PERFORMANCE-BASED ANALYSIS OF CURRENT SOUTH AFRICAN SEMI-TRAILER DESIGNS

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Abstract

In South Africa, heavy vehicles are currently designed according to stringent prescriptive standards designed and enforced by the national Department of Transport (DoT); these standards are regulated in terms of mass, dimensions and configurations. The current prescriptive standards leave little room for innovative designs.

Performance Based Standards (PBS) for heavy vehicles have been developed and implemented in Australia, Canada and New Zealand since the mid-1980s. This is an alternate regulatory system designed to improve the dynamic stability and performance of heavy vehicles. PBS regulates the performance of a vehicle rather than limiting it with regard to size and mass, thus creating more flexibility for innovative designs, increased productivity and improved safety.

This paper presents the analysis and evaluation results of five current South African semi-trailer combination vehicles assessed in accordance with the PBS approach.

Keywords: heavy vehicle dynamics, performance based standards, dynamic stability, tractor semi-trailers, directional response, static rollover threshold

Introduction

South African heavy vehicles are currently designed according to prescriptive standards designed and enforced by the national Department of Transport (DoT); these standards are regulated in terms of mass, dimensions and configurations. Due to advancements in modern vehicle technology, many products have been designed to reduce tare mass and increase vehicle productivity. These include Central Tyre Inflation (CTI), on-board weighing, new materials such as Domex and vehicle satellite tracking, all leading towards increased payloads and reduced costs. There have also been improvements in technology such as Electronic Braking Stability and active distance control to improve the safety of heavy vehicles. However, the current prescriptive standards leave little room for innovative designs.

Performance Based Standards (PBS) for heavy vehicles have been developed and implemented in Australia, Canada and New Zealand since the mid-1980s (OECD, 2005). This is an alternate regulatory system designed to improve the dynamic stability and performance of heavy vehicles. PBS regulates the performance of a vehicle rather than limiting it with regard to dimensions and mass, thus creating more flexibility for innovative designs, increased productivity and improved safety.

Due to the rapid increase in the number of heavy vehicles on the South African road network the current infrastructure, and the national freight corridors in particular, is under increasing pressure to safely accommodate these vehicles; this is evident in a study conducted by the CSIR, Nordengen *et al*. (2008), which shows that during the past 10 years the number of registered heavy vehicles in South Africa has increased exponentially by over 40%.

A second study by Nordengen (2008) showed that the safety performance of heavy vehicles on South African roads is significantly worse than that in other competitive countries. In some instances the results show a fatality rate in South Africa of five to six times more per 100 million heavy vehicle kilometres travelled compared with that of other countries.

A need for innovative design in our current transportation industry is thus imperative. As part of a PBS research programme, two demonstration projects have been launched in the forestry industry, run and monitored by Mondi and Sappi.

It was important to establish the performance of the current South African vehicles, in order to create a benchmark on which future design and analysis can be based. The objective of this paper was therefore to set up PBS performance manoeuvres, and model, simulate and evaluate the results of five South African semi-trailer configurations to determine whether they pass the required performance levels set out in the PBS guidelines. This paper presents the analysis and evaluation results of the semi-trailer combinations, assessed according to Australian PBS guidelines developed and enforced by the National Transport Commission (NTC) of Australia.

Performance Based Standards

The Performance Based Standards (PBS) scheme in Australia utilises 20 standards to assess vehicles, 16 of which are based on the safety standards of the vehicle, while the remaining four standards deal with vehicle impact on the current road infrastructure.

For the purpose of this report only six safety standards were selected. These represent a comprehensive overview of the dynamic handling and stability of the vehicles. For the various reasons detailed below, the remaining standards were not selected. Startability, gradeability and acceleration capability were not selected as these standards primarily depend on engine and driveline characteristics of the vehicle. Tracking ability on a straight path, although an important standard, was not selected because the road profile necessary to analyse the vehicle had not yet been completed by the National Transport Commission (NTC) of Australia.

Standards that were not selected were either of greater concern to multi-combination vehicles, or had no significant value to the desired outcomes of this report.

Australia's National Transport Commission underwent a large-scale operation to classify the current road network into four levels of network access, with the purpose of providing a match between the performance of a vehicle and the route on which it may travel. Level 1 allows for general access to the road network and thus requires more stringent performance standards, whilst Levels 2, 3 and 4 are more lenient as they are intended for b-doubles (interlinks), double road train and triple road train configurations, respectively. Due to the fact that road trains are not permitted in South Africa, only Levels 1 and 2 were listed.

Table 1 presents the list of standards that were analysed and their required performance levels. A complete list of the 16 Australian PBS safety standards, four infrastructure standards and the relevant performance levels are given in the National Transport Commission, Performance Based Standards Scheme – The Standards and Vehicle Assessment Rules (2007).

Table 1. List of analysed PBS measures and their corresponding performance levels. Levels 1 and 2 are for two different road classifications.

Safety Standard		Performance Levels	
		Level 1	Level 2
Low-Speed Swept Path (LSSP)	Not greater than	7.4 m	8.7 m
Frontal Swing			
Part A - Prime Mover	Not greater than	0.7 m	
Part B - Trailing Unit (MoD)	Not greater than	0.2 m	
Tail Swing	Not greater than	0.3 m	0.35 m
Static Rollover Threshold (SRT)	Not less than	0.35 g	
Rearward Amplification (RA)	Not greater than	5.7 X SRT	
High-Speed Transient Off Tracking (HSTO)	Not greater than	0.6 m	0.8 m

After: National Transport Commission, Performance Based Standards Scheme – The Standards and Vehicle Assessment Rules (2007).

Low-speed directional performance

This group of standards is used to determine the directional performance of a vehicle during cornering at low speeds. The standard is generic for measuring various low-speed directional outputs, such as Low-Speed Swept Path (LSSP), frontal swing, tail swing and (see Figures 1-4) Steer Tyre Friction Demand (STFD).

The vehicle being tested has to follow a prescribed path of a 90 degree turn, of radius 12.5 m, at a speed no greater than 5 km/h. The vehicle must be tested at both maximum laden and unladen mass (see Figure 1).

Low Speed Swept Path (LSSP) is measured in order to limit the safety risk imposed by vehicles during cornering at low speeds. When a vehicle makes a low speed turn the rear of the vehicle does not follow the path taken by the front of the vehicle but rather tracks inside this path. A high value of LSSP is undesirable as the vehicle will require more road space to perform a low speed turn, thus may result in collisions with oncoming traffic users, or damage to roadside objects. The maximum width of the swept path, SPW_{max}, is the distance measured between the two path trajectories, perpendicular to their respective tangents (see Figure 2).

