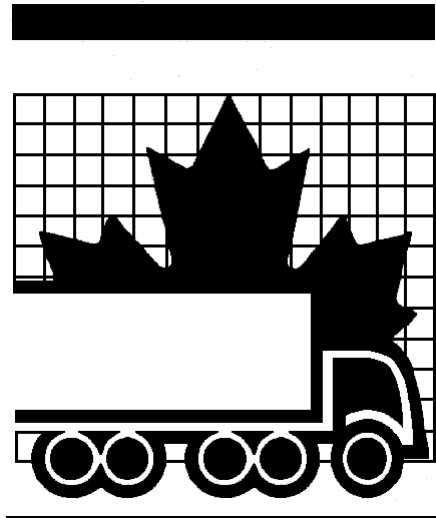


VEHICLE WEIGHTS AND DIMENSIONS STUDY
IMPLEMENTATION PLANNING SUBCOMMITTEE

**RECOMMENDED REGULATORY
PRINCIPLES FOR INTERPROVINCIAL
HEAVY VEHICLE WEIGHTS AND
DIMENSIONS**



SEPTEMBER 1987

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Preface:

The report which follows constitutes the draft final report of the Implementation Planning Subcommittee of the Joint RTAC/CCMTA Committee on Heavy Vehicle Weights and Dimensions. Following the completion of the Vehicle Weights and Dimensions Research Program, marked by the delivery of the Technical Steering Committee Report in December 1986, the Implementation Planning Subcommittee was charged with the following responsibilities:

1. To develop a plan that will assist each jurisdiction in implementing vehicle weight, dimension and configuration regulatory principles that will lead to national uniformity.
2. To develop schedules for proposed implementation of the recommendations.
3. To monitor the progress of implementation of the recommendations as they may be agreed to by the Council of Ministers Responsible for Transportation and Highway Safety at its meeting in September 1987.

With due consideration to the findings of the research program, and in recognition of the safety of the users of the system, engineering, economic and operational constraints of the highway system, the operational requirements of the trucking industry, and the capabilities of the truck and trailer manufacturing industries, the committee has developed a proposed regulatory environment which provides improved opportunities to safely exploit the available capacities of both the highway system and the motor transport fleet on a national basis.

The regulatory principles and recommended limits have been developed in the context of the following objectives:

1. To encourage the use of the most stable heavy vehicle configurations through the implementation of practical, enforceable weight and dimensions limits.
2. To balance the available capacities of the national highway transportation system by encouraging the use of the most productive vehicle configurations relative to their impact on the infrastructure.
3. To provide the motor transport industry with the ability to serve markets across Canada using safe, productive, nationally acceptable equipment.

The regulatory framework and principles described herein represent the work and collective efforts of all jurisdictions involved in the regulation of highway transport in Canada.

H.K. Walker
Chairman, Implementation Planning Subcommittee

1.0 Introduction

1.1 Background

In 1984 a joint government/industry research program was launched with the goal of achieving uniformity in interprovincial weights and dimensions regulations. The research was intended to provide insight into and answers to technical questions which stood in the way of obtaining agreement between jurisdictions on acceptable vehicle configurations, axle loadings and spacings, and overall dimensions.

The research conducted under the Vehicle Weights and Dimensions Study constitutes a major advancement in understanding the influence of heavy vehicle weights and dimensions on the stability and controllability of the vehicles which use the highway system and the impacts they have on the system's infrastructure. The research findings have also served to highlight the limitations of the capacities and capabilities of both the vehicles and the highway system itself, while providing direction on opportunities which exist to improve the productivity of the highway transport system.

Weights and dimensions regulations have traditionally been established primarily in consideration of the capacities or expected rate of consumption of the highway system infrastructure. The research program confirmed that a direct relationship also exists between weights, dimensions and vehicle stability. Consequently, any revision of existing limits has implications for the stability of heavy combination vehicles and for the safe operation of the highway system as a whole.

1.2 Vehicle Stability and Control Performance Criteria

The extensive programs of testing and computer simulation carried out under the research program served to document the wide range of stability and control characteristics of vehicles currently found in the commercial transport fleet. In reviewing the findings of the program, it was recognized that both the configuration of the vehicle and the manner in which it is loaded profoundly influence its stability and control characteristics and its compatibility with the highway geometry.

