Transport
Roads & Maritime Services

GREEN TRUCK PARTNERSHIP

Case study

Aerodynamic device
Vortex generators on road train

Trial summary

This trial sought to further quantify the fuel efficiency benefit of an aftermarket device fitted to reduce aerodynamic drag. The trial was conducted for one road train tip truck running a bulk material line haul application in Western Australia.

Fuel benefit (L/100 km)	GHG benefit (g CO_2 e/km)	Economic benefit ($/100 km)
No change	No change	No change

↑ performance better than conventional vehicle

↓ performance worse than conventional vehicle

*L/100 km = litres per 100 kilometres
g CO_2 e/km = grams per kilometre of carbon dioxide emission
$/100 km = dollars per 100 kilometres
% = per cent

The *Green Truck Partnership* is designed to be a forum to objectively evaluate the merits of clean vehicle technologies and fuels by heavy vehicle operators. This is the third report to examine the impact of vortex generating aerodynamic devices, this time fitted to a side tipping road train configuration. The trial was conducted over the 2015-2016 period. It ran for five months and covered a combined distance of over 120,000 kilometres (baseline + trial).

1 Aerodynamic trailer tabs

Aerodynamic drag is created as air resists the movement of a vehicle. The vehicle engine must work harder to overcome this resistance and therefore consumes more fuel. At high speeds in particular, aerodynamic drag can be a significant consumer of energy in heavy vehicles (up to 50 per cent).

Aftermarket aerodynamic devices redirect air flow more efficiently, thereby reducing drag and improving fuel efficiency.

A vortex generator device was examined in this trial. The device may be attached to both trucks and trailers to reduce drag at critical points (usually at the truck-trailer gap and at the rear of the trailer).

These devices work by breaking up the air flow into counter rotating vortices, thereby dispersing the energy more evenly. They are easily attached – essentially glued to the vehicle in a vertical strip at the crucial drag production points. Affixed to the rear of the trailer as in this trial, vortex generators are designed to change the dominant flow pattern from the trailing edge of the vehicle.

The literature suggests that aerodynamic devices can achieve fuel savings of two to three per cent individually and up to 15-20 per cent in combination 1, 2, 3, 4. For vortex generator devices specifically, manufacturers claim potential fuel efficiency savings of three to five per cent up to 11 per cent depending on the specific vehicle configuration and application.

Vortex generators are used in other sectors, such as aerospace – for example on the leading edge of a wing. Their installation on the trailing edge of a vehicle surface appears less common.

Two publicly available case studies for this type of technology were identified, which suggest the range of potential fuel savings that could be expected: a track test which found a 1.6 to 4.1 per cent improvement[5]; and a wind tunnel test which found a four to six per cent improvement[6].

2 Trial objective

This trial assessed the economic and environmental performance of an aftermarket aerodynamic device (vortex generators) in a road train configuration.

Figure 1: The road train

Figure 2: Side detail of prime mover

Figure 3: Roof detail of prime mover

Figure 4: Trailer left side detail

Figure 5: Trailer right side detail

3 Methodology

The trial involved an in-field assessment of a three-trailer road train using side-tipping trailers, operating in two shifts carrying up to 86.5 tonnes payload per trips.

The devices were fitted simultaneously to the rear of the prime mover and to the rear of the trailers. Photographs of the installed devices are shown in Figures 1 to 5 above.

The truck primarily ran between two sites – a mine and a depot – three times each shift. It carried 86.5 tonnes of mine product one way, and around 70 tonnes of waste the other way. The truck mostly operated on dirt roads, which explains the dusty condition in the photos.

3.1 Data collection

Changes in fuel efficiency were quantified by examining fuel and duty cycle data during a baseline period (no aerodynamic parts fitted) , and then comparing to a trial period after the vortex generators were fitted. The baseline operated between September 2015 and November 2015, covering 66,000 kilometres. The trial period operated from November 2015 to February 2016, and covered 62,000 kilometres.