Frontal swing is measured in order to minimise the safety risk of a vehicle when performing a tight turn at low speed. During the low speed turn the front overhang of the hauling unit will cause the front outside corner to track outside the intended path to be followed by the front wheel. A large amount of frontal swing is undesirable as the vehicle will therefore require more road space to perform a low speed turn, thus encroaching into other lanes, endangering pedestrians or colliding with roadside objects (see Figure 3). There are two parts to frontal swing, Part A deals with the prime mover, and Part B is concerned with the trailing units.

Tail swing is of great importance to vehicles with a large amount of rear overhang performing tight turns. A high value of tail swing is undesirable as the vehicle would therefore pose a severe safety risk to other road users by tracking into adjacent lanes, resulting in collisions (see Figure 4).

During the simulation various points of interest on the vehicle are tracked and then plotted. These plots allow one to measure the required lateral displacements; the values are then compared to the corresponding PBS performance level to determine if they meet the required performance level.

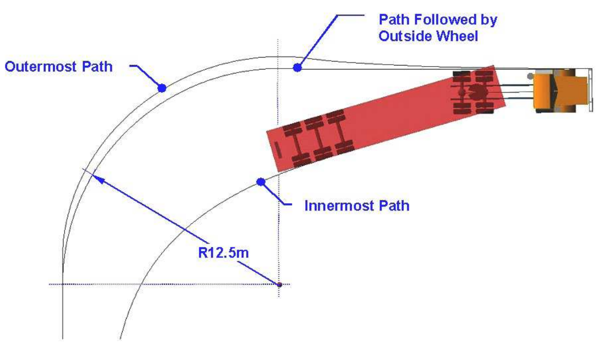

Figure 1. Illustration of low speed swept path.
National Transport Commission, Performance Based Standards Scheme – The Standards and Vehicle Assessment Rules (2007).

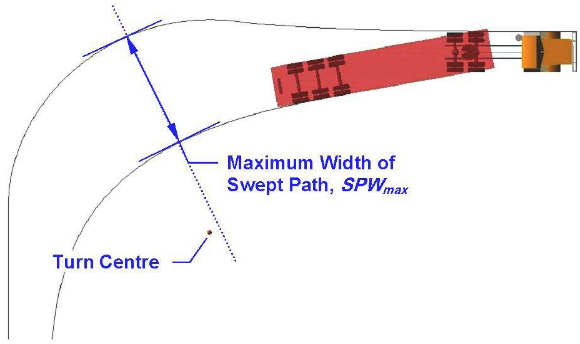

Figure 2. Illustration of maximum width of swept path, SPW_{max}.
National Transport Commission Performance Based Standards Scheme – The Standards and Vehicle Assessment Rules (2007).

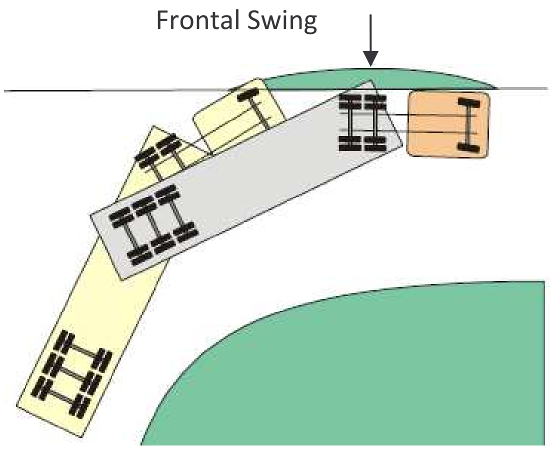

Figure 3: Illustration of frontal swing.
Australian Road Transport Suppliers Association. PBS Explained – Performance Based Vehicles for Road Transport Vehicles (2003).

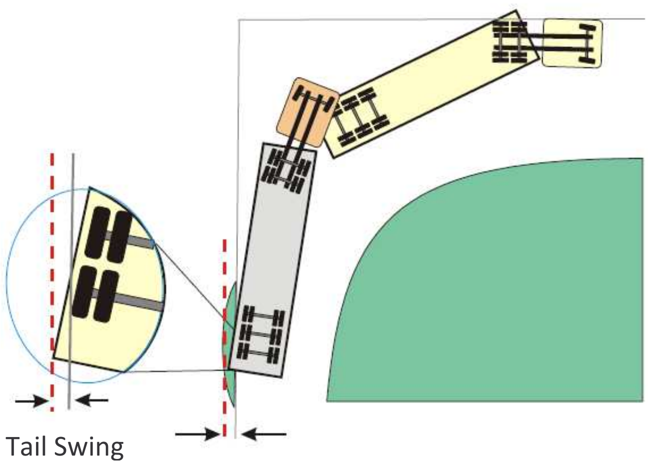

Figure 4: Illustration of tail swing.
Australian Road Transport Suppliers Association. PBS Explained – Performance Based Vehicles for Road Transport Vehicles (2003).

Static Rollover Threshold

This standard is arguably the most important performance standard in terms of vehicle stability, as it has been strongly linked to crashes involving rollovers.

Static Rollover Threshold (SRT) is a measure of the lateral acceleration a vehicle can withstand without rolling over during a constant radius turn, or on a tilt table test. When a vehicle travelling at high speed enters a steady turn it is subjected to an outward lateral acceleration which could result in the vehicle rolling over. High values of SRT are desirable as an indication of increased resistance to rollover. SRT is expressed as a fraction of acceleration due to gravity in units of 'g', where 1 g represents an acceleration of 9.807 m/s^2 corresponding to the force exerted by the earth's gravitational field.

There are two test procedures used to determine the SRT for vehicles, namely a constant radius turn and a tilt table test (Figures 5 and 6). In order to get a good insight into the dynamic stability of semi-trailer configurations, both procedures were simulated.

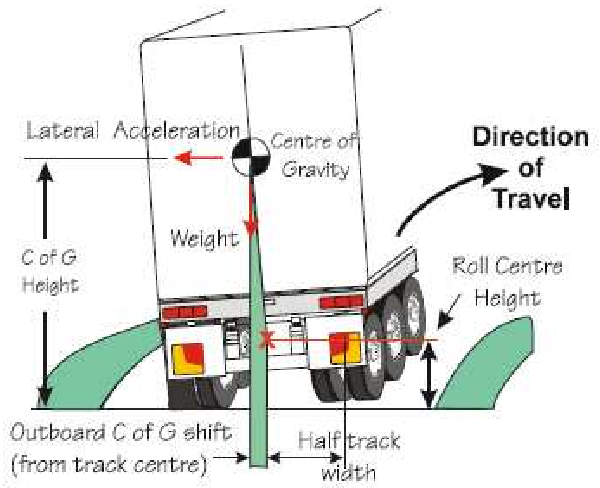

Figure 5. Illustration of SRT circular test.

