MONITORING RESULTS OF PBS VEHICLES IN THE TIMBER INDUSTRY IN TERMS OF PRODUCTIVITY, SAFETY AND ROAD WEAR PERFORMANCE

Obtained BSc from the University of KwaZulu-Natal and MSc from the University of the Witwatersrand. Completing his PhD at the University of KwaZulu-Natal. Principal Researcher at the CSIR, Past President of the SA Road Federation and President of the IFRTT.

P. NORDENGEN
The Council for Scientific and Industrial Research (CSIR)
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, manufacture and operate a number of PBS or Smart Truck demonstration vehicles in order 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. The Smart Truck demonstration projects have been designed and manufactured to comply with the safety standards of the Australian PBS system. These include directional and non-directional manoeuvres such as acceleration capability, slow speed swept path, static rollover threshold and rearward amplification. The infrastructure performance standards are based on South African bridge and pavement design standards. This paper presents a summary of the monitoring data of 31 PBS demonstration vehicles in the forestry sector. Initial results indicate a number of improvements in performance of the Smart Trucks compared with the baseline vehicles.

Keywords: Performance-Based Standards for heavy vehicles, Smart Trucks, Road Transport Management System (RTMS), heavy vehicle productivity, heavy vehicle safety, payload, vehicle dynamics simulation, road wear

1 Introduction

As a result of successful initiatives in Australia, New Zealand and Canada, the introduction of a Smart Truck or performance-based standards (PBS) approach in the heavy vehicle sector in South Africa was identified by the CSIR as a research area warranting funding because of the potential benefits in terms of transport efficiency, road/vehicle safety and the protection of road infrastructure. The PBS approach involves setting standards to specify the performance required from the operation of a vehicle on a network rather than prescribing how the specified level of performance is to be achieved. The PBS approach allows a more optimum "match" between vehicles and the road infrastructure.

A need was identified to design, manufacture and operate a number of PBS demonstration projects in South Africa in order to gain practical experience in the PBS approach and to quantify and evaluate the potential benefits. Operators of Smart Trucks are required to be certified through the Road Transport Management System (RTMS) self-regulation accreditation scheme (Nordengen and Oberholzer, 2006; Standards South Africa, 2007). Initially, two PBS demonstration projects were implemented in the forestry industry, which were designed and manufactured to comply with Level 2 safety standards of the Australian PBS system (Nordengen *et al*., 2008). These include directional and non-directional manoeuvres such as acceleration capability, slow speed swept path, static rollover threshold and rearward amplification. The positive performance of the demonstration project has resulted in the approval to date of 34 additional permits for PBS demonstration vehicles in the forestry sector, some of which incorporate additional modifications in order to further optimise performance.

2 Research Method and Preliminary Results

2.1 Monitoring Programme

Monitoring of the PBS demonstration vehicles commences once an approved PBS vehicle has been commissioned. Data including combination mass and payload per trip, average trip speeds, number of trips and distance travelled per month, average monthly fuel consumption, record of routes travelled (vehicle tracking reports), maintenance costs and records of incidents and crashes are collected on a monthly basis.

The first two PBS vehicles went into operation in November and December 2007 respectively and the monitoring of the first eight months of operation was reported on in March 2010 at the HVTT11 symposium in Melbourne (Nordengen, P.A., 2010). As a result of the positive performance of these two PBS vehicles, the KwaZulu-Natal Department of Transport decided to increase the number of permits for PBS demonstration vehicles in their area of jurisdiction. To date, 58 PBS permits have been issued, most of which are for vehicles operating in the forestry transport sector in the provinces of KwaZulu-Natal and, more recently, Mpumalanga. A number of other PBS vehicles for operation in other sectors are in the design phase. A Level 3 PBS road train (overall length 42 m and combination mass 176 tons) has been approved for operation at a mine in KwaZulu-Natal, ten of which commenced operation in July 2012. Table 1 shows the number of demonstration projects underway per industry and per province. Figures in round brackets ( ) indicate projects that have been approved but are not yet operational. Figures in square brackets [ ] indicate projects that are in the design phase, but have not yet been approved.

