

**AN INITIATIVE TO INTRODUCE A PERFORMANCE-BASED STANDARDS (PBS)
APPROACH FOR HEAVY VEHICLE DESIGN AND OPERATIONS
IN SOUTH AFRICA**



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Abstract

The introduction of PBS for heavy vehicles in South Africa was first identified in the National Overload Control Strategy as a potential concession of a proposed self-regulation initiative. In August 2004 a PBS committee was established to investigate PBS and the following initial tasks were identified: 1) develop a PBS strategy; 2) review the status of PBS in other countries; and, 3) initiate pilot projects to demonstrate the potential benefits of PBS. Two concept designs (a truck/trailer and a B-double) were initially developed and considered. The truck/trailer concept vehicle was selected, and after a number of iterations a satisfactory vehicle design was achieved. At a total mass of 67.5 t and length of 27 m the new combination satisfies the PBS performance standards considered and delivers a payload increase of 15%. By contrast, the baseline vehicle with lower payload capacity was not able to satisfy several PBS performance requirements.

Keywords: Performance-based standards, heavy vehicles, self-regulation, vehicle safety, productivity.

Résumé

L'introduction des normes de performance (PBS) pour les poids lourds en Afrique du Sud a été d'abord considéré comme une possible concession pour une initiative d'auto-régulation dans la stratégie nationale du contrôle des surcharges. En août 2004 un comité ad hoc a été constitué pour étudier le sujet et les tâches suivantes identifiées pour commencer: 1) développer une stratégie de PBS; 2) regarder l'état des PBS dans les autres pays; et 3) démarrer des projets pilotes pour montrer les avantages potentiels des PBS. Deux concepts de silhouette (un tracteur à remorque et un B-double) ont été d'abord conçus et considérés. Le véhicule tracteur à remorque choisi a fait l'objet d'itérations jusqu'à obtenir un véhicule satisfaisant. Avec une masse totale de 67,5 t et une longueur de 27 m, ce nouvel ensemble satisfait aux normes de performance PBS et permet de transporter 15% de charge en plus. A contrario, le véhicule de base avec une capacité d'emport plus faible ne satisfaisait pas aux exigences de performance de plusieurs PBS.

Mots-clés : norme de performance, poids lourds, auto-régulation, sécurité des véhicules, productivité.

1. Introduction

South Africa's economic well-being is directly affected by the efficiency of its freight logistics system, especially with regard to manufactured goods and raw materials. One of the significant problems in South Africa is that many of the major manufacturing areas are located great distances from the sea ports and to a lesser extent, from airports. The bulk of local product costs to customers are rooted in the cost of transport of these goods from the point of production to the point where they are finally loaded onto ships and aircraft for transportation to foreign destinations, and logistics costs have been identified as a constraint to South Africa's competitiveness (Department of Transport, 2005). One of the purposes of introducing Performance-Based Standards (PBS) vehicles is to improve transport productivity by reducing the costs associated with transporting raw materials and minimising the cost of delivery to customers. A significant spin-off lies in the enhanced safety features inherent in the design of these vehicles.

Current standards for vehicles focus on their ability to adequately haul their loads up inclines, ensure that their braking systems adequately decelerate the vehicle when fully loaded, negotiate curves, and undertake certain manoeuvres without becoming unstable. Loading legislation focuses on axle and axle unit loadings, the maximum permissible vehicle and combination masses, as well as the so-called "bridge formula". While the current standards for vehicles address a range of safety issues, there are some aspects of heavy vehicle safety performance that are not adequately controlled by these regulations.

The PBS approach addresses factors for which vehicle designers and road safety practitioners have always had a healthy respect, in particular the highly important aspect of a vehicle's stability and dynamic performance. PBS vehicles must thus comply with certain prescribed static and dynamic performance standards such as Maximum Swept Path, Acceleration Capability, Steer Tyre Friction Demand, Static Rollover Threshold (SRT), High Speed Transient Offtracking and Rearward Amplification.

Designing vehicles to safely carry greater loads is only one aspect of PBS. Another important aspect is the design enhancements and features that make it possible to achieve higher levels of safety. In this regard, greater commitment and diligence are required of operators to properly maintain their vehicles. Similarly they will also have to ensure that loads are properly positioned and, where necessary, secured.

