these vehicles. One such vehicle was included in the recent series of tests of tank trucks, and it achieved a static roll threshold of 0.42 g [21]. This vehicle was fitted with wide single tires of the type considered here, but only had semitrailer track width of 2.44 m (96 in). However, it was a non-SPIF configuration with only seven axles and 9,000 kg (19,841 lb) on the front axle. A SPIF configuration with eight axles may have had a slightly lower payload, but the added axle on the semitrailer would also increase the roll resistance and static roll threshold.

7 INSTALLATION ISSUES

7.1 Installation of Wide Single Tires on Existing Vehicles

The simulation study conducted above addresses newly constructed vehicles designed and built with wide single tires at full track width, or vehicles converted by replacing the axles to meet the same dimensions. As such, it ignores a number of practical issues that might arise when a carrier considers installing wide single tires to replace dual tires on an existing trailer.

From Table 1, if wide single tires would be fitted to an existing tractor with narrow track axles, the track width over the tires would be about 2.26 m (89.0 in). The provinces have no track width requirement for tractors, so such a tractor would not be illegal. If wide single tires would be fitted to an existing trailer with wide track axles, the track width over the tires would be about 2.41 m (95.0 in), which is less than the minimum track width of 2.50 m (98.4 in) in the M.o.U. [1], and implemented by all provinces.

Track width can be increased by using a rim that sets the tire out from the centre-line of the rim. Such an outset increases the bending moment on the axle end, which may lower the rating of that hub and/or axle. The Technology and Maintenance Council (TMC) of the American Trucking Associations is developing a recommended practice for carriers regarding installation of wide single tires on existing vehicles. It has proposed tables for various combinations of axle and hub that reduce the gross axle weight rating depending on the wide single tire outset. For some combinations an outset no more than 50.8 mm (2 in) is recommended, while for others, 101.6 mm (4 in) may be possible. 50.8 mm (2 in) outset might just allow the minimum track width of 2.50 m (98.4 in) to be realized, while 76.2 mm (3 in) outset would be necessary to regain the original track width of dual tires. However, some combinations of hub and axle might not have sufficient gross axle weight rating with 50.8 mm (2 in) or 76.2 mm (3 in) outset for a 9.000 kg (19,841 lb) axle load. The TMC recommended practice is not final at this time, so may be subject to change, it has clearly identified an issue.

7.2 Performance of Vehicles with Wide Single Tires on Narrow Axles

An additional limited series of simulation runs were made to evaluate the effect of installing wide single tires without offset on standard narrow track tractor axles, and wide track trailer axles. Each vehicle configuration was run for all tire fitments as given in Table 4, for a single condition, which was the 14.65 m (48 ft) semitrailer or 18.5 m (728 in) box length B-train with Load Case 1 as given in Table 3 and a high payload height. The results presented in Chapter 4 provide a high level of confidence that such a limited set of runs could be generalized to the entire spectrum of load cases and payload heights.

The results for static roll threshold are presented in Table 27. There are two rows for each vehicle. That row with a track width of **W** is for axles using the full track width available, and the wide suspension spring spacings that go with these axle track widths, and is the top row of Table 5 through Table 10 for a payload height of 2.44 m (96 in). That row with a track width of **N** is for narrow track axles on the tractor and wide track axles on the trailer, the normal suspension spring spacings that go with these axle track widths, and wide single tires with rims with no outset. Entries that do not meet the static roll threshold performance standard of 0.35 g are highlighted in bold. The result for dual tires is the same for each track width. It is evident from Table 27 that use of a narrow track width without use of rims with outset results in a significant degradation of the static roll threshold for all tire fitments using wide single tires, and all vehicle configurations.

The results for the high-speed performance measures are presented in Table 28, using the same format as for Table 27. There are two rows for each vehicle configuration. That row with a track width of **W** is for axles using the full track width available, and the wide suspension spring spacings that go with these axle track widths, and is the top row of Table 11 through Table 16. That row with a track width of **N** is for narrow track axles on the tractor and wide track axles on the trailer, the normal suspension spring spacings that go with these axle track widths, and wide single tires with rims with no outset. Entries that do not meet the performance standard are highlighted in bold. The result for dual tires is the same for each track width. It is evident from Table 28 that use of a narrow track width without use of rims with outset results in a degradation of dynamic performance for all tire fitments using wide single tires, and all vehicle configurations.

7.3 Discussion

If an existing vehicle is modified to use wide single tires on rims without outset, this results in a significant degradation of the static roll threshold and all dynamic performance measures.

If an existing vehicle is modified to use wide single tires on rims with outset, the gross axle weight ratings may be reduced. This work may not be straightforward, and it is evidently desirable that the work should be done either by the original manufacturer of the vehicle, or an entity that has the appropriate qualifications to design and make the changes. The work should involve discussions with the manufacturers of the hubs, axles and suspension on the vehicle, to ensure proper ratings are obtained for these components, or appropriate replacement components are selected. The entity that does the work should place a sticker on the vehicle that indicates the revised gross axle weight ratings, as already required for conversion of vehicles to SPIF configuration [2].

