Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

Improving heavy vehicle safety and road transport efficiency: a Performance-Based Standards approach in South Africa

P.A. Nordengen[a,*], C.C. de Saxe[a], R. Berman[a], A. Steenkamp[a], J. Deiss[b]

[a]*CSIR Built Environment, Pretoria, 0001, South Africa*
[b]*University of the Witwatersrand, Johannesburg, 2001, South Africa*

Abstract

As part of a performance-based standards (PBS) research programme for heavy vehicles in South Africa, a need was identified to design and operate a number of PBS demonstration vehicles in a pilot project. The purpose of the project is to gain practical experience in the PBS approach and to quantify and evaluate the potential infrastructure preservation, safety and productivity benefits for road freight transport. To date, 450 permits for PBS demonstration vehicles (including 200 car-carriers) have been issued. The pilot project reached the minimum target of 100 million PBS vehicle kilometres in June 2017. The project has shown significant improvements with a reduction in the crash rate of 39% compared with the baseline fleet. Significant financial savings have also been recorded with a weighted average reduction in trips of 28% and an average reduction of 12.2% in fuel consumption and CO_2 emissions. The project has thus far shown the possibility to improve heavy vehicle safety and decrease road freight transport costs by several percentage points. This paper provides an overview of the PBS pilot project including measured benefits based on the monitoring data.

Keywords: Performance-based standards for heavy vehicles; Smart Trucks; Road Transport Management System (RTMS); heavy vehicle safety; heavy vehicle productivity

* Corresponding author. Tel.: +27-12-841-3945; fax: +27-12-841-4044.
E-mail address: pnordengen@csir.co.za

Nomenclature

ALTC	Abnormal Loads Technical Committee
COTO	(South African) Committee of Transport Officials
OECD	Organisation for Economic Co-operation and Development
RTMS	Road Transport Management System
PBS	Performance-Based Standards

1. Introduction

According to the 2016 Logistics Barometer, the cost of road freight transport in South Africa during 2016 was 5.52% of GDP (Havenga *et al.*, 2016). Currently approximately 85% of freight in South Africa is transported by road. In addition to the high costs of road freight transport in South Africa, a 2011 OECD report, "Moving Freight with Better Trucks", shows that South Africa experienced in excess of 12.5 road fatalities per 100 million heavy vehicle km travelled in 2005, compared with rates ranging from 0.8 to 3.0 of the other countries included in the study (OECD, 2011). The disproportionately high cost of road freight transportation and road deaths are a serious concern for South Africa and have a significant negative effect on the economy.

Typically, heavy vehicle use on road networks is controlled by prescriptive regulations, where vehicle performance is governed indirectly by regulating vehicle mass and dimensions. These regulations may differ significantly from country to country, and efforts in various parts of the world to achieve regional harmonisation have been time-consuming or have had limited success. Furthermore, in trying to be a one-size-fits-all solution, prescriptive regulations can and do result in some vehicle designs that are inherently unsafe on the road, or which impose excessive loading on the infrastructure.

An alternative approach to heavy vehicle regulation is to consider actual on-road performance of heavy vehicles, and to specify minimum safety and infrastructure performance measures: a Performance-Based Standards (PBS) approach (OECD, 2005; NTC, 2008). The PBS approach has been a proven method to improve both heavy vehicle safety (reduced crashes) and productivity (lower costs), whilst also reducing the impact the vehicles have on the road infrastructure (road wear/tonne of payload) and the environment (reduced emissions) (Kienhöfer *et al.*, 2013).

In addition, the PBS approach gives vehicle designers and operators greater flexibility in implementing innovative heavy vehicle designs, leading to more productive and efficient road freight logistics solutions. This results in a better "match" between the vehicle and road infrastructure (roads and bridges). PBS vehicles are typically longer and/or heavier than standard "prescriptive" vehicles, and are therefore limited to a specific subset of the road network that has been assessed as suitable, to ensure the safety of other road users and the protection of the road infrastructure.

As a result of successful initiatives in Australia, New Zealand and Canada (NTC, 2008; De Pont, 2010; Billing and Madill, 2010), the application of PBS in the heavy vehicle sector in South Africa was identified by the Department of Transport as a research area warranting investigation. The potential benefits were seen to be: improved road/vehicle safety, improved transport efficiency, reduction in vehicle trips and congestion, and improved protection of road infrastructure and the environment (Nordengen, 2012).