If PBS vehicles are introduced into South Africa, it would be essential for their owners to implement higher standards of management and loading of those vehicles. In this respect, the Road Transport Management System (RTMS) offers a solution. The introduction of PBS vehicles should also be considered against the background of the mechanisms of road wear, which is accelerated not only by heavy (overloaded) axle loads, but also by the significant changes that have been introduced in heavy vehicle tyre technology. This is particularly relevant to countries such as South Africa where roads with light pavement structures (paved low volume roads) are very common. The effect of the trend of increasing heavy vehicle tyre pressures during the past few decades has been to reduce the size of the contact patch between the tyre and the road surface, inducing far greater stresses in the upper layers of road pavements. Improving freight logistics by introducing PBS should therefore be approached with an appreciation for the additional need to introduce more effective operational management procedures, and vehicles that are "kinder" to road pavements.

2. The Road Transport Management System (RTMS)

RTMS is an industry-led, voluntary self-regulation scheme that encourages consignees, consignors and transport operators engaged in the road logistics value chain to implement a vehicle management system that promotes the preservation of the road infrastructure, the improvement of road safety and an increase in the productivity of the logistics value chain (National Productivity Institute, 2006; Nordengen and Oberholzer, 2006). This scheme also supports the Department of Transport's National Freight Logistics Strategy (Department of Transport, 2005).

All players in the road logistics value chain are aware of the problems concerning road logistics that affect their industries. The road infrastructure is deteriorating rapidly due to, inter alia, overloading and there are an unacceptable number of accidents attributed to heavy trucks (see Figure 1). Both road safety and road infrastructure protection are public concerns subject to strict regulation by governments, particularly when abused. Overregulation, road deterioration and high accident rates pose a significant threat to the long term sustainability and global competitiveness of the road logistics value chain.

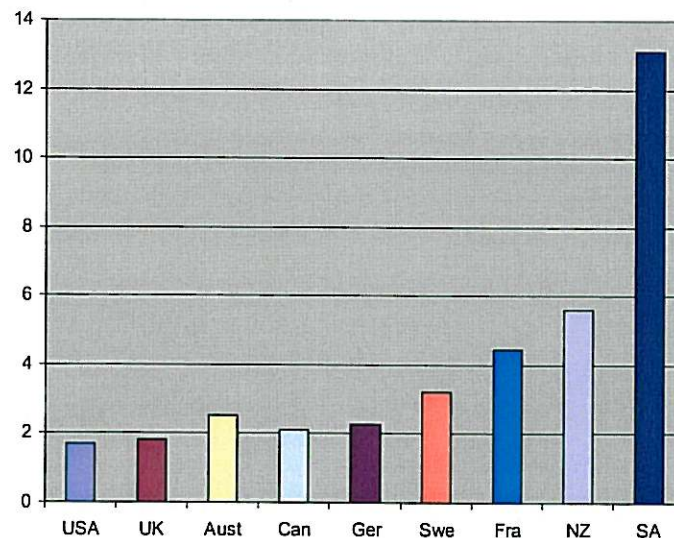


Figure 1 - Benchmarking heavy vehicle safety – heavy vehicle fatalities per 100 million kilometres (2002) (Moore, 2007)

This has prompted users of road haulage (consignors and consignees) and providers of road haulage (transport operators) to jointly develop strategies aimed at protecting the road network, improving road safety and transport productivity for the benefit of the country's citizens and the industry itself.

The industry also recognises that poor compliance to transport regulations creates an unfair competitive environment. It was, therefore, felt that a self-regulation scheme is required to create standard rules for the industry, and that these rules should become the "business norm" - supporting the principles of good corporate governance. It is for this reason that industry is leading this initiative, to ensure its quick adoption by all businesses participating in the road logistics value chain.

Furthermore, industry recognises its critical role in the economy's growth. Efficient movement of goods between a country's centres of production and its centres of export boosts competitiveness in international markets. RTMS is one of the key innovative and pro-active initiatives that will make this possible.

3. PBS as a concession of the Road Transport Management System

PBS could play a significant role in improving productivity and safety in the transport industry, which in turn is vital for the country's competitiveness in international markets. It is essential that all PBS participants are certified in accordance with the RTMS accreditation scheme to avoid the situation where truck and trailer manufacturers start designing vehicles on an ad hoc basis. It should be borne in mind that PBS vehicles are designed to include certain safety features, and be loaded in the correct manner, and that the RTMS approach offers the most suitable way of ensuring that these requirements are met.