It is clearly preferred that any vehicle that will use wide single tires should be built new for this purpose. This vehicle will have the maximum axle track width on tractor or trailer, and the suspension spacing will be appropriate so the vehicle achieves the maximum roll resistance.

Table 27: Static Roll Threshold for Wide and Narrow Track Axles

Vehicle	Track	DD	DS	SD	SS
Tandem	W	0.358	0.370	0.355	0.370
Tandem	N	0.358	**0.346**	**0.334**	**0.322**
Tridem	W	0.361	0.374	0.360	0.377
Tridem	N	0.361	**0.348**	**0.343**	**0.327**
SS Tri-axle	W	0.385	0.375	0.380	0.439
SS Tri-axle	N	0.385	0.365	0.363	0.352
SS Quad	W	0.382	0.391	0.387	0.390
SS Quad	N	0.382	0.369	0.369	0.362
7-axle B-train	W	**0.342**	0.352	**0.336**	0.347
7-axle B-train	N	**0.342**	**0.325**	**0.329**	**0.314**
8-axle B-train	W	**0.347**	0.357	**0.340**	0.353
8-axle B-train	N	**0.347**	**0.329**	**0.330**	**0.314**

Table 28: High-speed Performance Measures for Wide and Narrow Track Axles

Vehicle	Tr	High-speed Offtracking (<0.46 m)				Load Transfer Ratio (<0.60)				Transient Offtracking (<0.80 m)			
		DD	DS	SD	SS	DD	DS	SD	SS	DD	DS	SD	SS
Tand'm	W	0.406	0.345	0.381	0.320	**0.600**	**0.611**	0.575	0.585	0.537	0.478	0.484	0.430
Tand'm	N	0.406	0.349	0.388	0.326	**0.600**	**0.659**	**0.601**	**0.665**	0.537	0.489	0.498	0.406
Tridem	W	0.429	0.380	0.403	0.354	**0.641**	**0.656**	**0.613**	**0.626**	0.646	0.579	0.588	0.525
Tridem	N	0.429	0.384	0.408	0.360	**0.641**	**0.713**	**0.636**	**0.712**	0.646	0.591	0.599	0.547
SS Tri	W	**0.525**	0.433	**0.482**	0.417	0.579	**0.603**	0.549	0.578	0.681	0.621	0.627	0.553
SS Tri	N	**0.525**	0.442	**0.513**	0.423	0.579	**0.631**	0.577	**0.639**	0.681	0.627	0.638	0.577
SS Q	W	**0.507**	0.447	**0.487**	0.426	**0.641**	**0.678**	**0.608**	**0.633**	0.771	0.724	0.709	0.646
SS Q	N	**0.507**	0.450	**0.493**	0.431	**0.641**	**0.726**	**0.625**	**0.721**	0.771	0.733	0.717	0.685
7-ax B	W	**0.547**	**0.478**	**0.522**	0.452	**0.669**	**0.700**	**0.650**	**0.670**	**0.944**	**0.813**	**0.873**	0.742
7-ax B	N	**0.547**	**0.484**	**0.527**	**0.460**	**0.669**	**0.770**	**0.667**	**0.761**	**0.944**	**0.828**	**0.883**	0.768
8-ax B	W	**0.527**	**0.481**	**0.500**	**0.457**	**0.666**	**0.687**	**0.646**	**0.661**	**0.944**	**0.842**	**0.870**	0.773
8-ax B	N	**0.527**	**0.486**	**0.503**	**0.463**	**0.666**	**0.756**	**0.660**	**0.743**	**0.944**	**0.856**	**0.879**	0.796

8 CONCLUSIONS

This work has assessed the dynamic performance of Ontario configurations of Safe, Productive Infrastructure Friendly (SPIF) tractor-semitrailers and B-trains when fitted with wide single tires. This work examined wide single tires on the tractor only, on the trailer only, or on both tractor and trailer. It assumed that all vehicles with wide single tires would be newly constructed, with a wheel track width over 2.50 m (98.4 in), and the wider suspension spring spacing this allows.

Use of wide single tires increased the static roll threshold by about 2% on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This increase is accrued when wide single tires are fitted on the trailer only, or on both tractor and trailer. There is negligible benefit when wide single tires are fitted only on the tractor. A 2% increase in static roll threshold represents an increase of about 0.008 g for these vehicles in their most critical condition.

Use of wide single tires on the tractor only, trailer only, or both tractor and trailer decreased the high-speed offtracking by about 5%, 10% and 15% respectively, on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This effect diminished as payload weight diminishes, and may actually increase high-speed offtracking at the lowest payload weight considered. However, the performance at this payload was well inside the performance standard, so would not be an issue.

Use of wide single tires decreased the load transfer ratio by up to 3.5%, on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This effect hardly changed as payload weight diminished.