The regulatory principles and proposed weight and dimension limits which appear in the following sections have been selected in consideration of each vehicle configuration's demonstrated performance against seven measures. As recommended by the Technical Steering Committee of the research program, vehicles which exhibit performance which meets or exceeds the reference levels for the following measures should be encouraged for use in interprovincial carriage.

It is recognized that the desired targets for vehicle stability and control performance can not, and will not, be achieved solely through the application of weight and dimension limits. However, the influence of weight and dimensions on vehicle stability was carefully considered in developing and selecting the limits proposed in this document. It is recommended that the seven measures of performance described in the following section be considered in any future revisions to heavy truck weights and dimensions, and that the recommended minimum or maximum levels within each be held as desired targets, achievable through judicious application of regulatory control developed in concert with the manufacturing and operating industries.

Stability and Control Measures:

A. Static Rollover Threshold

The Static Rollover Threshold defines the maximum severity of steady turn which a vehicle can tolerate without rolling over. The measure expresses the level of lateral acceleration, in units of g's of lateral acceleration, beyond which overturn occurs. In general, loaded trucks exhibit rollover threshold values in the range of 0.25 to 0.40 g, a range which lies modestly above the severity levels encountered in the normal driving of passenger cars. This measure of truck roll stability is known to correlate powerfully with the incidence of rollover accidents in highway service.

Target Performance Level:

Vehicles, in the loaded condition, should exhibit a static rollover threshold of 0.4 g or better.

B. Dynamic Load Transfer Ratio

Dynamic Load Transfer Ratio characterizes the extent to which a vehicle approaches the rollover condition in a dynamic steering manoeuvre such as in avoiding an obstacle in the roadway. This measure is expressed in terms of the fractional change in tire loads between left- and right-side tires in the manoeuvre, thus indicating how close the vehicle came to lifting off all of its tires on one side, and rolling over. The value which is determined reflects the amplification tendencies by which multiple-trailer combinations tend to "crack the whip" in rapid steering manoeuvres. The Load Transfer Ratio is calculated as follows:

$$\text{Load Transfer Ratio} = \frac{\sum |F_L - F_R|}{\sum (F_L + F_R)}$$

where: F_L = Left side tire loads

F_R = Right side tire loads

Target Performance Level:

When a vehicle in the loaded condition negotiates an obstacle avoidance, or lane change manoeuvre at highway speeds, the load transfer ratio should not exceed 0.60.

C. Friction Demand in Tight Turns

The measure termed, Friction Demand in a Tight Turn, pertains to the resistance of multiple, non-steered axles to travelling around a tight-radius turn, such as at an intersection. Especially with semitrailers having widely spread axles, the resistance to operating in a curved path results in a requirement, or demand, for tire side force at the tractor's tandem axles. When the pavement friction level is low, such vehicles may exceed the friction which is available and produce a jackknife-type response. The friction demand measure describes the minimum level of pavement friction on which the vehicle can negotiate an intersection turn without suffering such a control loss. When the vehicle design is such that a high friction level is demanded, the vehicle is looked upon as inoperable under lower-friction conditions such as prevail during much of the Canadian wintertime.

Target Performance Level:

When a vehicle negotiates a 90° turn with an outside radius of 11 m, the peak required coefficient of friction of the highway surface to avoid loss of traction by the tractor drive tires should not exceed 0.1.

D. Braking Efficiency

A Braking Efficiency measure is used to indicate the ability of the braking system to fully utilize the tire/pavement friction available at each axle. It is defined as the percentage of available tire/road friction limit that can be utilized in achieving an emergency stop without incurring wheel lockup. For example, a vehicle achieves only a 50% braking efficiency level when it suffers wheel lockup while braking at 0.2 g's on a surface which could ideally support a 0.4 g stop. The braking efficiency measure is meant to characterize the quality of the overall braking system as the primary accident avoidance mechanism.

It is recognized that in-service heavy vehicle braking characteristics are influenced by a multitude of factors including the state of adjustment of the mechanical elements of the braking system, the response characteristics of the air supply system, the type and condition of tires on the vehicle, the load distribution between axles and the characteristics of the road surface. As a consequence, the performance measure described above is somewhat theoretical in nature, and may not be easily verified through physical testing of appropriately configured vehicles. Nonetheless, the Braking Efficiency measure as determined using simulation or analysis techniques does provide a valuable, consistent basis upon which valid comparisons of the braking performance of differing vehicle configurations can be made, and provides a reasonable target performance level which vehicles in the fleet should be capable of achieving.