The South African Draft Green Transport Strategy: (2017-2050) identifies the need to reduce greenhouse gas emissions in South Africa by 5% in that period. It also speaks of "immediate and targeted interventions" to reduce heavy vehicle emissions (DoT, 2017). Besides the reduction of crash rates and heavy vehicle trips, a reduction in CO_2 emissions per tonne.km has been one of the key driving factors behind the PBS pilot project.

A need was identified to design, manufacture and operate a number of PBS demonstration vehicles in South Africa as part of a pilot project in order to gain practical experience in the PBS approach and to quantify and evaluate the potential benefits. Operators of PBS vehicles are required to be certified through the Road Transport Management System (RTMS) self-regulation accreditation scheme (Nordengen and Oberholzer, 2006), which is based on a national standard, SANS 1395 (Standards South Africa, 2014). The RTMS originated from recommendations of the South African National Overload Strategy (Steyn *et al*, 2004), which sought to address the problem of heavy vehicle overloading and constraints regarding overload control enforcement. A PBS steering committee was established in 2004, representing stakeholders from government, academia and industry, and a PBS strategy, with defined objectives, was developed (PBS Steering Committee, 2007). In an effort to encapsulate the objectives of the PBS pilot project, and for the purpose of communication with various stakeholders and the public at large, the Steering Committee decided to introduce the term "Smart Truck" to refer to PBS demonstration vehicles.

Initially two PBS demonstration projects were implemented in 2007 in the forestry industry (Nordengen *et al.*, 2008; Nordengen, 2010), which were designed and manufactured to comply with the Level 2 safety standards of the Australian PBS system. These include directional and non-directional manoeuvers such as acceleration capability, slow speed swept path, static rollover threshold, yaw damping and rearward amplification. The positive performance of the pilot project has resulted in the approval to date of 450 additional permits for PBS demonstration vehicles, including 200 car-carriers (De Saxe and Nordengen, 2013). Guidelines for participation in the Smart Truck pilot project have been developed by the National Department of Transport's Smart Truck Review Panel (DoT, 2017). These guidelines describe the process that a transport operator is required to follow in order to participate in the pilot project, monthly data requirements for both PBS vehicles and baseline vehicles for the purpose monitoring and sanctions that will be imposed for various categories of non-compliance. Baseline vehicles are conventional legal vehicles operated by the same operator and performing the same freight task on the same route, and provide a valuable comparison against which to measure the performance of the PBS vehicles. The infrastructure performance standards are based on South African methodologies for pavement and bridge design loading analyses.

2. Research method

For the purpose of the PBS pilot project in South Africa, it was decided to make use of international heavy vehicle PBS research, development and implementation. After reviewing the PBS initiatives in Australia, Canada and New Zealand (NTC, 2008; Billing and Madill, 2010; De Pont, 2010), the Australian PBS scheme was selected as the basis for the South African PBS project. It was recognised that if this scheme was adopted by the SA Department of Transport in the long term, it would need to be adapted to accommodate South African-specific conditions (*e.g.* maximum vehicle width is 2.5 m in Australia and is 2.6 m in South Africa). After consideration of both the safety and infrastructure performance standards contained in the Australian PBS scheme, it was decided that only the safety performance standards would be used; infrastructure performance standards have been developed based on existing approaches in South Africa for pavement and bridge design and assessment. The safety performance standards include low-speed swept path (LSSP), tail swing (TS), static rollover threshold (SRT), rearward amplification (RA), yaw damping co-efficient (YDC), high-speed transient off-tracking (HSTO) and tracking ability on a straight path (TASP).

For road pavements, the current South African Mechanistic-Empirical Design and Analysis Methodology (SAMDM) (Theyse *et al*., 1996), which is the basis of the South African pavement design manual for flexible pavements, TRH4 (DoT, 1996), is used to assess the relative road wear of the proposed PBS vehicle combination and a representative baseline vehicle. The requirement for PBS demonstration vehicles is that the road wear per tonne of payload of the PBS vehicle must be less than the equivalent road wear of the baseline vehicle. As the number of different PBS demonstration vehicles increases, the intention is to develop a set of road wear benchmarks (for different vehicle configuration categories) against which proposed PBS vehicles can be assessed. To ensure the acceptable safety of structures, a computer application that was originally developed for assessing the effect of abnormal load all-terrain mobile cranes on structures, compares maximum bending moments and shear forces generated on a range of span lengths (including two- and three-span continuous structures) by the vehicle being assessed with those of a reference load, in this case the South African TMH7 NA and NB30 bridge design loads.