The data collected included:

- DISTANCE: kilometres travelled
- IDLE TIME: time spent at idle
- ENGINE LOAD: percentage theoretical maximum loading (%)
- AVERAGE SPEED: average speed in kilometres per hour (km/h)
- FUEL CONSUMPTION: total fuel consumed in litres (L)
- VEHICLE LOCATION: GPS data.

Other datasets were collected but were not relevant to this particular trial.

3.2 Data analysis

The first stage of the analysis involved validating that the fuel consumption results in the baseline and trial periods could be compared fairly. This was done by ensuring that the duty cycle (such as speed profile and engine load profile) was similar during both periods.

Extreme outliers, such as very short trips, were removed.

The two speed profiles were compared, and are shown in Figure 7 (located under Conclusion). The speed profiles showed a reasonable correlation.

The two engine profiles were then compared, and are shown in Figure 10 (located under Conclusion). These showed some divergence.

The fleet operator indicated that the duty cycle of the truck hadn't changed in any practical way between the baseline and trial periods.

More likely, the differences in engine load were due to the way the data was being aggregated by the telemetry: high utilisation and operation across midnight created confusing data totals for days, trips and shifts.

As a result, a second layer of data analysis was applied. This used a natural grouping of heavy and light loaded trips in the data. When separated along these lines, the engine profiles showed tight correlation of baseline and trial data.

The speed profiles were checked again using this heavy and light load split, and the data showed more consistency (though not quite as consistent as the total light and heavy grouping).

It was concluded that, with the split between heavy and light loads, the truck had been operated in a broadly similar manner before and after installation of the aerodynamic device; and that direct comparison of the fuel consumption values was valid (ie there were no major differences in duty cycle that were thought to significantly affect fuel consumption).

Three statistical checks were then performed to ensure rigorous statistical analysis.

Test 1

This test compared mean (average), standard deviation, and other statistical metrics for individual trip fuel efficiency (kilometres per litre) in both the baseline and trial periods. This was repeated three times: for all loads, heavy loads, and light loads.

Test 2

The second test analysed baseline and trial data to a standard equivalent to that required for scientific publications, assessing the probability of a null hypothesis. In other words, what is the probability that the difference in fuel efficiency was “statistically significant”, and not simply random (or part of the natural “noise”).

Test 3

The final statistical test aggregated the total distance travelled and all litres consumed, in order to provide overarching efficiency in kilometres per litre. This effectively takes into consideration trip distances, as larger trips will then be weighted proportionately. This was repeated three times (all loads, heavy loads, light loads).

4 Results

Test 1

The results of the first statistical test showed that, for validated fuel consumption data, on average there was less than one per cent fuel efficiency difference between the baseline and trial periods as shown in Figure 6 (located under Conclusion). Assessed separately for heavy load groupings and light load groupings, the difference was closer to two per cent.

Test 2

The test for the null hypothesis showed there was a 30 per cent chance that this was simply a result of "noise". For comparison, a common convention is to consider five per cent or less as "statistically significant". In other words, it is likely that the small difference in fuel consumption was just random. For heavy and light load groupings, this was 1.2 per cent and 7.2 per cent respectively – meaning the heavy loads had a significant result, but the result for the light loads was not statistically significant.

Test 3

On the basis of the whole dataset, the change in total fuel efficiency was found to be less than one per cent. Heavy and light load groupings showed 2.7 per cent and 2.3 per cent difference respectively.

5 Conclusion

The findings of this trial suggest that in this road train application, vortex generators provide no fuel efficiency benefit, no economic benefit, and no greenhouse gas (GHG) benefit.

The fact that no benefit was seen after five months and 120,000 kilometres of testing is important. Previous studies on different truck configurations have shown vortex generators to have a benefit in fuel efficiency. This indicates the devices may be sensitive to the configuration of the truck and trailer.

It is worth noting that the little "difference" in fuel consumption in Section 4 was a slight penalty; but that the statistical results show this difference was generally not significant.

The one statistical exception was the "heavy load" fuel consumption, which showed as a "significant" two per cent penalty. This was not seen as a likely cause of the aero device – it was more likely that some unaccounted change in task or environment (eg dirt roads, heavy train weight, driver skill), or the aggregation of data, created this effect.