Target Performance Level:

Vehicles in the loaded or unloaded condition should exhibit braking efficiencies of 70% or better. Braking efficiency is defined as the percentage of available tire/road friction limit that can be utilized in an emergency stop of 0.4 g's deceleration without incurring wheel lockup.

Offtracking Measures:

E. Low Speed Offtracking

Low-Speed Offtracking is defined as the extent of inboard offtracking which occurs in a turn. In a right-hand turn, for example, the rearmost trailer axle follows a path which is well to the right of that of the tractor, thus making demands for lateral clearance in the layout of pavement intersections. This property is of concern to compatibility of the vehicle configuration with the general road system and has implications for safety as well as abuse of roadside appurtenances.

Target Performance Level:

When a vehicle negotiates a 90° turn with an outside radius of 11 m, the maximum extent of lateral excursion of the last axle of the vehicle, relative to the path followed by the tractor steering axle, should not exceed 6 m.

F. High Speed Offtracking

A High-Speed Offtracking measure has been defined as the extent of outboard offtracking of the last axle of the truck combination in a moderate steady turn of 0.2 g's lateral acceleration. This measure is expressed as the lateral offset, in meters, between the trailer and tractor paths. Recognizing that the driver guides the tractor along a desired path, the prospect of trailer tires following a more outboard path that might intersect a curb, or an adjacent vehicle or obstacle poses a clear safety hazard.

Target Performance Level:

When a vehicle negotiates a turn with a radius of 393 m at a speed of 100 km/h, the maximum extent of outboard lateral excursion of the last axle of the vehicle, relative to the path followed by the tractor steering axle, should not exceed 0.46 m.

G. Transient High Speed Offtracking

The Transient High-Speed Offtracking measure is obtained from the same obstacle avoidance manoeuvre as that used to define the dynamic rollover stability level and is defined as the peak overshoot in the lateral position of the rearmost trailer axle, following the severe lane-change-type maneuver. The amount of overshoot in the rearmost-axle path can be viewed as a relative indication of the extent of potential intrusion into an adjacent lane of traffic, or the potential for striking a curb (risking an impact-induced rollover). In layman's terms, this measure quantifies the magnitude of the "tail-wagging" in response to a rapid steer input.

Target Performance Level:

When a vehicle negotiates an obstacle avoidance, or lane change, manoeuvre at highway speeds, the maximum lateral excursion of the rearmost axle of the vehicle, relative to the final lateral path displacement of the steering axle, should not exceed 0.8 m.

1.3 Regulatory Approach, Rationale and Application

The regulatory principles were established on the basis of the findings of the research program and were used to select weight and dimension limits which have been developed in the context of the following objectives:

1. To encourage the use of the most stable heavy vehicle configurations through the implementation of practical, enforceable weight and dimensions limits.
2. To balance the available capacities of the national highway transportation system by encouraging the use of the most productive vehicle configurations relative to their impact on the infrastructure.
3. To provide the motor transport industry with the ability to serve markets across Canada using safe, productive, nationally acceptable equipment.

The regulatory principles and limits proposed in this document are intended to apply only to those vehicles engaged in interprovincial carriage. These vehicles will fall into one of the following four categories:

- a. Tractor Semitrailer
- b. A Train Double

- c. B Train Double
- d. C Train Double

If implemented, the regulatory agreement would permit vehicles which are in compliance to travel unrestricted across each jurisdiction in Canada on a designated system of highways. The regulatory proposals are not intended to inhibit the ability of individual jurisdictions to meet the needs of the transportation system in their region, and to develop appropriate heavy vehicle weights and dimensions for intraprovincial goods movements.

2.0 Discussion of Proposed Regulatory Controls and Limits

Vehicle stability and infrastructure impacts are influenced to varying degrees by many components of the vehicle and the physical configuration of the components. In some cases the research demonstrated a clear and significant correlation between a vehicle parameter and a performance measure, thereby providing an opportunity for effective regulatory control. In other cases the research findings were to a certain extent inconclusive, or raised issues or concerns for which weight and dimension regulatory controls would be ineffective, inappropriate or premature. However, many findings in the latter category should be considered by the manufacturing and operating sectors of the trucking industry in view of the potential benefits to stability and productivity voluntary action would provide.

