Case study

Aerodynamic device
Vortex generators on semi-trailer

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 semi-trailer running a regional line haul application in Perth.

Fuel benefit (L/100 km)*	GHG benefit (g CO_2 e/km)	Economic benefit ($/100 km)
2.7 - 4.1%↑	2.7 - 4.1%↑	2.7 - 4.1%↑

↑ 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 report discusses the second trial of vortex generating aerodynamic devices. The device was fitted to a curtain-sided semi-trailer in 2015 and monitored over six months and over 80,000 kilometres (baseline + trial).

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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, up to half of the truck's fuel burn can be for overcoming aerodynamic drag.

Aerodynamic devices redirect air flow more efficiently, reducing drag and improving fuel efficiency.

This trial involved a vortex generator device. The device was fitted to the trailing edges of both the prime mover and trailer, to reduce drag in areas where it is most significant: usually at the truck-trailer gap and at the rear of the vehicle.

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 strip along the trailing vertical and horizontal edges of the truck cab and trailer.

The literature also suggests that various kinds of 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 between 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 1.6-4.1 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 the environmental performance of an aftermarket aerodynamic device (vortex generator) on a curtain-sided semi-trailer operating in a regional line haul distribution role from Perth.

3 Methodology

The trial involved an in-field assessment of one prime mover and three trailers (as the prime mover rotates between trailers).

Vortex generators were fitted to the rear of the truck cab and to the rear of the trailers. Photos of the installation are shown in Figures 1 to 4.

The effectiveness of the device was quantified by assessing the difference in fuel efficiency between a baseline period (no device) and the trial period (with the device fitted).

Figure 1: Device installed on prime mover

Figure 2: Detail on prime mover

Figure 3: Device fitted to trailer

Figure 4: Detail on trailer

3.1 Data collection

The trial operated during the period of October 2015 to April 2016, with the baseline period ending in January 2016. The total distance travelled in the trial was close to 80,000 kilometres.

Data loggers were installed and 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 analysis involved validating that the fuel consumption results in the baseline and trial periods could be compared fairly. This was done by comparing the duty cycle descriptors (such as speed profile and engine load profile) for the truck during both periods. Extreme outliers, such as very short trips, were removed.

As shown in Figures 5 and 6 a comparison of the engine load profiles for the validated data during the baseline and trial periods showed a good correlation. The speed profile in both the baseline and trial periods also shows a good correlation for the remaining data (outliers removed), which suggests that the selected data is from periods with similar duty cycles.

The correlation between the data in the two periods indicated that the truck had been operated in a 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 checks were then performed to assess the statistical validity of the results. The first test analysed the individual trip fuel consumptions (litres per 100 kilometres) in both the baseline and trial periods. These were analysed for their average, standard deviation, and other statistical metrics. They were plotted as a histogram and assessed against a standard normal curve. The mean (average) of litres per 100 kilometres were then compared between the baseline and trial.

The second statistical test analysed the baseline and trial data to a standard equivalent to that required for scientific publication. This assessed the probability of a null hypothesis: that is to say, testing the probability that the difference in litres per 100 kilometres (L/100km), between the baseline and trial, was simply random (just part of the natural “noise”).

The third test took an aggregate total of all km travelled and all litres consumed, in order provide an overarching L/100km fuel consumption. This is prudent as it effectively takes into consideration trip distances, as larger trips will then be weighted proportionately.

As a final check, the operator’s own data was also analysed. This is not an approved *Green Truck Partnership* data collection system, but it did provide supplementary insights.

Firstly, this data was used to isolate trips between two specific locations, and covered a total of nearly 64,000 kilometres (baseline and trial). Secondly, total aggregate performance for distance and fuel over the whole trial were analysed. The total distance was 89,000 kilometres (baseline and trial).