Figure 6: Summary table of results

	Test 1 Trip fuel efficiency	Test 2 Statistically significant	Test 3 Aggregated total
All loads	**< 1% ↓**	**No**	< 1%↓
Heavy loads	2%↓	Yes	2.7%↓
Light loads	2%↓	No	2.3%↓

↑ performance better than conventional vehicle

↓ performance worse than conventional vehicle

Figure 7: Average speed duty for baseline and trial – all loads

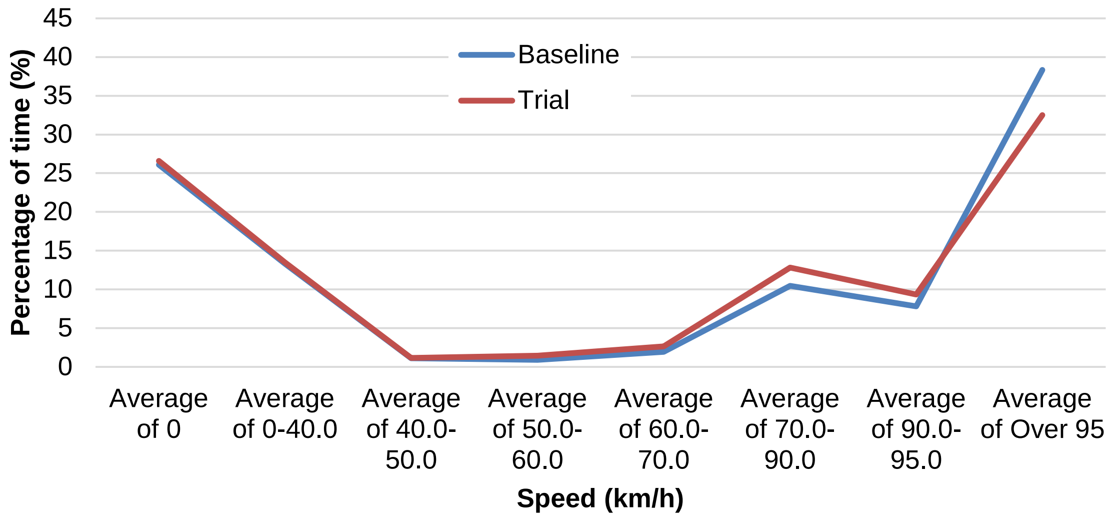


Figure 8: Average speed duty for baseline and trial – heavy loads

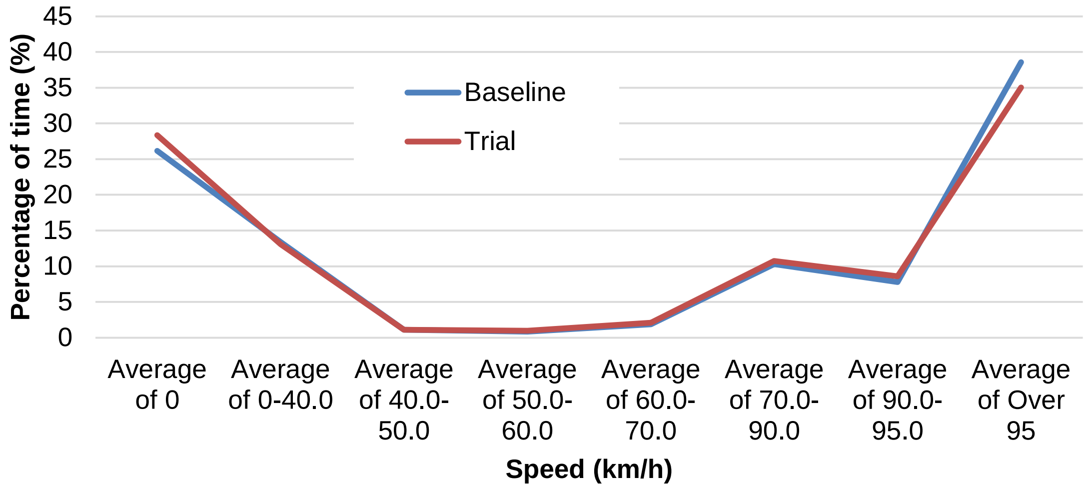


Figure 9: Average speed duty for baseline and trial – light loads

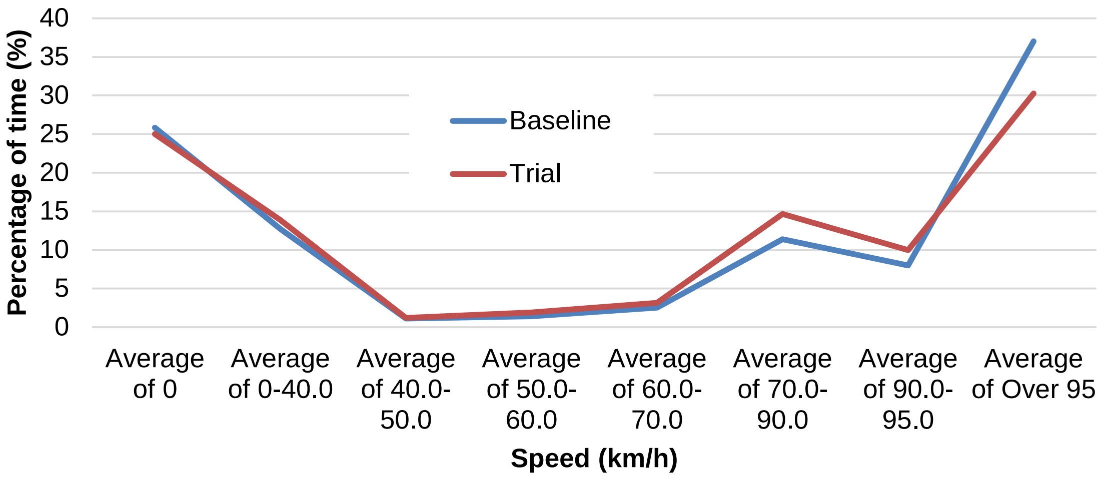


Figure 10: Average engine duty for baseline and trial – all loads

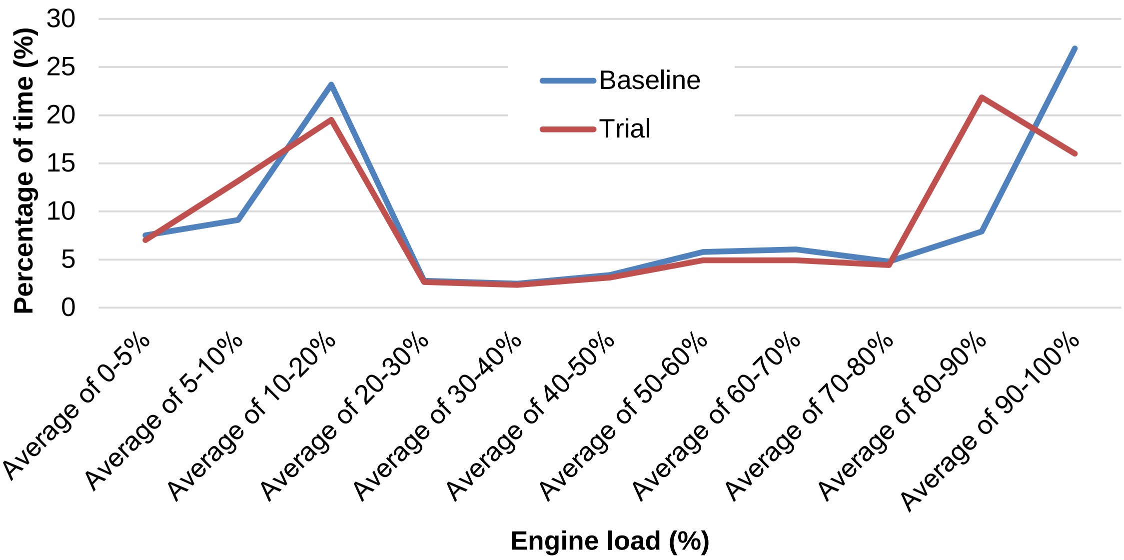