Australian Road Transport Suppliers Association. PBS Explained – Performance Based Vehicles for Road Transport Vehicles (2003).

Figure 6. Illustration of SRT tilt table test.

http://www.carsim.com/applications/TS%20tilt%20table%20example/index.php

Rearward Amplification

Rearward Amplification (RA) is a performance measure that is designed to limit the lateral directional response of a vehicle performing an avoidance manoeuvre at high speeds. This performance measure is more of a concern for vehicles with two or more articulation points.

As the name suggests, the lateral acceleration of each unit is an amplification of the unit directly ahead of it. Thus the rear unit in the vehicle combination will experience the highest level of lateral acceleration (see Figure 7), which could result in rollover; the required performance level for this manoeuvre is therefore directly related to Static Rollover Threshold.

The vehicle being assessed must be loaded to the permissible maximum combination mass and least favourable load conditions, and must perform a single lane change manoeuvre in accordance with 'Single Sine-Wave Lateral Acceleration Input' specified in International Standards Organisation (ISO) documentation[1].

RA is calculated by the ratio of the maximum lateral acceleration response of the rear most unit, measured at the centre of mass, to the lateral acceleration of the input, measured at the front steer axle. This value must not exceed 5.7 times the SRT value for that particular vehicle.

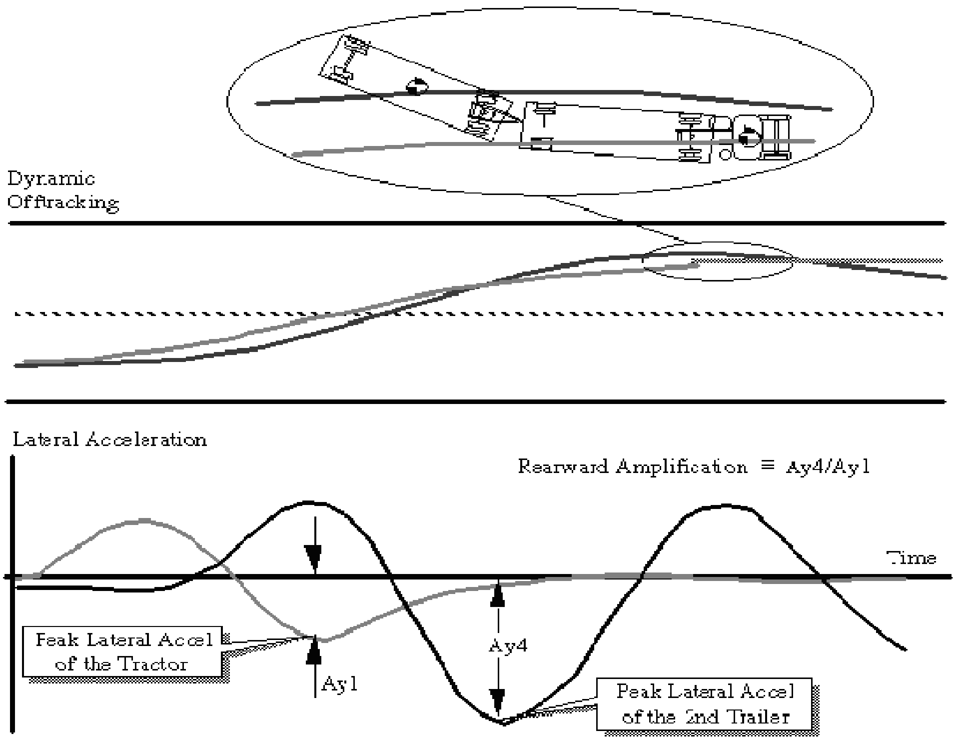

Figure 7. Illustration of rearward amplification.
http://www.fhwa.dot.gov/reports/tsstudy/vehiclsaf.htm

High-Speed Transient Off-Tracking

High-Speed Transient Off-tracking (HSTO) is a performance measure used to limit the lateral displacement of the rearmost trailer of an articulated vehicle, whilst performing an avoidance manoeuvre at high speeds.

During the avoidance manoeuvre the rear end of the rearmost trailer may overshoot the final path of the front steer axle; this measure of lateral overshoot is referred to as HSTO. The avoidance manoeuvre that is to be performed is based on the same ISO lane change manoeuvre described above in 'Rearward Amplification'. HSTO is determined by measuring the maximum lateral displacement of the centre rearmost axle of the rearmost vehicle unit from the exit tangent of the desired path.

[1] In accordance with ISO 14791:2000(E), 'Single Lane Change'

Software

Trucksim

Trucksim[2] is a vehicle dynamic simulation software package, which allows the user to model, simulate and analyse the dynamic behaviour of various truck-trailer configurations. It makes use of a primary Graphical User Interface (GUI), which allows the user to select various vehicle configurations, input controls and parameter settings and analyse the results through an Engineering Plotter as well as a post-processing animation feature.

Trucksim is a commercially available software package that is based on over 40 years of research and development through experimental testing and specialised laboratory analysis. This initiative started at the University of Michigan Transport Research Institute (UMTRI), but is now under licence to Mechanical Simulation Corporation.

Trucksim was utilised in order to perform all PBS longitudinal and directional dynamic analyses at both high and low speeds.

Hellberg Transport Management

Hellberg Transport Management (HTM) Transolve software is a package which allows end-users to optimise their vehicle configurations, manage legal payload limits, analyse vehicle performance and compare different vehicles in the same class.
HTM was used to generate four generic vehicle configurations that are widely used throughout the South African transportation industry.

Manex

MANCAS or MANEX is an in-house software development for MAN Truck and Bus Company, from which various prime mover data was obtained.

Vehicle configuration

The vehicle configurations selected for this report were a prime mover and five semi-trailer combinations. The prime mover semi-trailer combination is one of South Africa's most widely used configurations, in all areas of the transportation industry on both provincial and national routes, and is widely regarded as a 'workhorse' of the South African fleet.

Five different vehicle configurations were selected in order to obtain a large dataset from which result tendencies could be established. Four of these designs were obtained through HTM's Transolve software (Refrigeration, Side Curtain, Tipper, and Skeletal), whilst the final design was a South African vehicle selected from a recently completed worldwide research study on the performance of heavy vehicles, conducted by the Organisation for Economic Co-operation and Development (OECD) and analysed by ARRB Group Ltd.