Use of wide single tires on the tractor only or trailer only, or both tractor and trailer decreased the transient offtracking by about 10% and 18% respectively, on average over all vehicle configurations considered, for the most critical case of a vehicle loaded to its allowable gross weight, with a high payload height. This effect diminished as payload weight diminished, and may actually increase transient offtracking at the lowest payload weight considered. However, the performance at this payload was well inside the performance standard, so would not be an issue.

Complete replacement of dual tires by wide single tires on the vehicle configurations considered is estimated to result in a reduction in collisions by about 0.96%, which is estimated to result in an annual combined saving in direct collision costs and congestion costs of almost $10 million. A transition to wide single tires would take almost ten years to become substantially complete for tractors, and at least fifteen years for trailers.

A transition to wide single tires should provide a modest improvement in vehicle dynamic performance, a modest reduction in collisions, and a modest cost saving.

Use of wide single tires allows the frame rail spacing of a trailer to increase by about 0.15 m (6 in). This allows a tank to sit a bit lower on the chassis, which might increase the static roll threshold of a vehicle with a circular tank by 0.005 to 0.012 g, and a vehicle with a modified oval tank might increase its static roll threshold by no more than 0.005 g. Much greater increases in static roll threshold are available by other changes in design with the intention to maximize the static roll threshold.

If an existing vehicle would be modified to use wide single tires on rims without outset, this would result in a significant reduction in track width and a corresponding degradation of the static roll threshold and all dynamic performance measures. If an existing vehicle would be modified to use wide single tires on rims with outset, the gross axle weight ratings might be reduced. This work may not be straightforward, and it is evidently desirable that the work should be done either by the original manufacturer of the vehicle, or an entity that has the appropriate qualifications to design and make the changes. The work should involve discussions with the manufacturers of the hubs, axles and suspension on the vehicle, to ensure proper ratings are obtained for these components, or appropriate replacement components are selected. The entity that does the work should place a sticker on the vehicle that indicates the revised gross axle weight ratings, as already required for conversion of vehicles to SPIF configuration. It is clearly preferred that any vehicle that will use wide single tires should be built new for this purpose. This vehicle will have the maximum axle track width on tractor or trailer, and the suspension spacing will be appropriate so the vehicle achieves the maximum roll resistance.

The computer simulation used for this work depends on the vehicle configuration, payload weight and payload distribution, and also on the properties of steering, suspensions, tires and hitches. It was not possible to get sufficient data from tire manufacturers for the full non-linear tire characteristics file demanded by the simulation. The data provided were therefore blended with the complete characteristics of earlier generation wide single tires to produce composite characteristics for a generic 445/50R22.5 drive tire, and a generic trailer tire. The resulting generic files certainly are not the precise characteristics of the products of either manufacturer. A simulation run with these files would not be expected to match exactly the responses of a specific vehicle equipped with specific tires of one of the manufacturers. However, it is believed that the files should be somewhat representative of the mix of tires that might be in operation on the highway. The differences between vehicles with dual tires and vehicles with wide single tires are generally rather modest and in the expected direction. There would be greater confidence in the results if samples of the tires had been purchased and tested, and the test results would have been used directly in the simulations.

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CONCLUSION

This analysis involved two approaches to evaluating the costs and benefits associated with the implementation of a maximum weight allowance change from 8,000 kg to 9,000 kg for wide based single tires. The purpose of the study was to provide information and insight to the Ministry of Transportation so future policy direction could be determined.

The analysis concluded that the potential savings attributable to wide based single tires operating at 9,000 kg. is in the order of $85M per year based on an uptake rate of 50%. This figure is the sum of:

- the economic benefits derived under **Part One** of the report ($79.6M) and is based on three main categories: economic; environmental; and societal and
- the savings in collision and congestion costs ($5M) formulated under **Part Two** of the report and is based on dynamic performance of the vehicle.

Note that although this figure is significant, it will take time to fully realize. Our estimate for substantial completion of the conversion to wide based single tires is ten years for tractors and 15 years for trailers, based on current life expectancy.

The savings expressed in percentages[1] and listed largest to smallest are:

- savings from an increase in fuel economy = 62.1%[2]
- reduction in new vehicle costs = 14%
- reduction in emissions and environmental impacts 6.3%[3]
- reduction in tire ownership costs = 6.2%
- collision avoidance – stability = 6.2%
- reduction in vehicle maintenance = 3.7%
- savings associated with operational efficiency = .6%
- reduction in tire disposal costs = .2%
- reduction in tire production emissions - <.1%
- collision avoidance – exposure reduction = <.1%

In summary, wide based single tires have numerous potential economic benefits as the total annual savings for the industry as a whole sums to slightly less than $85 million per year based on an uptake rate of 50%. More than 62% of this potential savings relates to improvements in fuel efficiency.

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[1] See Table 17 in Part One of the Report.
[2] based on $1/L and a 1.5% fuel savings per axle.
[3] based on $1/L and a 1.5% fuel savings per axle.