Table 1 – Summary of current and planned Smart Truck demonstration projects in South Africa per province

	KwaZulu-Natal	Mpuma-langa	Lim-popo	Gau-teng	Free State	N. Cape	E. Cape	W. Cape	North West
Forestry	34	10 + [14]							
Mining	10					2			
Car carriers	2	[2]	[2]	(1)	(2)	[2]	(2)	[2]	[2]
General freight	(1)	[1]		[1]	(1)				
Cement							(1)	[1]	
Beef						(1)			(1)

2.2 Infrastructure Standards

For the purposes of the PBS research and demonstration programme in South Africa, it was decided to adopt the PBS safety standards as developed by the National Transport Commission in Australia (National Transport Commission, 2007). It was further decided that the infrastructure performance standards should be aligned with South African road traffic regulations and design codes of practice. Thus all axle and axle unit loads of PBS vehicles that operate on public roads must comply with the requirements of the South African National Road Traffic Regulations (NRTR) (Department of Transport, 2000). In addition, PBS vehicles had to initially comply with Regulation 241, the "bridge formula", which limits the load intensity of a vehicle and any part of a vehicle.

2.3 Road Structures

At the beginning of 2010, the Smart Truck Committee decided to apply the more complex, but less conservative "Abnormal Load" bridge formula (Department of Transport, 2010), which is based on South African bridge design loading (NA + NB30), to PBS vehicles rather than the standard bridge formula that is applicable to all legal heavy vehicles. The adoption of the abnormal load bridge formula for PBS demonstration projects is based on the premise that the PBS vehicles are operating in a more controlled environment (including the RTMS self-regulation accreditation requirement) than the general heavy vehicle fleet. Hence the risk of overloading and speeding is considerably reduced. In fact, it is likely that the operations involving PBS vehicles are considerably more controlled and compliant than many abnormal load operations.

The adoption of the abnormal load bridge formula enabled one of the original PBS vehicles to be shortened by 1.24 m from 27.0 m to 25.76 m by reducing the length of the trailer drawbar without compromising on the permissible maximum payload. This combination, at 67 500 kg, has a minimum factor of safety of 44.8% in terms of the abnormal load bridge formula. A reassessment of the safety standards showed an improved performance in terms of Tracking Ability on a Straight Path, Low Speed Swept Path, Steer Tyre Friction Demand and Static Rollover Threshold. Although there was a reduced performance in terms of Rearward Amplification (2.8%), High Speed Transient Offtracking (5.6%) and Yaw Damping Coefficient (15%), the modified vehicle combination still meets all the requirements of a Level 2 PBS vehicle.

All new PBS demonstration projects are required to be assessed in terms of the abnormal load bridge formula. PBS vehicles are required to be as short as practically possible (to minimise overtaking provision requirements) but at the same time may not compromise the safety of structures.

2.4 Road Pavements

In order to assess the relative road wear between the Smart Truck and baseline vehicles, the CSIR Pavement Design Software MePads (mePADS, 2008) is being used. MePads is the electronic version of the current South African Mechanistic-Empirical Design and Analysis Methodology (SAMDM) (Theyse *et al*, 1996). It is intended that this methodology will be used to develop a pavement infrastructure performance standard for Smart Trucks in South Africa. The software combines a stress-strain computational engine with pavement material models developed in South Africa. Pavement layer life is expressed in terms of the number of repetitions of an axle load until failure. Layer life is based on the typical linear-log damage functions (or “transfer functions”) obtained (and calibrated) from experience and from the results of Heavy Vehicle Simulator (HVS) testing on the various pavement types carried out in South Africa since 1975.

The SAMDM approach is used to estimate the Load Equivalency Factors (LEFs) of each vehicle under static loading based on the critical pavement layer life approach. The pavement life or bearing capacity of the pavement under consideration is also determined under a Standard 80 kN axle with four tyres (two dual sets) at a tyre inflation pressure of 520 kPa. The Load Equivalency Factor of the vehicle (LEF) is calculated as the sum of the ratios (for all axles of a particular vehicle) between the critical layer life of the pavement determined from the Standard 80 kN axle with four tyres (two dual sets) at an inflation pressure of 520 kPa (i.e. the bearing capacity of the pavement), divided by the critical layer life under each individual axle load and its associated tyre pressures as follows:

$$LEF\ of\ Vehicle = LEF_v = \sum_{i=1}^{n} \frac{N_{critical}\ from\ Standard\ Axle\,(80kN\ \&\ 520kPa)}{N_{critical}\ from\ Axle_i}$$

where:

n = number of axles on vehicle

Ncritical from Standard 80 kN/520 kPa Axle = Minimum layer life of pavement under the loading of the Standard axle of 80 kN and 520 kPa inflation pressure on 4 tyres (i.e. 20 kN per tyre @ 520 kPa contact stress (= inflation pressure))