Figure 5: Comparison of vehicle average speed across baseline and trial periods

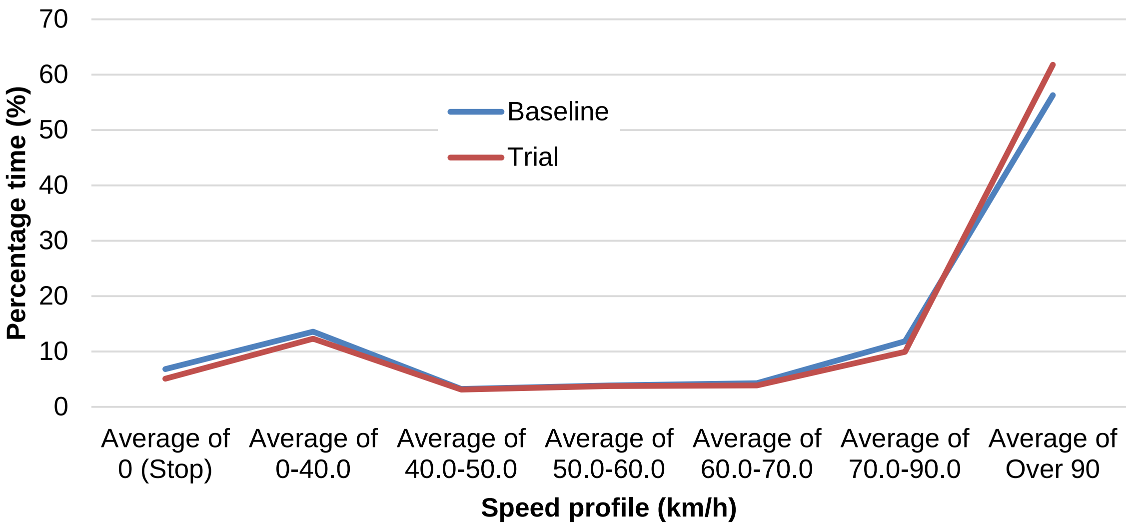
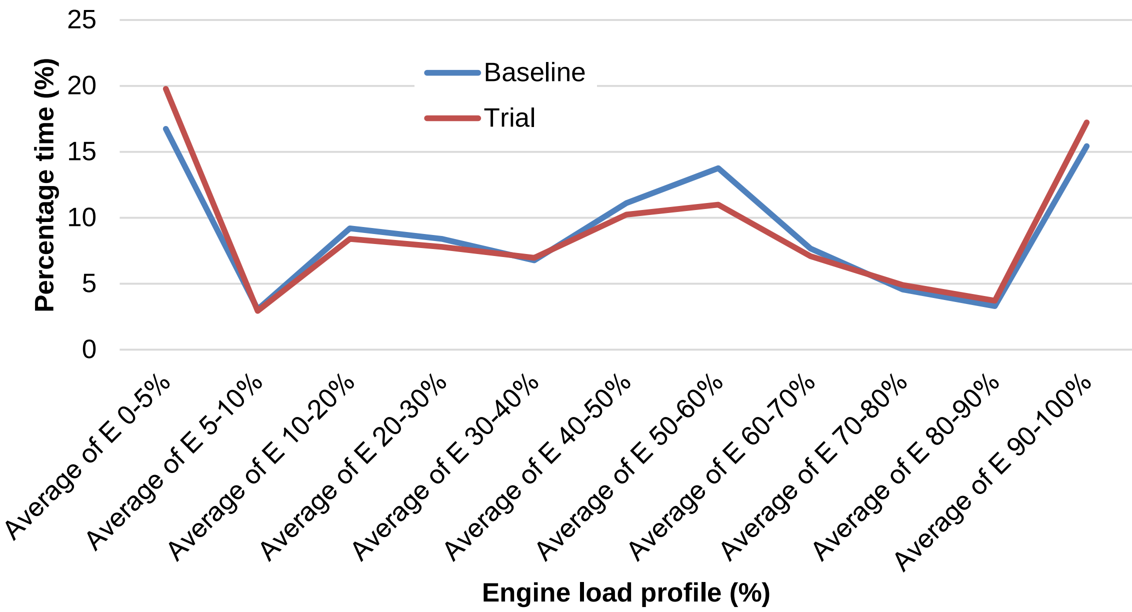