As part of the pilot project, PBS assessments of a baseline vehicle and the proposed PBS design are required. The assessment of the baseline vehicle highlights any safety shortcomings of a legal vehicle (that meets all the heavy vehicle prescriptive requirements). The assessment of the proposed PBS vehicle may be iterative, with design modifications eventually resulting in a final design that meets all the PBS requirements.

Monitoring data are required to be submitted by the operators of PBS vehicles on a monthly basis. Data for all PBS vehicles as well as data from a representative sample of baseline vehicles operating on the same or similar routes include:

- Kilometres travelled per vehicle per month
- Number of trips
- Tonnage transported
- Fuel used
- Crash information

3. PBS pilot project progress

To ensure the success of the PBS initiative, for the benefit of all stakeholders (government, industry, and society), all the identified pilot project objectives should be addressed. The pilot project has made significant progress in the defined objectives to date.

3.1. PBS concept

The concept of PBS has been successfully introduced in South Africa. The underlying ethos of the performance-based standards approach to heavy vehicle design, and its value and importance, particularly in terms of vehicle safety, have been disseminated to large portions of the transport and related sectors, with many industry and government representatives participating and promoting the observed benefits of the PBS approach.

3.2. PBS committees

A PBS (Smart Truck) Review Panel and PBS Steering Committee have been formed. The Review Panel guides and manages the project and consists of key experts from government, CSIR and academia. The Steering Committee consists of a wider range of representatives from participating industries, where ongoing industry feedback is provided, and where important updates from the management structures are disseminated. Both the Review Panel and Steering Committee report to the COTO Abnormal Loads Technical Committee (ALTC).

3.3. Data collection and monitoring

The benefits and viability of the PBS project have been demonstrated through the ongoing collection of valuable data from participating transport operators. Data on kilometres travelled, fuel consumed, emissions generated, incidents and crashes and violations have been collected for all the participating vehicles, and paint a positive picture of the benefits of the PBS pilot project. A minimum target of 100 million PBS vehicle kilometres was set in order to ensure that statistically meaningful data was obtained from which to draw conclusions, particularly with respect to incident and crash data.

3.4. PBS framework

The overall PBS framework for South Africa has been largely defined. This includes definitions of how vehicle designs should be evaluated and the standards against which they should be assessed, the classification of road networks, the formulation of a practical approval process, the definition of monitoring and control requirements, and the formulation of a legislative framework under which PBS might be formally adopted. Much of this has been formulated through the course of the pilot project, including the adoption of the Australian PBS rules, which were selected as the framework for evaluation of PBS vehicles in South Africa (NTC, 2008), subject to additional requirements specified by the Smart Truck Review Panel. Guidelines and requirements for participating in the PBS pilot project are contained in the Smart Truck Rules document (CSIR, 2017). There is now a need to formalise all of these into policies, procedures and standards for the project going forwards.

3.5. PBS research programme

An extensive and successful research programme has been initiated, involving academics from CSIR and the Universities of Witwatersrand, KwaZulu-Natal, and Pretoria. This research programme has helped to mould the technical framework of the PBS project in South Africa, improve the safety and road wear impact of new vehicle designs, and has helped to optimise and streamline the vehicle assessment process. In addition to having direct relevance for the PBS project, much of this research has also been disseminated through international peer-reviewed conferences. To date, outputs of the PBS research programme have included a PhD thesis, three Master's dissertations, over 25 research papers presented at both local and international conferences, three journal articles, numerous popular articles and three technology demonstrators.

4. Monitoring results

Figure 1 summarises the analysis results of all the monitoring data collected during the PBS pilot project until June 2017 (since the first two timber PBS vehicles were commissioned in November 2007). Data are shown as a comparison between PBS vehicles and “baseline” vehicles, where the baseline vehicles are conventional vehicles adhering to normal mass and dimension limits performing the same freight task. As far as is possible, the selected baseline vehicles operate on the same or similar routes as the PBS vehicles, with similar lead distances.

In June 2017 there were 245 PBS vehicles (excluding PBS car-carriers) operating on various routes. As at the end of June 2017, 102.25 million PBS vehicle km had been covered representing a range of commodities transported: timber, sugar, sugar cane, paper reels, mining products (including coal, chrome ore and platinum ore), aluminium ingots, fuel, beer, cattle and containers. There are also 22 bi-articulated PBS buses that operate on various approved routes in the province of Mpumalanga.