Prime mover

The prime mover selected for the purpose of this report was a MAN TGA 26.480 BLS front over cab. This prime mover is a conventional unit which is widely used throughout the transportation industry in South Africa. It has an output power of 352 KW, and makes use of both leaf spring (steer axle) and air suspension (drive axles) (Table 2).

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[2] http://www.carsim/products/trucksim/

Table 2. Key Dimensions for Prime Mover[3].

Parameter	MAN 26.480
Prime Mover Dimensions	
Length	6775
Width	2500
Height	3421
Wheel Base	
Axle 1 - 2	3200
Axle 2 - 3	1350
Front Overhang	1475
Rear Overhang	750
Mass of Prime Mover	7523
Axle - Track width	
Steer	2030
Drive	2030
Tyres	315/80R22.5
Fifth Wheel dist. Back	3475
Height of CG	1019

Trailer

In order to generate an enhanced overview of dynamic handling and stability, five semi-trailers were selected. Each semi-trailer, although different in terms of mass, axle load and dimensions, made use of a generic triaxle leaf spring suspension system.

For the purpose of this report a number of assumptions were made during the modelling process of the semi-trailer configurations. The reason for this was to ensure that the results obtained from the analysis were due to the load carried, geometry, and design of the vehicle configuration itself.

Therefore a generic triaxle suspension system, generic axles and 315/80R22.5 tyres were used for all combinations in order to limit potential disturbance of other component subsystems. The key dimensions of various parameters for each vehicle are provided in Table 3.

[3] All dimensions are in mm, whilst masses are in kg

Table 3. Key dimensions for vehicle combinations[4].

Parameter	Vehicle 1 Refrigeration	Vehicle 2 Side Curtain	Vehicle 3 Tipper	Vehicle 4 Skeletal	Vehicle 5 OECD
Overall dimensions					
Length	18620	17600	16058	17500	17745
Width	2600	2600	2600	2600	2600
Height	4169	4280	3422	3422	4220
Trailer dimensions					
Length	15470	14300	11593	14200	14200
Wheelbase	10000	10000	9000	10000	10000
Frontal overhang	1800	1500	385	1550	1300
Rear overhang	2310	1450	858	1300	1540
Height of Cargo floor above ground	1472	1433	1336	1535	1562
Mass of vehicle					
Unladen	19120	16820	18060	15800	18820
Payload	29551	32050	28920	32408	30000
GCM	48671	48870	46980	48208	48820
Axle - track width	1910	1910	1910	1910	1975
Tyres	315/80R22.5	315/80R22.5	315/80R22.5	315/80R22.5	315/80R22.5
Fifth wheel height	1200	1200	1200	1200	1200
Height of CG	2550.8	2571.8	2170.4	2289.8	2625.2

Simulation results

Low speed swept path

Factors that influence LSSP include prime mover and trailer wheelbase, number of articulation points, frontal overhang, and rear coupling overhang. An increase in the prime mover and trailer wheelbase and frontal overhang have a negative effect on the performance measure, whilst an increase in the number of articulation points and rear coupling overhang have a positive effect.

Reference points required for tracking the vehicle include the outermost point on the outer tyre sidewall, centre of front axle (which is represented in Figure 8 as the Target Path), and the furthest inside wall of the middle axle of the trailer tri-axle suspension (Figure 8).

One of the limitations of this standard is that the front centre axle must not deviate from the target path by more than 30 mm; this is evident in the Figure 9, which illustrates the lateral deviation from the target path of the front centre axle (represented in Figure 9 as 'Vehicle'). This maximum deviation is 23 mm which is within the PBS limitation.

[4] All dimensions are in mm, whilst masses are in kg.

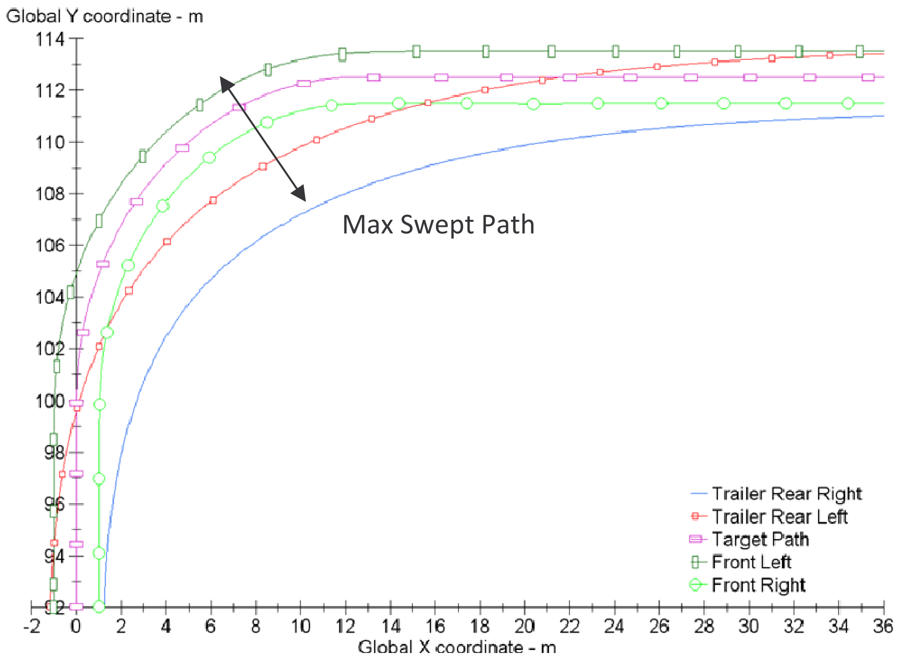


Figure 8. Simulation results – global tracking of the front and rear tyres.