The idea is that the PBS vehicle design approach is not bound by the accepted prescriptive standards and that a redesigned vehicle will still conform to road infrastructure and safety conservation principles.

As an example, PBS-designed vehicles could, therefore, safely carry heavier loads with no additional effects on the road network apart from normal deterioration. This will have a positive effect on the productivity and safety record of the transport industry.

4. Support of the Department of Transport

The Department of Transport (DoT) fully supports the self-regulation approach of the RTMS because it contributes to the overall aim of improving the productivity of the transport logistics value chain, which will in turn contribute to the growth of the economy.

With reference to the specific request to support the proposed PBS initiative and demonstration projects:

- The DoT supports the initiative with the understanding that it seeks to improve system efficiency by optimising truck payloads, improving truck safety and protecting road infrastructure through innovative vehicle design and technology application.
- The DoT maintains that exceeding current dimension and load limits should be restricted to the demonstration projects for evaluation purposes, if such approval is obtained. For full scale roll-out, the heavy vehicle owners will need to demonstrate innovation in increasing payload through vehicle design and technology within the current load and dimension limits. If Government is convinced that vehicle owners have explored this approach sufficiently, then the larger vehicle load and dimension concessions could be considered for vehicle owners that have a proven track record of self-regulation (e.g. those within the RTMS or those complying with the national standards in this regard).
- Government acknowledges the RTMS to be an industry-led process, and will support it as such in accordance with the recommendations of the National Overload Control

Strategy (Department of Transport, 2004). As such, industry has to ensure sustainability of the initiative beyond pilot stage.

Government will continue to implement its regulatory interventions and ensure compliance with legislation through intensified law enforcement, while acknowledging any specific concessions that may be granted to the self-regulation initiatives.

5. Objectives

The over-arching objective of PBS is to design heavy vehicle combinations that conform to road infrastructure and safety conservation principles and according to specific standards as a point of departure, but accepting that some of the constraints in the current prescriptive regulations may be relaxed to allow for the PBS approach to be optimised.

Individual role players, however, have their own objectives that should be borne in mind:

Government (National and Provincial)

- Reducing infrastructure damage
- Improving road safety
- Reducing the burden of law enforcement
- Improving freight logistics – cost and time
- Supporting transport efficiency and productivity
- Improving South Africa's global competitiveness
- Improving awareness
- Improving compliance with the Road Traffic Act

Industry

- Improving efficiency, productivity and profit
- Supporting competitiveness
- Creating a level playing field – promoting fair competition
- Complying with best practice standards
- Improving road safety – reducing cost of accidents
- Promoting professionalism
- Complying with corporate governance standards

6. Demonstration Projects

Because the RTMS self-regulation scheme was initiated in the forestry industry, it was identified as the logical industry to commence with PBS demonstration projects. Both Sappi Forests (Pty) Ltd (Sappi) and Mondi Business Paper (Mondi), the two major timber growers and pulp and paper companies in South Africa, decided to initiate PBS demonstration projects, and both companies set up project teams consisting of various manufacturers, suppliers and consultants. Sappi approached and subsequently appointed Mechanical System Dynamics Pty Ltd (MSD) in Australia to assist with the development and analysis of the PBS vehicle.

Two concept vehicle designs, a truck/trailer and a B-double, were initially developed and considered by the project team. The team comprised representatives from Sappi, truck (DaimlerChrysler South Africa (Pty) Ltd), trailer (Afrit) and suspension (BPW Axles (Pty)

Ltd) manufacturers, a transport operator (Timber24), CSIR Built Environment and MSD. At the outset a number of important design parameters were decided and set; some were outside the direct control of the project team, while others – set by Sappi – were directly related to the timber product (log lengths) and the requirements of the current and expected future log transport task. For example, maximum overall length was controlled by the regulators, maximum axle loads and spacing was consistent with the prevailing pavement and bridge load requirements, and safety items linked to the current regulations were retained. While there was a clear focus on productivity, in view of the number of rollovers and crashes reported by operators, safety performance was given a high priority, so much so that a loss of productivity was considered to be acceptable if it meant a higher level of safety could be achieved. Therefore, it was a primary design goal and requirement that the vehicle should have acceptable safety performance and meet all of the applicable PBS safety standards.