The number of PBS vehicles per province is also indicated in Figure 1. This includes 22 PBS fuel tankers that recently started operating on the N3 highway between Durban and Johannesburg. These are the first PBS vehicles to operate on the N3 corridor and are the only PBS vehicles currently operating in the provinces of Gauteng and the Free State. The 245 PBS vehicles are predominantly operational in KwaZulu-Natal, Mpumalanga and Limpopo, with a few operating in Gauteng, Free State and the Eastern Cape. The PBS vehicles currently operating in the Northern and Western Cape are road trains operating in remote areas as part of mining operations (Loeriesfontein and Namaqwa Sands).

A comparison of actual (as opposed to theoretical) payload and fuel consumption data between the PBS and baseline vehicles, shows that the 245 PBS vehicles save approximately 6 240 trips, 737 000 km and 203 500 litres of fuel per month. The reduction in trips and vehicle km represent a 28% savings compared with the baseline vehicles. The average fuel consumption savings (and reduction in greenhouse gas emissions) is 12.2%. These savings are primarily as a result of the increased payload of the PBS vehicles. After 102 million PBS km, the PBS crash rate was 1.37 crashes/million km compared with 2.24 crashes/million km, a reduction of 39%. As mentioned previously, certification in terms of the RTMS standard, SANS 1395, is a prerequisite for operators to participate in the PBS pilot project. This is to ensure a minimum level of compliance in terms of vehicle fitness, driver fitness and hours, loading and vehicle speed. The baseline vehicles are thus also part of RTMS-certified fleets and are therefore relatively compliant, providing a better-than-average benchmark against which to compare the PBS vehicles.

5. Overtaking considerations

As a result of concerns raised by various stakeholdes regarding increased overtaking times of longer vehicles and the associated potential safety risks, the overtaking times for baseline and various PBS vehicles were calculated. Initial calculations assumed a light motor vehicle overtaking a baseline or a PBS vehicle, with the heavy vehicle travelling at 80 km/h (maximum speed limit for heavy goods vehicles in South Africa) and the light motor vehicle accelerating to a maximum of 120 km/h (maximum speed limit for light motor vehicles in South Africa) in order to complete the overtaking manoeuvre. The range of overtaking times are indicated in Figure 2. The overtaking time increases from 9.20 s for a 22 m baseline vehicle to 9.59 s for a 26 m PBS vehicle combination and to 9.95 s for a 30 m PBS vehicle combination. The permissible maximum length of a standard vehicle combination in South Africa is 22 m.

Of major significance is the effect that the speed of the heavy vehicle has on overtaking time, *i.e.* the speed differential between the overtaking light motor vehicle and the heavy vehicle. Figure 2 shows that the overtaking time increases to 10.96 s for a 22 m baseline vehicle travelling at 100 km/h and to 18.17 s for a 22 m baseline vehicle travelling at 110 km/h.