Ncritical from $Axle_i$ *= Minimum layer life of pavement under the loading of* $Axle_i$ *of vehicle under consideration*

This is done for eight typical South Africa pavement design types in both wet and dry conditions, two of which are shown in Figure 1. Load Equivalency Factors for a wet pavement are typically 50 to 100 percent more than the same pavement in a dry condition, depending on the pavement type. For the purposes of comparison, and to simplify the presentation of results, an average wear cost is calculated for the 16 cases (8 pavement types, wet and dry conditions) for the baseline and PBS vehicles.

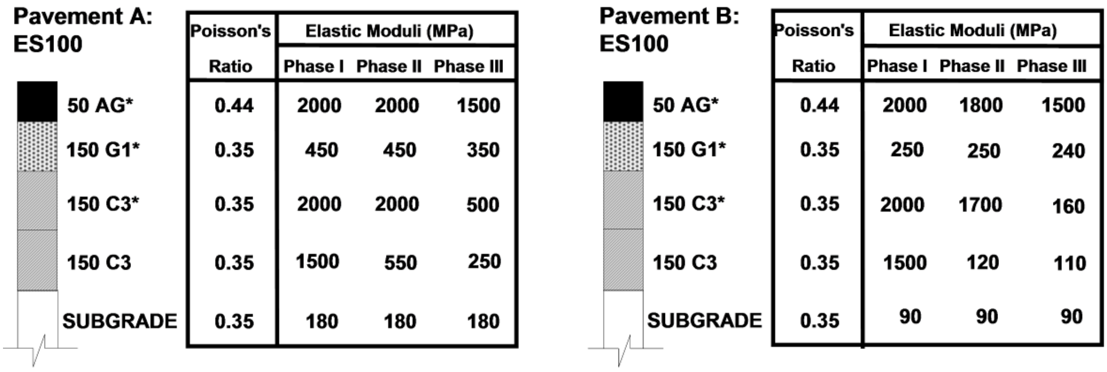

Figure 1 – Two examples of 8 road pavement structures and their material properties used for the mechanistic analysis for the PBS road wear comparative analysis (* classification according to TRH14, CSRA, 1985)

The average LEF's for various baseline and PBS vehicle combinations are given in Table 2 and shown in Figure 2. Taking into account the different permissible maximum payloads on each vehicle, the average LEF per ton of payload (LEF/ton) is also calculated for each vehicle combination. These are also shown in Table 2 and Figure 3.

Table 2. Load Equivalency Factors (LEFs) for various baseline and PBS vehicles

Vehicle Description	Combination mass (kg)	Payload (kg)	Average LEF	Average LEF per ton of payload (LEF/ton)
Forestry				
Baseline 1: 5-axle articulated	43 200	28 150	7.34	0.26
Baseline 2: 6-axle articulated	49 200	31 900	7.62	0.24
Baseline 3: 7-axle rigid-drawbar	56 000	38 500	8.50	0.22
PBS 1 (Sappi 2007)	67 500	48 200	8.89	0.19
PBS 2 (Mondi 2007)	64 250	45 200	9.11	0.20
PBS 3: twin steer axle unit	70 000	50 840	5.43	0.11
Cement				
Baseline 4: single tyres	56 000	40 760	16.86	0.41
PBS 4: dual tyres	77 160	57 260	9.14	0.16
Mining				
Baseline 5: single tyres	145 100	105 000	61.04	0.58
PBS 5: single tyres	173 800	122 000	76.30	0.63
PBS 6: dual tyres	173 800	122 000	20.85	0.17

Figure 3 shows a comparison of various baseline and PBS vehicle combinations in terms of road wear expressed as the Load Equivalency Factor per ton of payload. It can be seen that the original two forestry PBS vehicles (PBS-1 and PBS-2) are marginally more road friendly (9 and 13.6%) per ton of payload than the 7-axle baseline vehicle (BL-3), whereas a more recent design (PBS-3), which has a twin steer axle and a 50.84 ton payload, causes significantly less (50%) road wear than the 7-axle baseline vehicle.