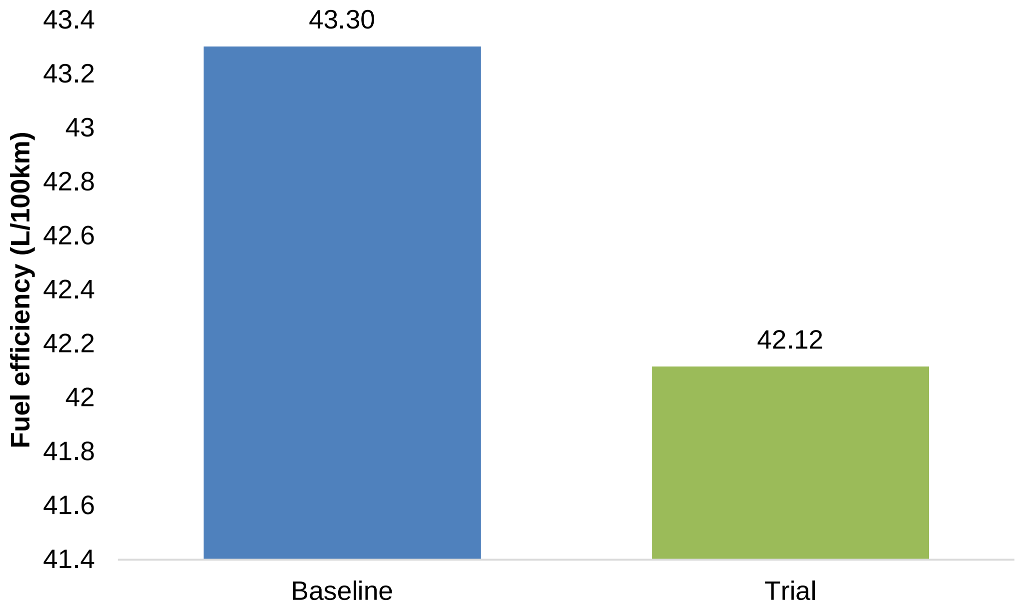
Figure 6: Comparison of vehicle average engine load across baseline and trial periods



4 Results

The results of the first statistical tests showed that for validated fuel consumption data, for an average trip there was a 2.8 per cent fuel efficiency improvement between the baseline and trial periods. Refer Figure 7 below.

Figure 7: Comparison of average trip fuel efficiency across baseline and trial periods



In the null hypothesis test, a common convention is to consider five per cent or less as "statistically significant". Applying this test to the data showed only a 0.2 per cent chance that the saving was simply a result of "noise" or coincidence. In other words, the fuel efficiency improvement is considered statistically significant.

The third analysis covering the entire aggregated dataset showed a 2.4 per cent improvement in fuel efficiency - a slightly smaller improvement than the individual trip fuel efficiency. Analysis of the geolocations showed that while most of the task revolved around locations A and B, some other locations were occasionally visited. These atypical locations tended to have lower fuel efficiencies, longer trip distances, and there were more instances in the baseline period. These atypical trips tended to "drag down" the aggregated improvement figure.

The supplementary analysis of the operator's own in-house data focused on a specific route between two locations. For trip A to B, this was a 4.1 per cent improvement. The reverse trip from point B to A was also 4.1 per cent. The grouping was also extremely tight, (statistical significance of 0.001 per cent and 0.009 per cent respectively), and the shift in fuel efficiency was greater than the standard deviation.

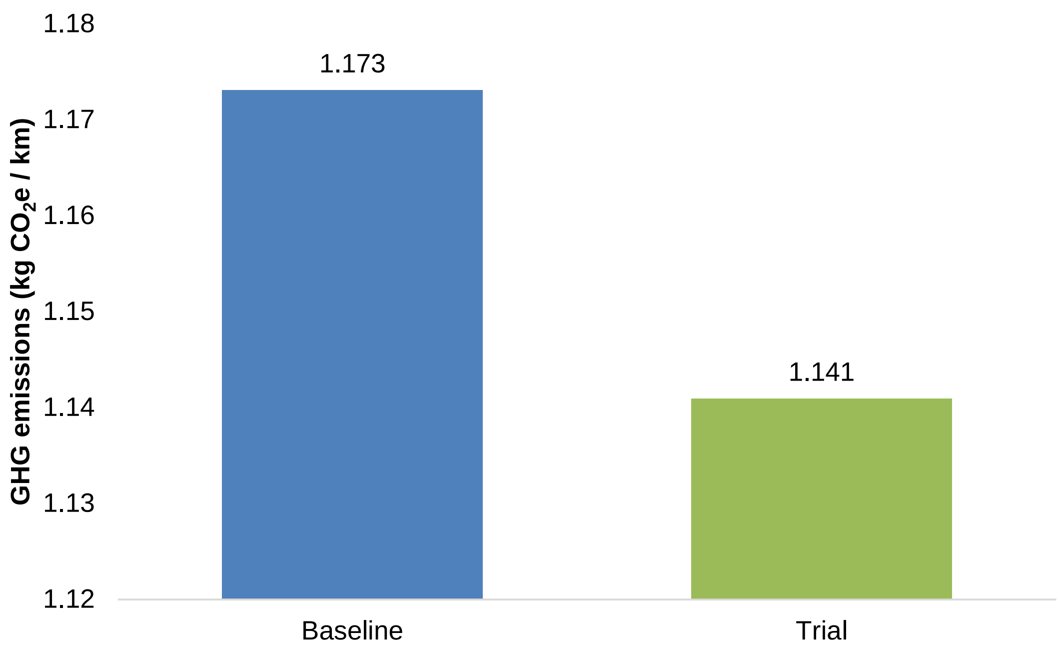
The final test, aggregating total fuel and total distance, showed a 2.7 per cent improvement for all trips (including atypical locations).