The research findings and proposed regulatory controls are discussed by vehicle component as follows:

2.1 Tractors:

Terminology:

Wheelbase: The longitudinal distance from the centre of the front or steering axle to the geometric centre of the driving axle(s). For tandem drive axle tractors, from the steering axle to the centre of the drive tandem.

Tandem Axle Spread: The longitudinal distance between the axle centres.

Fifth Wheel Offset: The longitudinal distance from the centre of the fifth wheel to the centre of the tandem drive axle group (for two axle tractors, to the centre of the drive axle). Convention: ahead of centre is positive setting, behind centre is negative setting.

Interaxle Spacing: The longitudinal distance between the centres of two adjacent axles.

2.1.1 Wheelbase:

The research demonstrated that the stability of combination vehicles improves with increasing tractor wheelbase. However, the tractor wheelbase also directly influences low speed offtracking performance, ie. longer wheelbases result in a greater degree of offtracking. In consideration of the trucking industry's expressed desire for operational flexibility and interchangeability of tractors between configurations, the proposed regulatory controls apply to the tractor in each of the four vehicle categories.

It is proposed that the minimum tractor wheelbase be determined by interaxle spacing requirement (section 2.13) and the maximum be 6.2 m because of the resultant low speed offtracking performance of a tractor semitrailer configuration consisting of a 6.2 m tractor coupled to a 12.5 m wheelbase semitrailer.

2.1.2 Tandem Axle Spread:

The research demonstrated that vehicle stability generally improves with decreasing axle spreads in tandem and tridem groups. On the tractor, the drive axle spacing should be kept as short as possible to reduce the forces required by the steering axle to overcome the "tire scuffing" of the drive axles which occurs in tight turns.

It is proposed that the spacing between the tandem drive axles be controlled, with a minimum of 1.2 m and a maximum of 1.85 m. The intent is to encourage the use of closely spaced axle groups, while providing flexibility to operators who require wider spreads for other reasons.

2.1.3 Interaxle Spacing:

The research determined that vehicle stability degrades with decreasing tractor wheelbase and that a minimum spacing must be maintained between the steering axle of the tractor and the first drive axle with respect to concern for bridge distress under load. A minimum interaxle spacing requirement is proposed on the basis of encouraging the use of more stable vehicle configurations, while reducing the demands on bridge structures.

It is recommended that the interaxle spacing on a tractor be a minimum of 3 m.

2.1.4 Fifth Wheel Offset:

Many tractors are equipped with moveable fifth wheels which enable load distribution between axles on the vehicle to be adjusted. In other instances, the position of the fifth wheel is selected to accommodate special requirements of the vehicle configuration or commodity carried (eg. automobile carriers).

The location of the fifth wheel on the tractor does influence the stability of the entire vehicle configuration. It is recognized that operational flexibility is required by the industry, and for this reason no regulatory control is proposed at this time. However, should industry practice in positioning fifth wheels result in significant degradation of vehicle stability, regulatory control may become necessary.

No control of fifth wheel offset is proposed at the present time.

2.1.5 Track Width:

Research has demonstrated that the stability of the tractor and the combination vehicle as a whole improves with increases in the track width, or overall width across the tires. Wider track axles are not currently available in quantity for tractor steering and drive axles, and their use would require engineering modifications to existing tractor designs.

Although it is not proposed to control the track width of tractors at this time, it is recommended that the industry be encouraged to use wider track axles which provide a nominal width across the tires of 2.6 m to obtain the benefits of improved stability. It is further recommended that the

Government of Canada work with the Government of the United States to pursue more rapid development of wider track axles for tractors.

2.1.6 Weight to Power Ratio:

While no regulatory requirement is proposed at this time respecting the horsepower of the tractor relative to the Gross Combination Weight, it should be recognized that interprovincial carriage through the province of British Columbia must meet that jurisdiction's regulatory requirement of a maximum of 150 kg/hp and the requirement for tandem drive axles on the tractor if the vehicle's Gross Combination Weight exceeds 38 000 kg.

2.2 Semitrailers:

Terminology:

Length: The longitudinal distance from the front to the rearmost point of the semitrailer.

Kingpin Setback: The longitudinal distance from the front of the semitrailer to the centre of the kingpin.

Wheelbase: The longitudinal distance from the kingpin to the turn centre of the semitrailer. For the purposes of this regulatory proposal, the turn centre is considered to be the geometric centre of the axle group on the semitrailer.

Rear Overhang: The longitudinal distance from the centre of the last axle to the rearmost point on the semitrailer (or load).