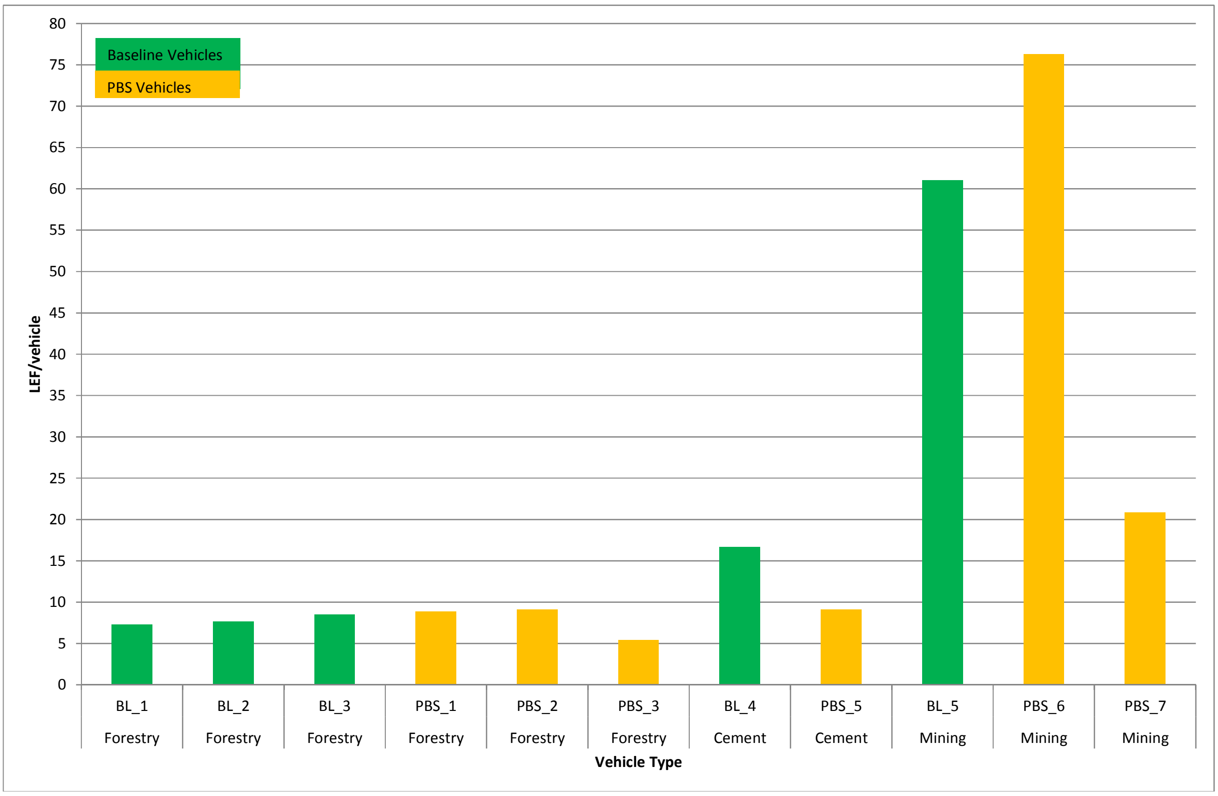

Figure 2 – Average LEFs for the various baseline and PBS vehicles

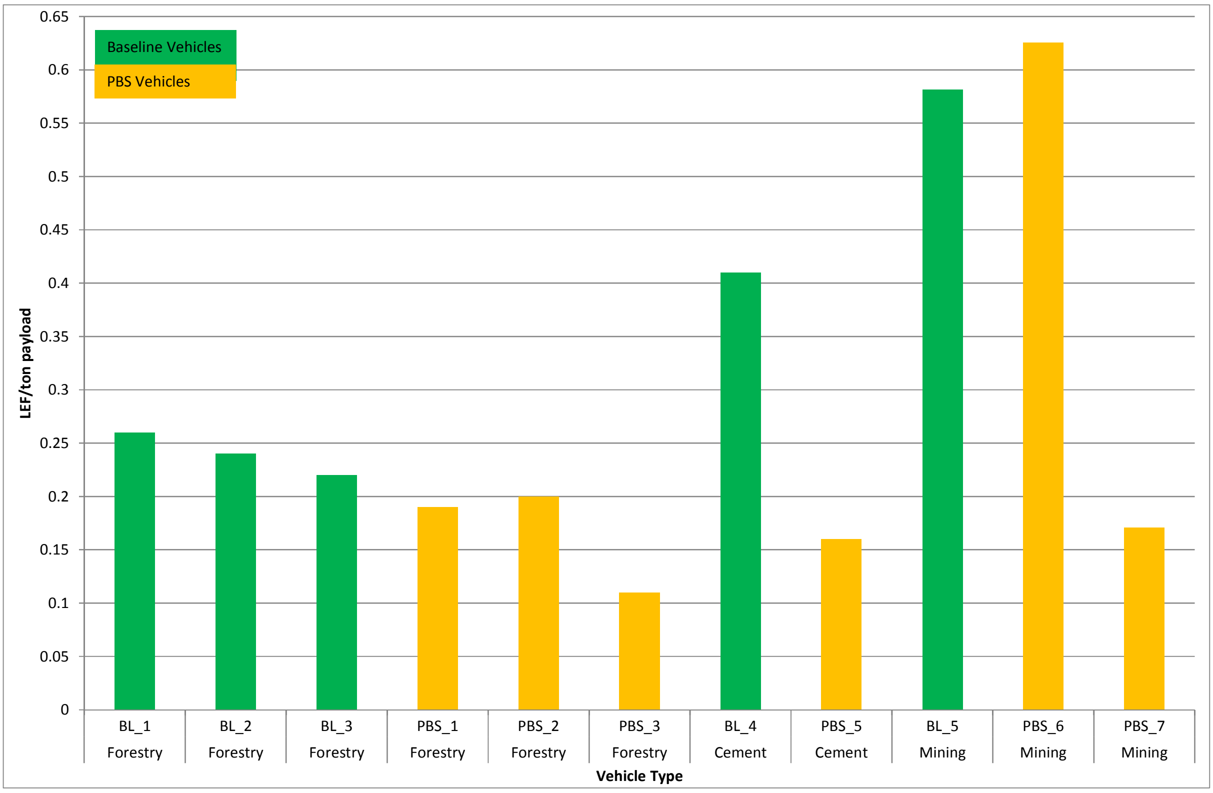

Figure 3 – Average LEF per ton of payload for various baseline and PBS vehicles

A proposed cement PBS vehicle (PBS-5) causes 61% less road wear per ton of payload compared with the baseline vehicle (BL-4). The primary reason for this improved performance is due to the fitment of dual tyres on the PBS vehicle as opposed to wide-based single tyres on the baseline vehicle.

An initial PBS mining vehicle (173.8t road train, PBS-6) causes 9% more road wear (per ton of payload) than the baseline vehicle (145.1t). Both these vehicle combinations have single tyres (425/65R22.5.5) on all the dollies and trailers. An alternative design (PBS-7) is fitted with dual tyres (315/80R22.5) on all the dollies and trailers and is more road friendly than the baseline vehicle by a factor of 3.4.

Analysis of the road wear assessment results shows that the steering axle of a vehicle combination normally has a disproportionately high contribution towards the LEF of the vehicle combination due to the relatively high axle load - surface contact area ratio. Thus, although the South African National Road Traffic Regulations allow a maximum of 7 700 kg on a steering axle, Smart Trucks with a lower steering axle load as well as wider steering axle tyres can be significantly more road friendly than the corresponding baseline vehicles.

2.5 Safety

One of the reasons for increasing the number of PBS demonstration vehicles in South Africa was to enable a more meaningful monitoring and evaluation of safety performance in a shorter time period. One of the timber transport operators in KwaZulu-Natal, Timber Logistics Services, has been operating 15 identical PBS vehicles, initially commencing operation with 4 vehicle combinations in September 2009 and increasing to 15 vehicles three months later. Table 3 shows a summary of the crash statistics of the standard and PBS vehicles for the period September 2009 to March 2012. The average crash rate of the PBS vehicles (0.69 crashes per million kms) is a factor of 6.7 less than the average crash rate of the standard vehicles (4.59 per million kms). One of the contributing factors to this improved safety performance is the fact that the drivers of the PBS vehicles are more experienced than the drivers of the standard vehicles.