Using the current log transport vehicles as a baseline, an example is shown below in Figure 2, and the concept designs as proposal PBS vehicles, state-of-the-art numerical modelling was used to establish benchmark performance levels and to guide and assess the new designs to achieve performance levels that would satisfy the PBS performance requirements and the transport task.



Figure 2 – Example baseline vehicle comprising a rigid truck towing a 4-axle drawbar trailer.

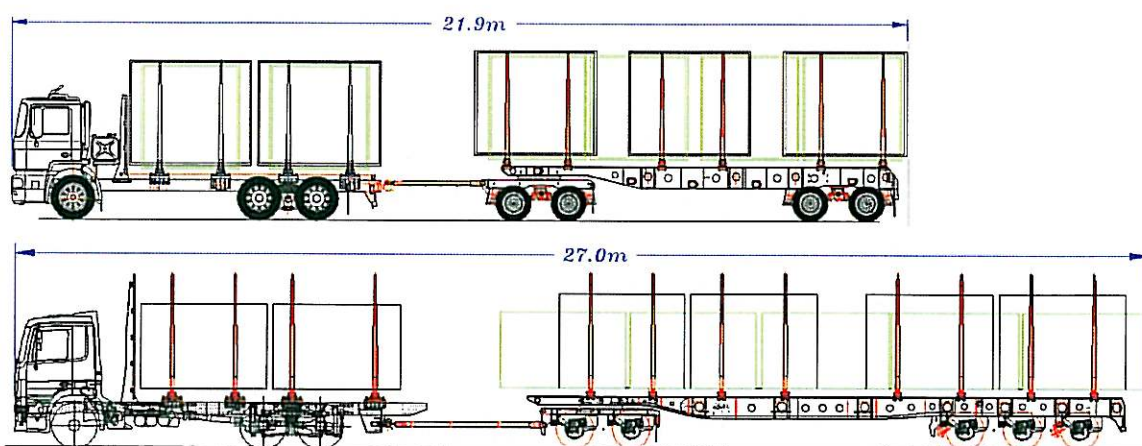


Figure 3 - Baseline (top) and PBS (bottom) vehicles at 58.8 t and 67.5 t GCM, respectively

The truck/trailer concept vehicle, comprising a three-axle rigid truck towing a five-axle drawbar trailer, was selected in favour of the B-double, and after a number of iterations a satisfactory vehicle design was achieved. At an overall length of 26.4 m and 27.0 m for the 4

and 5-bundle trailer log-loads, respectively, and a gross weight of 67.5 t, the truck/trailer combination satisfies the PBS performance standards considered and delivers an increase in payload capacity of 15%. By contrast, the baseline vehicle with both a lower gross weight (58.8 t) and payload capacity was not able to satisfy several PBS performance requirements, as described in the following section.

Side view drawings that highlight and contrast the key aspects of the baseline and proposal PBS vehicles are shown below in Figure 3.

7. Design Criteria

Drawing on the PBS standards developed in Australia jointly by the National Transport Commission (NTC) and Austroads, the following performance measures were chosen and considered in the performance analysis. These are a subset of the complete set of PBS standards (National Transport Commission, 2007a) and relate specifically to safety performance relevant to this assessment:

- 1) Tracking Ability on a Straight Path – the vehicle’s total swept width while travelling on a straight path, including the influence of variations due to crossfall, road surface unevenness and driver steering activity.
- 2) Low-Speed Swept Path – the maximum width of the vehicle’s swept path in a prescribed 90° low-speed turn.
- 3) Steer Tyre Friction Demand – the maximum friction level demanded of the prime mover steer tyres in a prescribed 90° low-speed turn.
- 4) Static Rollover Threshold – the steady state level of lateral acceleration during a constant-radius steady-speed turn that the entire vehicle can sustain without rolling over.
- 5) Rearward Amplification – the degree to which the trailers in a combination amplify the lateral acceleration of the prime mover in a prescribed lane change manoeuvre.
- 6) High-Speed Transient Offtracking – the maximum lateral distance, or sideways distance, that the last-axle on the rearmost trailer tracks outside the path of the steer axle in a prescribed lane change manoeuvre.
- 7) Yaw Damping Coefficient – the rate at which “sway” or yaw oscillations of the trailers take to “settle down”.