Figure 11 - Average engine duty for baseline and trial – heavy loads

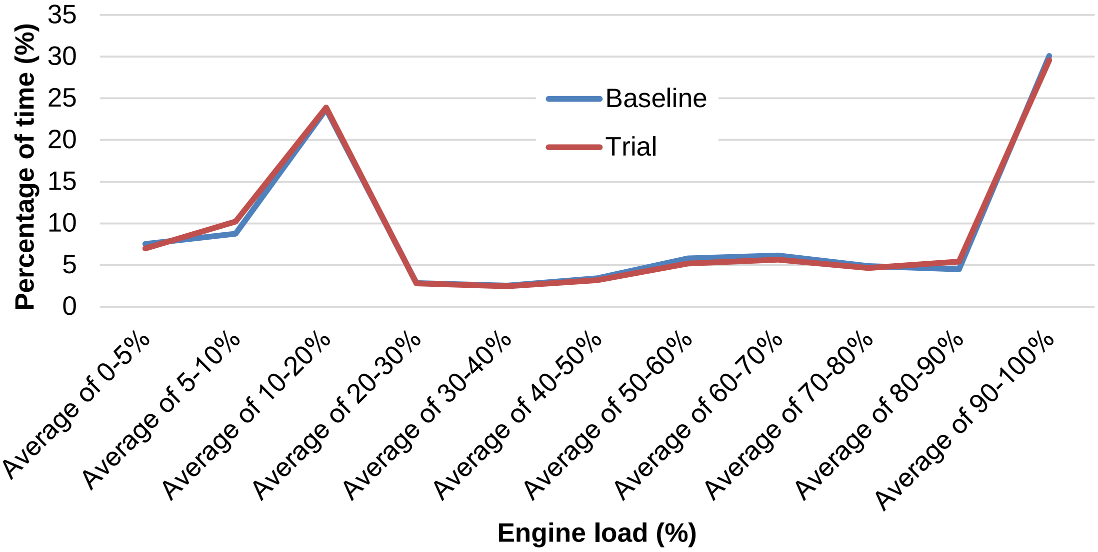
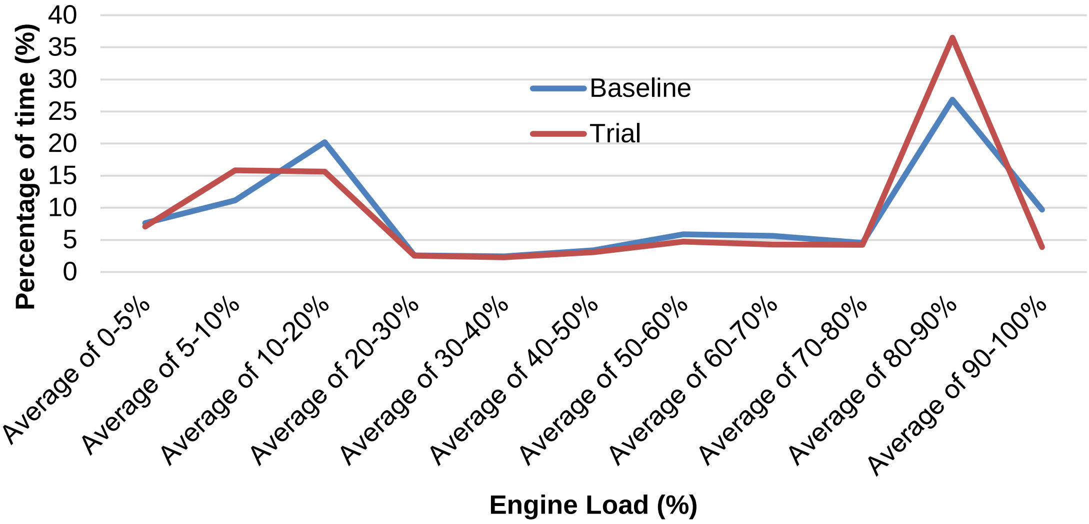


Figure 12 – Average engine duty for baseline and trial – light loads



6 References

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7 Document control

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