Table 3 – Crash statistics for PBS and standard vehicles: Timber Logistics Services

		2009 (Smart Trucks-3.5 months)	2010	2011	2012 (3 Months)	Total Period
No of Crashes	Smart Trucks	0	3	2	0	5
	Other	28	24	21	4	77
	Total	28	27	23	4	82
Total Kilometres	Smart Trucks	349 000	3 236 000	2 967 000	716 000	7 268 000
	Other	6 493 000	4 761 000	4 328 000	1 187 000	16 769 000
	Total	6 842 000	7 997 000	7 295 000	1 903 000	24 037 000
Crashes per million kms	Smart Trucks	0.0	0.9	0.7	0.0	0.69
	Other	4.3	5.0	4.9	3.4	4.59
	Total	4.1	3.4	3.2	2.1	3.40

By the end of 2012 an estimated 15 million km will have been travelled by PBS vehicles from six transport operators in the forestry industry during the period January 2011 to December 2012, which will improve the validity of the safety performance statistics determined to date.

2.6 Fuel efficiency

Since the commencement of the PBS demonstration project, monthly monitoring has been carried out to enable the performance evaluation of these vehicles compared with the respective baseline vehicles. Table 4 shows a summary of some of the data collected for the period January to December 2011, which represents 31 of the 43 PBS demonstration vehicles currently in operation. The remaining 12 vehicle combinations commenced operation during the latter half of 2011.

Based on the 31 Smart Trucks operating in 2011, approximately 4 100 trips were saved during this period as a result of the increased payload. This reduction in trips contributes to a reduction in congestion as well as the safety exposure risk.

Table 4 – 2011 Monitoring statistics of 31 Smart Trucks compared with baseline vehicles

	Average Kilometres travelled	Average Vehicle mass	Average Payload (tons)	Fuel consumption (litres/100km)	Fuel Efficiency (litres/ton.km)	Average %age fuel savings	Trips saved
SuperGroup baseline	22676	56.1	38.3	59.0	0.0154		
SuperGroup PBS (1 veh.)	22676	62.7	43.4	60.6	0.0140	9.4	95
Timber 24 Baseline	19497	55.3	38.0	58.1	0.0153		
Timber 24 PBS (1 veh.)	21837	65.2	46.0	59.7	0.0130	15.1	119
TLS Baseline	18512	55.2	37.9	58.7	0.0155		
TLS PBS (15 veh.)	16780	65.3	45.4	62.2	0.0137	11.5	1940
Timbernology baseline	12030	56.0	37.8	63.3	0.0167		
Timbernology PBS (7)	18240	63.2	44.5	57.2	0.0129	23.2	730
Unitrans baseline	15268	52.5	33.5	57.2	0.0171		
Unitrans PBS (2, 7 veh.)	18808	64.5	44.9	59.7	0.0133	22.1	1188

In the case of the Timbernology and Unitrans fleets (7 and 7 PBS vehicles), all the baseline vehicles are operating on routes with a much shorter lead distance than the PBS vehicles, so a meaningful comparison in terms of productivity, including fuel efficiency, is not possible. The remaining three transport operators show an average potential fleet size reduction (and hence safety exposure risk) of 17%, which is the same value calculated for the first eight months of operation of the initial two PBS vehicles (Nordengen, P.A. 2010). Average fuel efficiency improvement, and hence a reduction in CO_2 emissions, varies from 9.4 to 15.1%. This compares with an average fuel efficiency improvement of 12.7% for the first eight months of operation of the initial two PBS vehicles (Nordengen, P.A. 2010).

3 Conclusions

Since the first two South African PBS demonstration projects were commissioned in November and December 2007, 56 additional permits for PBS vehicles have been approved. Initial monitoring of these vehicles and their respective baseline vehicles indicate that although longer and heavier, the PBS vehicles are showing improved safety performance, improved productivity and a reduction in carbon footprint, while at the same time reducing the road wear per ton of payload and not compromising the safety of bridge structures.

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