All the analyses described above clearly support an improvement in the range of three to four per cent.

5 Conclusion

The findings of this trial suggest that vortex generators can provide a measurable improvement in fuel efficiency and greenhouse gas (GHG) benefit in a curtain-sided semi-trailer line haul application. The truck in this trial showed a 2.7-4.1 per cent improvement after the devices were fitted, refer Figures 7 and 8. Though the improvement may seem small, it is a statistically significant improvement and highly unlikely to be a random result.

Figure 8: Comparison of average trip GHG emissions across baseline and trial period



Similarly, the variation in improvement using different analysis techniques simply shows different analytical viewpoints, none of which are necessarily more right than others.

Similarly, the analytical techniques were applied to two different sets of data logging systems, and both data sets returned relatively consistent figures of improvement.

In financial terms, this would represent a $1.40 per 100 kilometres saving (or 1.4 cents per kilometre) on the truck used in this trial (using net diesel costs at the time of the trial of $1.20 per litre). Over an annual mileage of 150,000 kilometres in a regional line haul application, this could translate to a fuel saving of over $2,100 per annum.

Taking into account the purchase and installation cost at the time of the trial, this would result in a payback period of around one year (less with a higher diesel price). In addition, the device is low maintenance and relatively easy to install.

Previous studies on vortex generators, along with preliminary analysis of unpublished studies, suggest that the benefit may be sensitive to the configuration of the truck and trailer. In other words, different types of trailers may not achieve the same saving.

6 References

1. Carbon War Room 2012, *Road Transport: Unlocking fuel saving technologies in trucking and fleets*, Trimble Research Report Nov. 2012, *www.carbonwarroom.com/sites/default/files/reports/Unlocking%20Fuel%20Saving%20Technologies%20in%20Trucking%20and%20Fleets%20(Carbon%20War%20Room)_0.pdf*
2. Department of Industry 2012, *Improved vehicle aerodynamics, Energy Efficiency Exchange,* Australian Government, *http://eex.gov.au/resource/potential-energy-efficiency-opportunities-in-the-australian-road-and-rail-sectors/improved-vehicle-aerodynamics/*
3. International Energy Agency 2012, *Technology Roadmap: Fuel economy of road vehicles*, *www.iea.org/publications/fueleconomy_2012_final_web.pdf*
4. US Environment Protection Agency 2012, *Improved aerodynamics: A glance at clean freight strategies*, Smartway Transport Partnership, *www.epa.gov/smartwayshipper/forpartners/documents/trucks/techsheets-truck/420f00036.pdf*
5. IRTE/BTAC 2007, *Vortex Generators Technical Trials Articulated HGV – Tractor-Trailer Gap Tests,* Airtabs, *http://www.airtab.com/Site/documents/MIRAReport.pdf*
6. Lockheed Georgia 1982, *Lockheed Georgia lowspeed wind tunnel Honda Civic hatchback Airtab modification results,* Airtabs, *http://www.airtab.com/Site/documents/HondaWTReportV6.pdf*

7 Document control

Owner	Guido Zatschler – Senior Project Engineer Environment
File name	Case study_Aerodynamic device – Vortex generators on semi trailer
Online location	
Objective ID	
Document number	RMS 17.131
ISBN	978-1-925582-69-7
Version	1.0
Date	March 2017

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