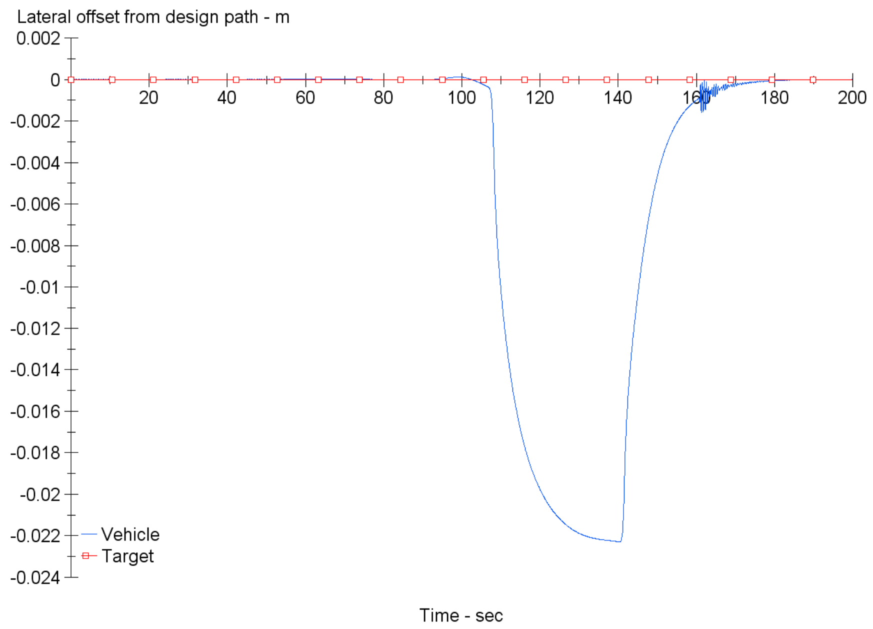


Figure 9. Simulation result - lateral offset from design path

Frontal swing

Part A – hauling unit

The two points of interest for this standard are the furthest forward outside point of the vehicle hauling unit and the outermost point on the outer tyre sidewall. Figure 10 illustrates the frontal swing of the front outside edge of the hauling unit, compared to that of the outermost edge on the tyre side wall. The two parameters that influence frontal swing are front overhang and the wheelbase of the prime mover. Frontal overhang is the best indicator for determining frontal swing, and has the greatest influence on its performance.

Due to the selection of one generic prime mover for all five vehicles the results of the analyses would be identical. It is evident from the results in Table 4 that the performance measure specified has been achieved, for both unladen and laden conditions.

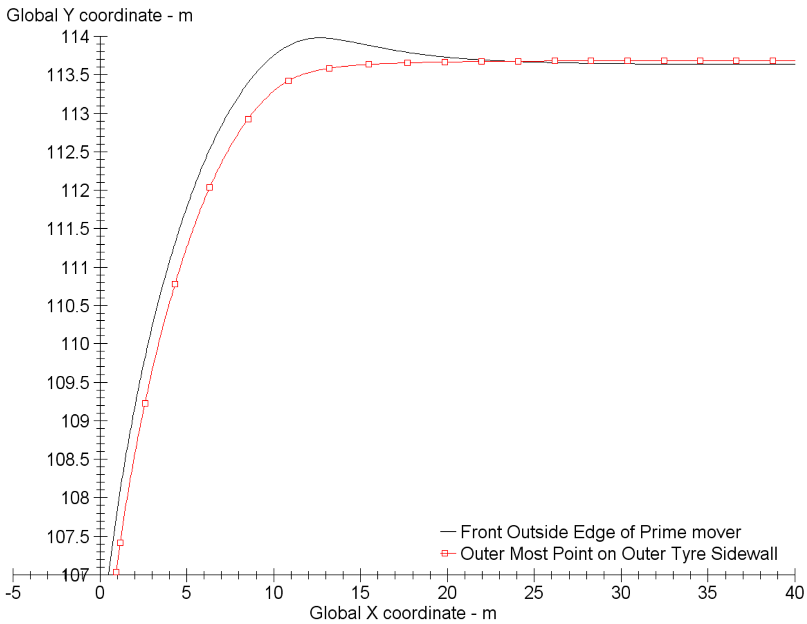


Figure 10. Simulation result – frontal swing of hauling unit.

Table 4. Frontal swing of hauling unit.

Vehicle	**FS max unladen (m)**	**FS max laden (m)**
Refrigeration	0.43	0.42
Side Curtain	0.43	0.42
Tipper	0.43	0.42
Skeletal	0.43	0.42
OECD	0.43	0.42

Part B – Trailing Unit – Maximum of Difference (MoD)
Frontal swing is a safety concern not limited to the prime mover only; it is also a concern for trailing units. The points of interest in this part of the standard are the furthest forward outside point of the prime mover and the semi-trailer, as well as the outermost point on the outer tyre sidewall. The parameters that influence the frontal swing for the trailing unit are similar to those of the hauling unit, frontal overhang of the semi-trailer, and wheelbase of the prime mover (see Figure 5).

From the results in Table 5, the performance range for frontal swing (MoD) - 0.18 to 0.2 m, for both unladen and laden conditions illustrate acceptable results, which satisfy the acceptable performance levels. It is evident from Figure 11 that an increase in frontal overhang leads to an increase in frontal swing, for both laden and un-laden conditions. A negative result indicates that the frontal swing of the trailing unit did not exceed the frontal swing of the prime mover.

Table 5. Frontal swing of trailing unit.

Vehicle	FS max unladen (m)	FS max laden (m)	Frontal overhang (mm)
Refrigeration	0.20	0.16	1800
Side Curtain	0.17	0.12	1500
Tipper	-0.12	-0.18	385
Skeletal	0.19	0.14	1550
OECD	0.14	0.11	1300

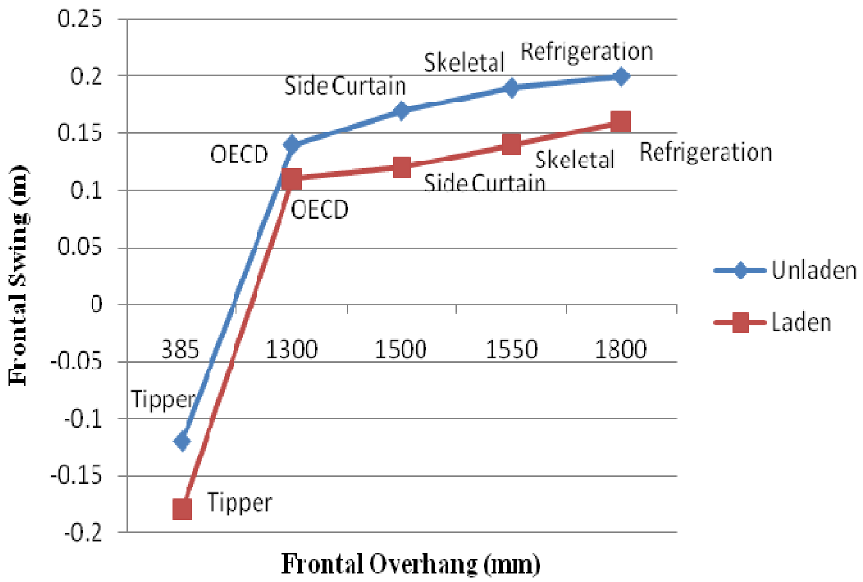


Figure 11. Simulation result – frontal swing of trailing unit.