Effective Rear Overhang: The longitudinal distance from the turn centre of the semitrailer to the rearmost point on the semitrailer (or load).

Hitch Offset: The longitudinal distance from the turn centre of the semitrailer to the centre of the hitching mechanism provided for towing an additional trailer (typically a pintle hook).

2.2.1 Length:

The research did not illustrate any direct relationship between trailer length and any of the performance measures. However, there are other criteria which must be considered in establishing size and weight limits, including enforcement concerns, the influence of overall vehicle length on highway capacity and level of service, and operational and manufacturing limitations.

It is recommended that the length of semitrailers be controlled under the limits developed for each type of configuration addressed in this proposal.

2.2.2 Wheelbase:

The research demonstrated that the wheelbase of a semitrailer has a direct influence on the stability of combination vehicles. Longer wheelbases improve dynamic stability while providing an opportunity to reduce the height of the centre of gravity of the payload. However, as wheelbases are increased the low speed offtracking is also increased. Generally, semitrailer wheelbases should be kept as long as possible, within the constraint of acceptable limits of low speed offtracking. As wheelbases decrease, the dynamic stability degrades and the friction demands on tractor drive axles in low speed turns increase (for multiple axle semitrailers).

It is recommended that the minimum and maximum wheelbases of semitrailers be controlled in all configurations, with appropriate limits selected in consideration of the inherent stability characteristics of the configuration.

2.2.3 Kingpin Setback:

As the distance from the front of the semitrailer to the kingpin is increased, the potential for the front corner of the semitrailer to intrude into adjacent traffic lanes in tight turning manoeuvres increases.

It is recommended that the kingpin setback on semitrailers in tractor semitrailer configurations and the first semitrailer in double configurations be controlled to limit lane intrusion in turning manoeuvres. It is recommended that no part of the trailer forward of the kingpin protrude beyond an arc of 2.0 m radius drawn about the centre of the kingpin.

2.2.4 Effective Rear Overhang:

The length of the trailer or load which extends beyond the turn centre of a semitrailer determines whether intrusion into adjacent lanes of the rear corner of the trailer or load will occur when a turn is negotiated. Because of the turning characteristics of longer wheelbase semitrailers, this problem is only of concern with the tractor semitrailer configuration.

It is recommended that the effective overhang on semitrailers in tractor semitrailer configurations be limited to a maximum of 35% of the wheelbase.

2.2.5 Rear Overhang:

In consideration of the proposed control of effective rear overhang, there is no proposed control of rear overhang. However, it is recommended that the development and implementation of standards for improved rear underride protection be undertaken by the Federal Government in concert with the Provincial Governments and the manufacturing industry.

2.2.6 Tandem and Tridem Axle Spreads:

The research demonstrated that the stability of semitrailers improves with decreasing axle spreads on multiple axle groups. Increased axle spreads also demand higher friction levels between tractor drive axles and the road surface in tight turning manoeuvres, consequently the maximum spread which can be recommended for a tandem or tridem is also dependent on the wheelbase of the semitrailer on which it is installed. However, bridge capacity considerations require that axle spreads be increased to accept particular loading levels. In addition, pavement damage increases with very wide axle spreads. To accommodate these conflicting objectives, and to provide maximum utility of vehicles in the trucking fleet, minimum and maximum axle spread limits are proposed for both tandem and tridem axle groups.

It is proposed that the maximum and minimum spreads of tandem and tridem axle groups be controlled with limits established for each vehicle configuration.

2.2.7 Track Width:

The research demonstrated that significant improvements in vehicle stability can be obtained by increasing the track width, or overall width across the tires, of all axles on a semitrailer. The full stability benefit of the increased axle width is only realized with a commensurate increase in the

spacing between the attachment points of the suspension on the axle. While this dimension is considered to be outside the practical limits of enforceable weights and dimensions controls at the present time, manufacturers are encouraged to exploit the full stability enhancement available through increased axle and suspension width.

It is recommended that wider track axles be used on trailers and semitrailers in all configurations, and that a nominal width across the tires of 2.6 m be required.

2.2.8 Hitch Offset (Double Trailer Configurations):

Where semitrailers are used in double trailer operations, the distance from the turn centre of the semitrailer to the hitching mechanism for the dolly drawbar(s) is related to the stability of the combination. Generally, this dimension should be kept as short as possible for the A Train Double and in particular for the C Train Double. As this dimension increases, the dynamic stability of both A and C Train Doubles, in terms of load transfer ratio and transient high speed offtracking, degrades markedly.