8. PBS Assessments and Results

For PBS assessment of the two concept vehicles and baseline (benchmark) vehicle, three numerical models were created using the ADAMS multi-body dynamics simulation software package (MSC.Software, 2007) and MSD’s *Atruck*TM toolbox. One model represents the truck/trailer combination, the second represents the B-double combination, and the third the baseline vehicle. In the final analysis only the truck/trailer design was taken through to manufacture.

In the modelling mechanical properties were assigned to components (sprung and unsprung masses, suspension, tyres, etc) consistent with components on each vehicle considered. To define datasets for each model, performance data and mechanical properties were obtained from various sources, including component suppliers for suspensions and tyres, Afrit for trailer details, a previous major study of the performance of the Australian heavy vehicle fleet

(Prem et al, 2002), and, where necessary, drawing from MSD's extensive heavy vehicle database and library.

For the analysis best estimates of the sprung mass CG heights were used based on information supplied by Afrit, individually modelled tyres, dolly and semi-trailers. Suspensions and tyres in each of the vehicle models were represented as non-linear systems incorporating state-of-the-art features - some general examples can be found in National Transport Commission (2007a) and Prem et al (2002). Where component level test data were supplied (suspensions and tyres, for example) the component models were adjusted and tuned to accurately reproduce the measured performance characteristics.

General views of the truck/trailer numerical model with the 4 and 5-bundle log loads are shown below in Figure 4.

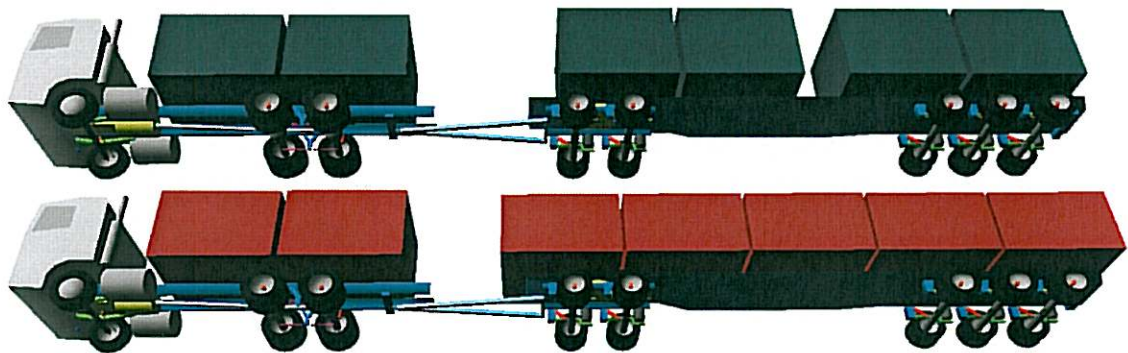


Figure 4 - Numerical models of PBS vehicle showing the trailer with 4 and 5-bundle log loads (top and bottom images, respectively) created in ADAMS with MSD's *Atruck*TM toolbox.

A range of simulations were performed using the numerical models and the precisely defined test conditions specified under PBS. The simulations comprised a low-speed 90° turn, high-speed travel along a 1.0 km long section of uneven surface in the presence of representative driver steering activity, a steady turn, a lane change manoeuvre, and a pulse-steer test. At the conclusion of the simulations the specified vehicle responses were analysed and the performance values calculated.

The main results of the PBS analysis are presented below in Table 1, which shows the PBS performance requirements for the various levels of road access in the right hand columns and the corresponding performance values from the analyses and associated road class access level in the middle three columns for the two design proposals and baseline vehicle. Under PBS in Australia, access to road class Levels 1 to 4 (L1 to L4), respectively, denote "General Access", "Significant Freight Routes", "Major Freight Routes" and "Remote Areas". Further information on the road classification system can be found in National Transport Commission (2007b). Further, a vehicle can only be granted access to a particular route if it meets all of the performance requirements specific to that route.

The results show that the baseline vehicle (current truck/trailer) fails to achieve the required PBS performance level on two of the safety standards. These are Static Rollover Threshold (performance = 0.305g, performance requirement is >0.35g) and Rearward Amplification (performance = 1.990, performance requirement is <1.738). By contrast the proposal

truck/trailer (4 and 5-bundle variants) satisfies the PBS performance requirements at PBS Level 2 (L2). In addition, the baseline vehicle has a significantly higher value for high-speed transient offtracking, achieving a performance outcome consistent with PBS L3 road network access. In Australia vehicles assigned PBS Level 3 (L3) status are generally restricted to road train routes. Table 1 results show the only area where the proposal vehicle performs significantly worse than the baseline vehicle is in low-speed turns, where due to its longer overall length and, in particular, much longer trailer, the Low-Speed Swept Path width is greater.