Tailswing

Tailswing is important for vehicles with a large rear overhang, as they can pose a severe safety risk to other road users, thus a high value of tail swing is undesirable. The point of interest in this standard is the furthest rearward outside point of the last trailing unit. Tail swing is influenced by two parameters, namely wheelbase and rear overhang, an increase in trailer wheelbase and a decrease in rear overhang lead to improve vehicle performance.

Figure 12 illustrates the output plot from Trucksim of a tail swing for a semi-trailer combination. It is evident from the performance results in Table 6 and Figure13 that an increase in rear overhang of a vehicle has significant negative effect on the performance. Another important factor to note is that of mass; the change in results from unladen to laden show that an increase in vehicle mass has a negative impact on the directional response of the vehicle.

The performance range, 0.013-0.11 m, for all vehicles both laden and unladen are within an acceptable performance range. There was no tail swing evident at the exit side of the manoeuvre for all vehicles, both laden and unladen.

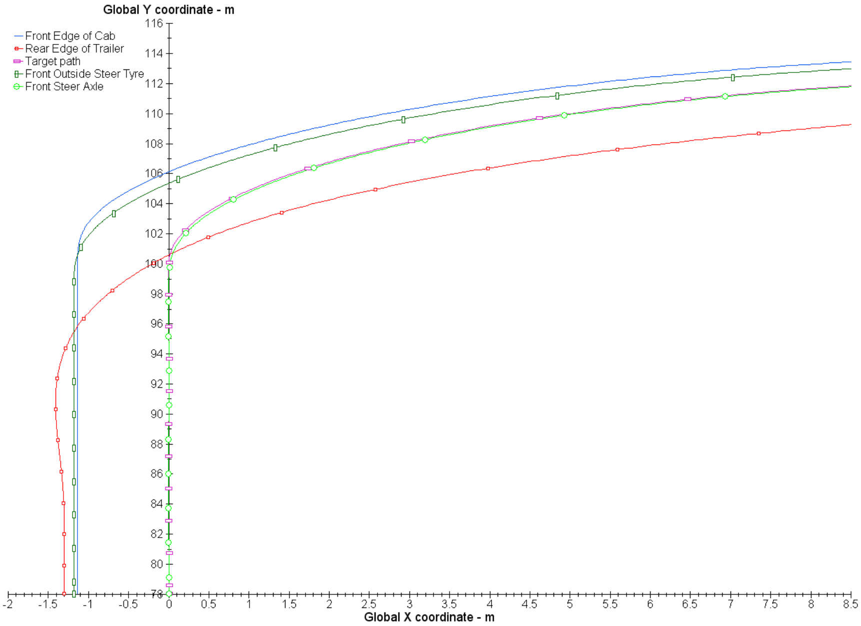


Figure 12. Simulation result – Tailswing of vehicle.

Table 6. Tailswing of vehicles.

Vehicle	Unladen		Laden		Rear overhang (mm)	Wheelbase (mm)
	TS entry (m)	TS exit (m)	TS entry (m)	TS exit (m)		
Refrigeration	0.094	No swing out	0.11	No swing out	2310	10 000
Side Curtain	0.032	No swing out	0.045	No swing out	1450	10 000
Tipper	0.013	No swing out	0.0198	No swing out	858	9 000
Skeletal	0.024	No swing out	0.036	No swing out	1300	10 000
OECD	0.053	No swing out	0.056	No swing out	1540	10 000

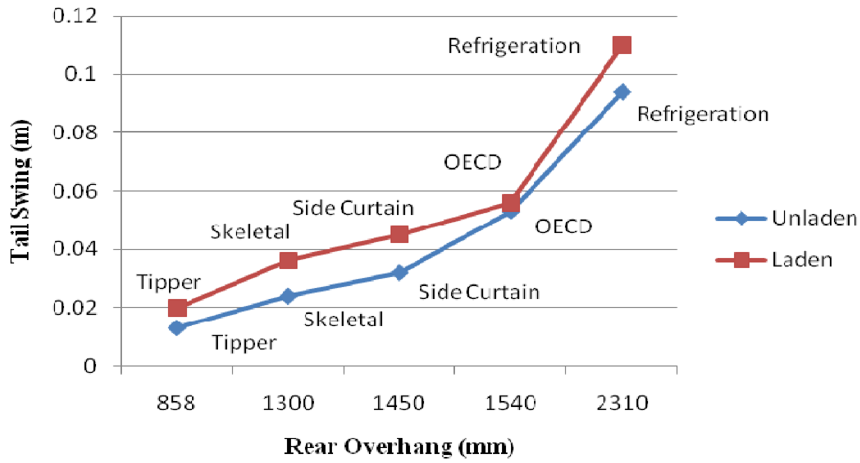


Figure 13. Influence tailswing to rear overhang.

Static rollover threshold

It is evident from Figure 14 that a simulated result of a typical semi-trailer performing a constant radius turn closely resembles an idealised graph of semi-trailer constant turn rollover in Figure 15. Figure 14 clearly illustrates semi-trailer group, drive group and steer axle lift off. Rollover occurs when there is an increase in lateral acceleration with a decrease in roll angle (see Figure 15); this correlates with the instant when the vertical forces, on all the tyres, on one side of the vehicle, excluding the steer axle, equal zero (see Figure 16). During the constant radius turn manoeuvre the vehicle must accelerate at a rate no greater than 0.5 km/h per second, around a circular track with a constant radius of 100 m. This increase in speed results in under steer, and the driver model must therefore increase the steer angle to counteract this effect in order to remain within the lateral deviation error limitations as evident in Figure 17.

Table 7 indicates that 80% of the vehicles achieved the 0.35 g minimum performance level for the circular test, whilst 100% of the vehicles achieved this same performance level for the tilt table procedure. The percentage deviation results range, 0.5-4.34%, indicates a good correlation between the two test procedures. The reason for the variation in results between the two SRT tests is that the circular test takes into account engine and driveline characteristics, whilst the tilt table test does not.

SRT is influenced by two primary parameters, namely height of CG (H) and track width (TW), a decrease in the height of CG and an increase in the track width both have a positive effect on the dynamic stability of the vehicle. The ratio of height of CG to track width indicates that a low ratio value results in an improved stability; this is illustrated in Figure 18.