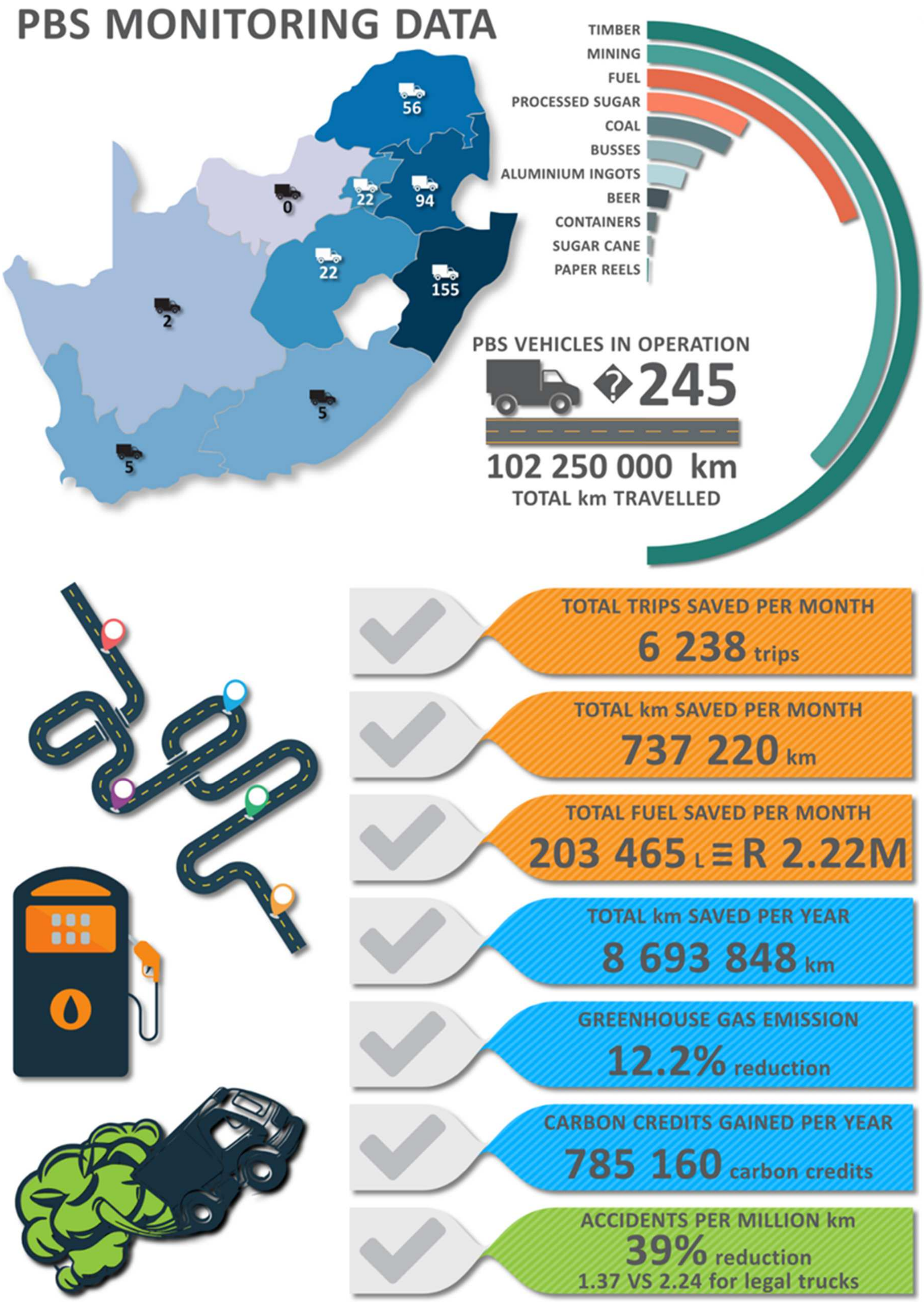

Fig. 1 Overview of PBS pilot project monitoring data analyses

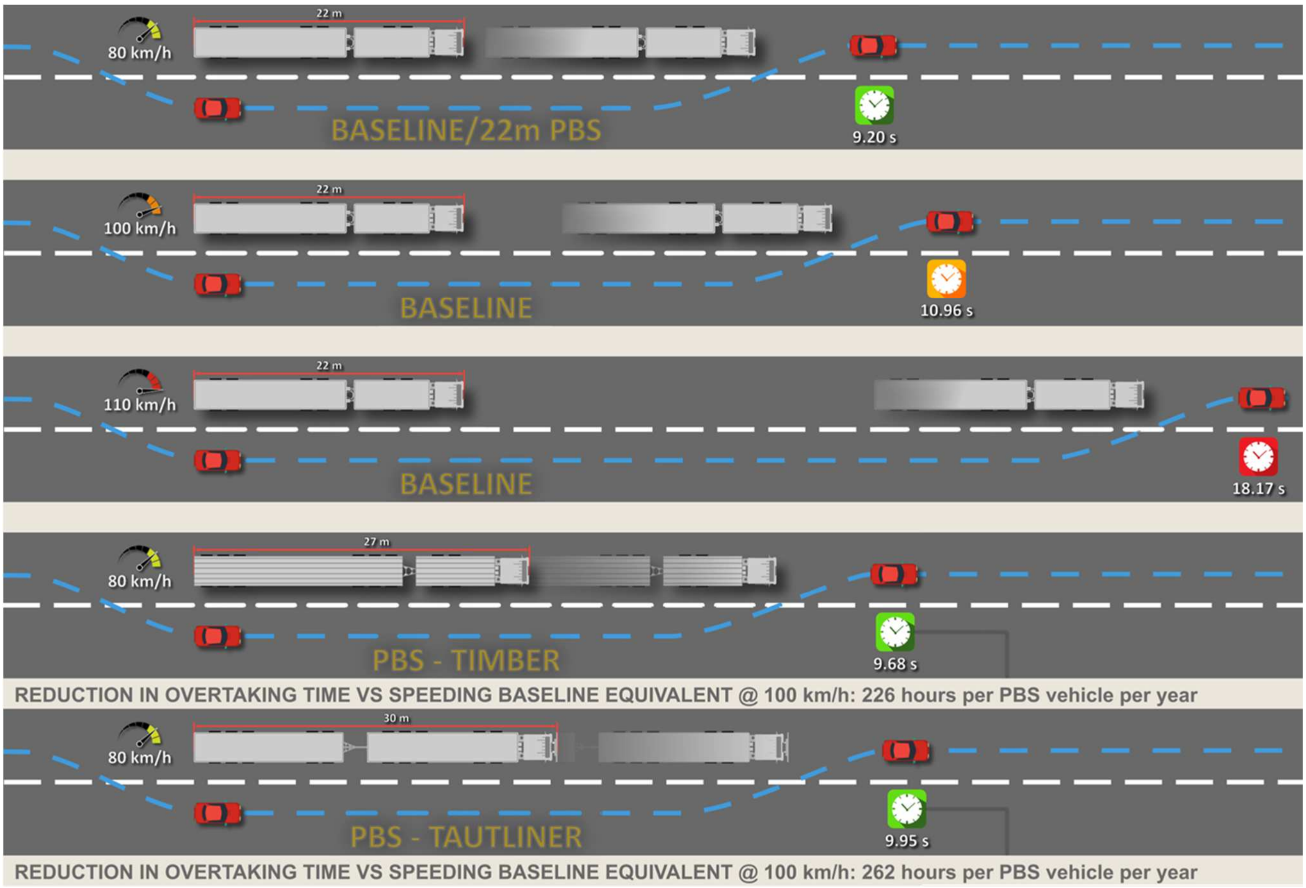

Fig. 2 Comparison of overtaking times of 22m baseline and PBS vehicles

This highlights the critical importance of heavy vehicle speed compliance with regards overtaking time and the associated risk of crashes during overtaking manoeuvres. One of the outcomes of both the RTMS and PBS initiatives is to greatly improve heavy vehicle speed compliance through self-regulation and, in the case of PBS vehicles, through proposed real time monitoring and exception reporting to road authorities. Non-compliance with regards heavy vehicle speeding is widespread in South Africa. The PBS pilot project has been an important driver of the RTMS self-regulation scheme: there are currently over 240 RTMS-certified fleets representing over 11 000 heavy vehicles in South Africa. It is thus likely that the improved compliance with respect to speeding of RTMS/PBS vehicles will more than offset the increased overtaking time of PBS vehicles that are longer than 22 m, particularly considering that such longer PBS combinations are restricted to suitable routes that are approved by the respective road authorities.

6. Conclusions

Since the first two PBS demonstration vehicles were commissioned in 2007, approximately 450 permits for PBS vehicles have been issued as part of a PBS pilot project in South Africa. The primary object of the pilot project is for both government and industry stakeholders to gain practical experience in the PBS approach and to quantify and evaluate the potential benefits. The pilot project reached the minimum target of 100 million PBS vehicle kilometres in June 2017. Analyses of the monitoring data that are required to be submitted to the Smart Truck Review Panel indicate significant improvements in heavy vehicle operations with a reduction in the crash rate of 39% compared with the RTMS-certified baseline fleet. Improved compliance with respect to vehicle speed appears to be offsetting the increase in overtaking times of the PBS vehicles that are longer than 22m, particularly considering that they are restricted to approved routes. Significant financial savings have also been recorded with a weighted average reduction in trips of 28% and an average reduction in fuel consumption and CO_2 emissions of 12.2%. The PBS pilot project has thus far shown the possibility to significantly improve heavy vehicle safety, reduce vehicle trips for a given freight task and decrease road freight transport costs and GHG emissions. A PBS evaluation report has been prepared based on the monitoring data collected to date. Based on the positive results in all areas measured, it is recommended that the pilot project move into an “intensive monitoring” phase, during which all nine provinces in South Africa become actively involved in the pilot project and additional data is collected for a more reliable analysis of crash statistics. During this phase of the project, the Smart Truck Rules document will need to be formalised into policies, procedures and standards for the project going forwards.

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