Table 1 – Summary of PBS results for baseline and PBS truck/trailer.

#	Performance Standard	Performance Value (Access Level)			Performance Requirement			
		Concept Vehicle		Baseline	L1	L2	L3	L4
		(4-bundle)	(5-bundle)					
		(67.5t, 26.4m)	(67.5t, 27.0m)	(58.8t, 21.9m)				
1	Tracking Ability on a Straight Path	2.89 (L1)	2.90m (L1)	2.89m (L1)	=2.9m	=3.0m	=3.1m	=3.3m
2	Low-Speed Swept Path Width	8.20m (L2)	8.20m (L2)	6.62m (L1)	=7.4m	=8.7m	=10.1m	=13.7m
3	Steer Tyre Friction Demand	21% (L1)	21% (L1)	18% (L1)	=80%			
4	Static Rollover Threshold	0.354g (L1)	0.354g (L1)	0.305g (-)	=0.35g (=0.40g road tankers/buses)			
5	Rearward Amplification*	1.767 (L1)	1.812 (L1)	1.990 (-)	=5.7 SRT_{rcu} (2.205, 2.428, 1.738)			
6	High-Speed Transient Offtracking	0.67m (L2)	0.68m (L2)	0.81m (L3)	=0.6m	=0.8m	=1.0m	=1.2m
7	Yaw Damping Coefficient	0.23 (L1)	0.27 (L1)	0.26 (L1)	=0.15			

* - SRT_{rcu} denotes SRT of the rearmost roll-coupled unit which may be different to the vehicle's SRT value.



Figure 5 – The as-built PBS truck/trailer (supplied courtesy Sappi, Afrit and Timber24)

9. Operation and driver feedback

The PBS vehicle commenced operations on 29 October 2007 and by 21 November had completed 36 trips with an average payload of 47.1 t. Detailed monitoring of the vehicle and comparison with the control vehicle is ongoing. Monitoring parameters include payload, trip times, fuel efficiency, average speed (empty and laden), drive train maintenance costs, tyres, accidents/incidents and feedback from other road users.

Initial feedback from the drivers has been very positive in terms of stability and manoeuvrability, which supports the improved performance features evidenced in the PBS vehicle compared with the baseline vehicle (Table 1).

10. References

- Department of Transport (2004). *National Overload Control Strategy*. DoT, Pretoria, South Africa, March 2004.
- Department of Transport (2005). *National Freight Logistics Strategy*. DoT, Pretoria, South Africa.
- Moore, B. (2007). *An integrated approach to the regulation of heavy vehicles*. Prepared for Special Session SP11, 23rd World Roads Congress, Paris. September 2007.
- MSC.Software (2007). "MSC.ADAMS". <<http://www.mscsoftware.com>> MSC.Software Corporation, USA. (November 15, 2007).
- National Transport Commission (2007a). *Performance Based Standards Scheme – The Standards and Vehicle Assessment Rules*. Prepared by National Transport Commission: Melbourne, Vic. July 2007.
- National Transport Commission (2007b). *Performance Based Standards Scheme – Network Classification Guidelines*. Prepared by National Transport Commission: Melbourne, Vic. July 2007.
- Prem, H., de Pont, J., Pearson, R.A. and McLean, J.R. (2002). *Performance Characteristics of the Australian Heavy Vehicle Fleet*. Prepared for National Road Transport Commission: Melbourne, Australia. February 2002.
- National Productivity Institute (2006). *Road Transport Management System Five-Year Strategy*. NPI, Midrand, South Africa, October 2006.
- Nordengen, P A and Oberholzer, F. (2006). A self regulation initiative in heavy vehicle transport to address road safety, accelerated road deterioration and transport productivity in South Africa. *Proc. Ninth International Symposium on Heavy Vehicle Weights and Dimensions, Penn State University, State College, USA, June 2006*.
- Standards South Africa (2007). *ARP 067-1: Road Transport Management Systems: Part 1: Operator Requirements – Goods*. ISBN: 978-0-626-19331-7. SABS, Pretoria, South Africa, 2007.