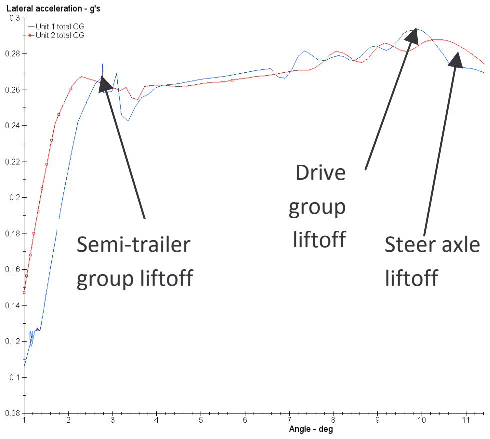


Figure 14. Simulation result – rollover of semi-trailer.

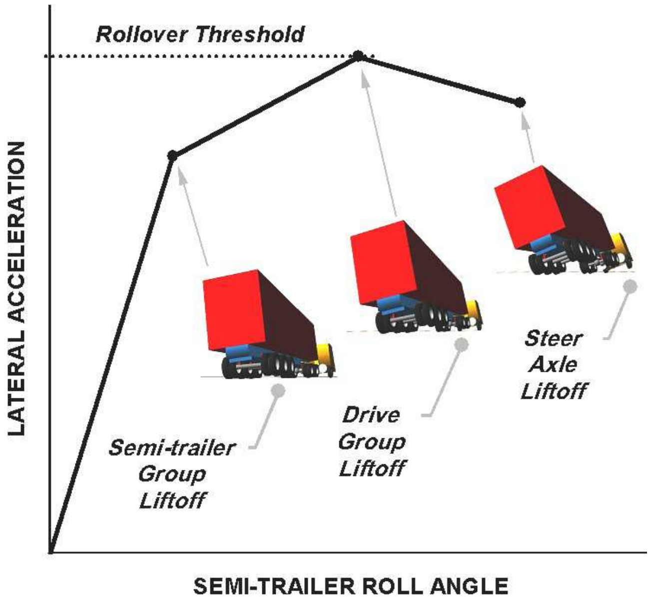


Figure 15. Idealisation of semi-trailer rollover.
NTC, Performance Based Standards Scheme, The Standards and Vehicle Assessment Rules, July 2007.

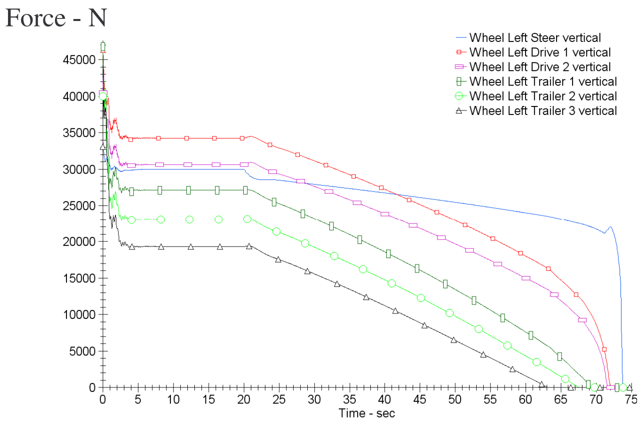


Figure 16. Simulation result – vertical tyre forces.

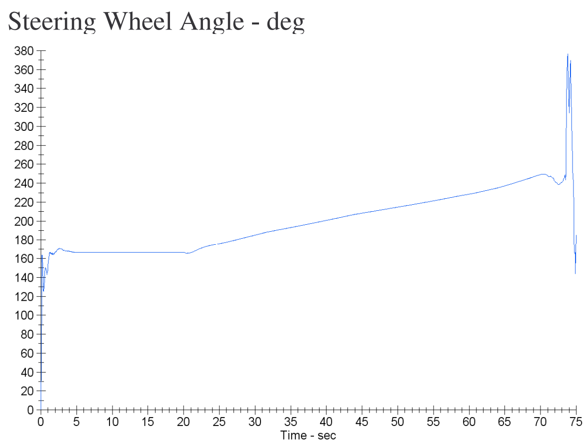


Figure 17. Simulation result – steering wheel angle.

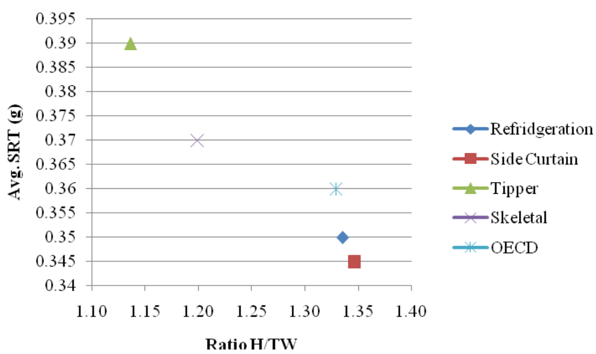


Figure 18. Illustration of ratio H/TW to average SRT.

Table 7. Static rollover threshold of vehicles.

Vehicle	LA - circular test (g)	Equiv LA - tilt table (g)	% deviation	Height of CG (mm)	Track width (mm)	Ratio H/TW
Refrigeration	0.34	0.35	1.86	2550.8	1910	1.34
Side Curtain	0.35	0.35	1.55	2571.8	1910	1.35
Tipper	0.39	0.39	1.05	2170.4	1910	1.14
Skeletal	0.36	0.36	0.5	2289.8	1910	1.20
OECD	0.36	0.38	4.34	2625.2	1975	1.33

Rearward amplification

The performance ranges shown in Table 8, 1.17-1.33, indicates that all vehicles experience a RA that meets the prescribed performance level. RA is influenced strongly by prime mover and trailer wheelbase, articulation points, tyre cornering stiffness and speed.

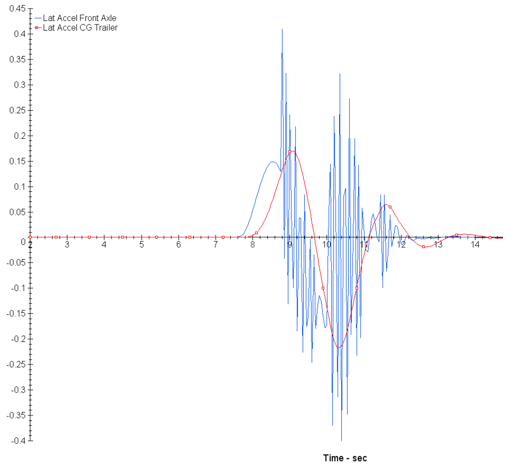
RA is mainly concerned with vehicles with more than one articulation point, for example B-double (interlink) and road train configurations, rather than those of single articulation semi-trailer configurations.