It is proposed that the distance from the effective turn centre of the semitrailer to the location of the hitching mechanism for dolly drawbars be kept as short as possible, and be limited to a maximum of 1.8 m.

2.3 Converter Dollies:

2.3.1 Drawbar Length: A Converter Dollies

The research did not provide conclusive evidence that the length of the drawbar on A Converter Dollies directly affected the stability and control performance of combination vehicles. As a consequence, and in view of other overall dimensional constraints on the A Train category, no control is recommended for the length of drawbar on A Converter Dollies.

2.3.2 Drawbar Length: B Converter Dollies

The research established a direct relationship between the length of the drawbar on the double drawbar or B converter dolly and the stability of the second trailer in a double configuration. Generally, as the drawbar length decreases, the dynamic highspeed offtracking improves. There are practical limits to the minimum length of drawbar, dictated in part by inter-trailer clearance requirements and by minimum interaxle spacing requirements determined by bridge capacity considerations.

It is recommended that a maximum allowable drawbar length of 2.4 m be established for B Converter Dollies.

2.3.3 Double Drawbar or B Dolly Converters:

The research determined that significant stability improvements can be achieved in double trailer configurations through the substitution of a properly designed and installed B Dolly for a conventional A Dolly. However the research also highlighted the complexities of the B Dolly design, and demonstrated instances where improperly designed dollies can render the stability performance of the "C Train" inferior to that of the "A Train".

In the absence of design and operational guidelines for the B Converter Dolly, it is recommended that the use of the C Train not be encouraged at the present time and that the size and weight restrictions on this configuration remain as described for the A Train Double. It is further recommended that high priority be given to developing such guidelines and implementing a means of ensuring manufacturing and operational compliance.

2.3.4 Number of Axles:

While the research did not provide evidence to suggest that multiple axle dollies exhibit undesirable performance characteristics, the stability limitations of the A Train Double and the as yet uncertain engineering requirements of the B Converter Dolly would suggest that additional load carrying capability by the dolly is unnecessary, and generally not desirable. The proposed weight restriction on the second trailer of A and C Train Doubles provides no incentive or requirement for additional load carrying capability.

To discourage excessive loading of the second trailer of A Train Doubles, and in view of the uncertain requirements of B Dolly design, it is proposed that only single axle converter dollies be allowed on A and C Train Double Configurations.

2.4 General Considerations:

2.4.1 Interaxle Spacing:

The distance between axles and axle groups on a heavy vehicle affects the response of the pavement and bridge structure to the loading of the vehicle, and hence its destructive effects. From the standpoint of bridge capacity constraints, there are minimum spacing requirements between axles which must be respected, regardless of vehicle configuration.

It is proposed that interaxle spacings be controlled in accordance with the following table:

<i>Single Axle - Single Axle</i>	<i>Min 3.0 m</i>
<i>Single Axle - Tandem Axle</i>	<i>Min 3.0 m</i>
<i>Tandem Axle - Tandem Axle</i>	<i>Min 5.0 m</i>
<i>Tandem Axle - Tridem Axle</i>	<i>Min 5.5 m</i>
<i>Tridem Axle - Tridem Axle</i>	<i>Min 6.0 m</i>

2.4.2 Suspension Type and Mix:

The research demonstrated that stability performance can be significantly affected by the varying characteristics of the range of suspensions commonly available to the fleet operator. In particular, it is evident that the stability of all four categories of vehicles can be improved through careful selection of compatible tractor and semitrailer suspensions. Conversely poor compatibility of suspensions can significantly degrade vehicle stability.

The research also provided preliminary insights to the relative potential damaging effects of differing suspensions types on the infrastructure due to dynamic loadings. The research suggested that certain types of suspensions would appear to inflict unnecessarily high dynamic loadings on the pavement and bridges as road roughness and vehicle speeds increase.

While no regulatory controls are proposed at this time for suspension types or mixes, it is recommended that further research be conducted in this area to determine whether regulatory controls are appropriate or warrant development.

2.4.3 Tire Type:

The research demonstrated that the use of radial tires can improve the dynamic stability of heavy vehicles, particularly the double trailer configurations.

While no regulatory controls are proposed at this time for the type of tire to be used on combination vehicles, the use of radial tires in all axle locations is encouraged.