Previous literature surveys[5] indicate that Autosim[6] steer controllers do not perform as well as other models used to determine dynamic analysis. For this purpose the driver model preview[7] time was adjusted to achieve acceptable results. Figures 19 and 20 illustrate the change in lateral acceleration output of the front axle by adjusting the driver preview time. From Figure 18 it is evident that the driver workload will increase drastically in order to control the vehicle, compared with that of the workload associated with Figure 20.

Table 8. Rearward amplification of vehicles.

Vehicle	5.7 x SRT	LA rear unit (g)	LA steer axle (g)	RA
Refrigeration	1.995	0.08	0.07	1.23
Side Curtain	1.995	0.09	0.07	1.33
Tipper	2.223	0.08	0.07	1.17
Skeletal	2.052	0.08	0.07	1.20
OECD	2.109	0.08	0.07	1.25

[5] NRTC, Comparison of Modelling Systems For Performance Based Assessment Of Heavy Vehicles, Working Paper 2001.
[6] A generic version of Trucksim
[7] Trucksim Help Manual – Driver Controls



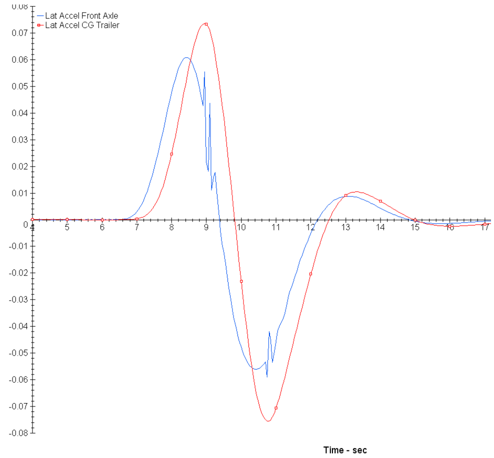


Figure 19. Simulation result – rearward amplification (original preview time).

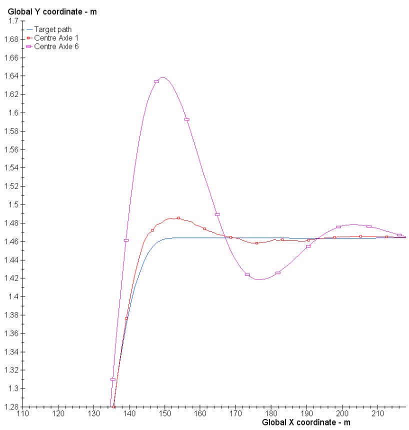
Figure 20: Simulation result – rearward amplification (adjusted preview time).

High Speed Transient Off-Tracking

When vehicles travelling at high speed perform a sudden evasive manoeuvre, the rear of the trailer may overshoot the desired target path. Parameters that influence HSTO are similar to those of RA, with the inclusion of mass, overall length and dolly types. From Table 9 it can be seen that the performance range, 0.17-0.19 m, satisfies the required performance level. Figures 21 and 22 illustrate the HSTO resulting from the simulation of 6-axle articulated vehicles performing an evasive manoeuvre.

Table 9. High speed transient off-tracking for vehicles.

Vehicle	Max overshoot (m)	Max target path (m)	HSTO (m)
Refrigeration	1.64	1.46	0.18
Side Curtain	1.65	1.46	0.19
Tipper	1.63	1.46	0.17
Skeletal	1.63	1.46	0.17
OECD	1.64	1.46	0.18



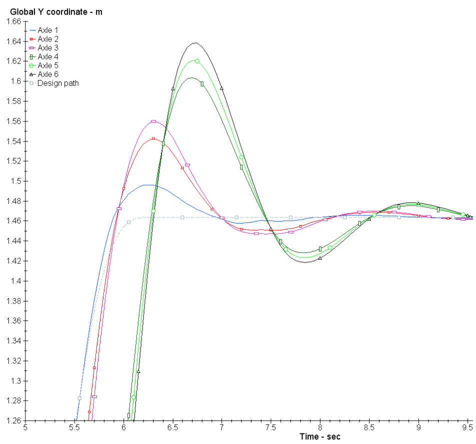


Figure 21. Simulation result – high speed transient off-tracking.

Figure 22: Simulation result – high speed transient off-tracking (all 6 axles).

Summary

Table 10. Summary of results for five semi-trailers assessed according to PBS measures.

Vehicle	Frontal Swing		Tail-swing	SRT	RA	HSTO	Performance level
	Part A	Part B					
Refrigeration	0.43	0.20	0.11	0.34	1.23	0.18	FAIL
Side Curtain	0.43	0.17	0.045	0.35	1.33	0.19	Pass - level 1
Tipper	0.43	-0.12	0.0198	0.39	1.17	0.17	Pass - level 1
Skeletal	0.43	0.19	0.036	0.36	1.20	0.17	Pass - level 1
OECD	0.43	0.14	0.056	0.36	1.25	0.18	Pass - level 1

Table 10 illustrates a summary for the five simulated vehicles according to six of the Australian PBS measures. As can be seen, four of the five vehicles achieved a performance level result according to level 1 criteria, therefore are capable of travelling on the entire road network.

However, one vehicle, Refrigeration, did not achieve the necessary 0.35 g for SRT, and is therefore not deemed stable and cannot achieve PBS status.

Future research

Future aspects of this research involve the analyses of various B-double combinations (7-axle truck tractor plus two semi-trailer 'interlink') to achieve a greater understanding of the dynamic performance of the most common heavy vehicles operating on the South African road network. Computer model verification through simulation comparisons will also be performed.

Conclusion

Simulations have been used to quantify the longitudinal and directional performance of a number of heavy vehicles on SA roads. Although the results need to be verified using physical measurements and computer simulation verification, this process provides a valuable system to evaluate the dynamic performance of vehicles. It also provides a valuable tool to assess possible changes in vehicle design that could improve performance without having to physically build a prototype.

To overcome the current constraint of road safety and congestion, SA will have to investigate the use of PBS vehicles. There are currently two PBS demonstration vehicles operating in the timber industry that have been developed at great expense by using overseas consultants; this system would enable consultants to evaluate certain designs locally, thus saving substantial amounts on cost.

The system could also be used to ensure adequate designs of current vehicles. It has already been shown that some current vehicles are not safe and this system enables one to explore changes to the design to ensure improved safety. For example, the refrigeration vehicle did not achieve the necessary 0.35 g SRT value in the circular test, which would then classify it as unstable.

South Africa is in the process of acquiring additional PBS vehicles in the forestry industry to increase the scale of the PBS demonstration project, which will allow for greater future development.

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