Transport Roads & Maritime Services

GREEN TRUCK PARTNERSHIP

Case study

Aerodynamic device
Vortex generators on B-double tanker

Trail 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 B-double tanker running a regional collection and delivery run in South East Queensland.

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 for the objective evaluation of the merits of clean vehicle technologies and fuels used by heavy vehicle operators. This report discusses the fourth trial of vortex generating aerodynamic devices. The device was fitted to a B-double tanker in 2016 and monitored for 7 months and over 30,000km (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, 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 the cab and trailers, 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 2-3% individually and up to 15-20% in combination [1, 2, 3, 4]. For vortex generator devices specifically, manufacturers claim potential fuel efficiency savings of 3-5% or more, 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% improvement[5;] and a wind tunnel test which found a 4-6% improvement[6].

2 Trail objective

This trial assessed the economic and environmental performance of an aftermarket aerodynamic device (vortex generator) on a B-double tanker operating a regional collection and delivery run in South East Queensland.

The vehicle typically set-off from the depot at around 7am, collecting liquid from scheduled locations, before delivering it into a factory, and returning to the depot at around 3pm.

Two runs were scheduled, on alternating days. Only two drivers were assigned to these runs, on a set roster with few exceptions (such as annual leave and operational circumstances). The route was mostly on sealed roads, apart from some slow off-road running in the "last mile" to the liquid collection points.

3 Methodology

The trial involved an in-field assessment of one prime mover with dedicated tanker trailers in a B-double configuration. This tanker configuration included a pump module on the rear tanker.

Vortex generators were fitted to the rear of the truck cab and to the rear of both trailers. Photos of the installation are shown in Figures 1 to 5.

The effectiveness of the device was quantified by comparing the difference in fuel efficiency between a baseline period (no device) and the trial period (with the device fitted), excluding any periods or trips when the duty cycles were markedly different.

Figure 1 **Device installed on the full combination**

Figure 2 **Detail of cab side**

Figure 3 **Detail of cab roof**

Figure 4 **Detail of installation on first trailer**

Figure 5 **Detail of rear trailer**

3.1 Data collection

The baseline operated during the period May 2016 to September 2016, with the trial period ending in November 2016. The total distance travelled in the trial was over 30,000km.

There were four data sets collated and analysed, each logging different metrics.

1. The “GTP Dataset”, captured via the Green Truck Partnership’s standardised telemetry system, includes the following parameters:

- **DISTANCE**: kilometres travelled.
- **IDLE TIME**: time spent at idle.
- **ENGINE LOAD**: percentage theoretical maximum loading (%).
- **SPEED PROFILE**: percentage of time (%) spent at different vehicle speeds (km/hr).
- **FUEL CONSUMPTION:** total fuel consumed (L) and fuel efficiency (L/100km).
- **VEHICLE LOCATION:** GPS data.
- **STOPPING INTENSITY:** average distance travelled (km) between stops.

2. The “BoM Dataset”, captured by the nearest Bureau of Meteorology weather station, which includes:

- **AMBIENT TEMPERATURE**: daily maximums, minimums, and recurring scheduled readings (degrees Celsius).
- **AMBIENT PRESSURE**: daily recurring scheduled readings (hPa).
- **RAINFALL**: daily rainfall (mm)
- **WIND**: daily maximums and recurring scheduled readings (km/hr)
- **RELATIVE HUMIDITY**: Recurring scheduled readings (RH).

3. The “Vehicle Dataset”, captured via the truck manufacturer’s own telemetry system, includes:

- **DRIVER PERFORMANCE**: a number of metrics around driver behaviour, including “anticipation and braking”, scored out of 100.
- **DISTANCE**: daily kilometres travelled (km).
- **FUEL CONSUMPTION**: daily fuel consumed (L).

4. The “Production Dataset”, logged via the fleet’s electronic production system, which includes:

- **PRODUCTION**: the total amount of liquid collected and delivered (L), per run.
- **DRIVER**: confirmation on which driver actually completed the run.
- **RUN**: which of the scheduled runs was completed.

3.2 Data analysis

The first stage of analysis involved collating all four data sets.

Next, outliers were identified by trip distance, and removed from the dataset. The comprehensive dataset also enabled extra levels of refinement, including filters for atypical truck runs, atypical drivers, and poor driver performance scores.

With the outliers removed, the baseline and trial periods were then validated to ensure the two 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.

Figures 6 & 7 compare the engine load profiles for the validated data during the baseline and trial periods, showing a good correlation. The speed profile in both the baseline and trial periods also shows a good correlation. The good correlation in both engine load and speed profile suggests that the truck had been operated in a similar manner in both periods (before and after installation of the aerodynamic device); and that direct comparison of the fuel consumption values was valid (i.e. 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 (L/100km) in both the baseline and trial periods. These were analysed for their average, standard deviation, and other statistical metrics. The mean (average) L/100km 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 L/100km between the baseline and trial was simply random (just part of the natural “noise”).

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

As a final check, the data was analysed to determine if the L/100km figures were strongly correlated with any of the residual variables such as production, stopping intensity, time spent over 90km/hr, driver performance, and ambient conditions (temperature, pressure, wind speeds and relative humidity). This analysis provided a check to ensure the trial did not receive unduly favourable conditions which could not be accounted for in the previous filtering.

4 Results

The results of the first statistical tests showed that, within the validated fuel consumption data, the average trip showed very little change in fuel efficiency between baseline and trial periods. The baseline averaged 39.44 L/100km relative to the trial’s 39.38, or a 0.2% fuel efficiency improvement (Figure 8).

In the null hypothesis test, a common convention is to consider 5% or less as “statistically significant”. Applying this test to the data showed a 70% chance that the saving was simply a result of “noise” or coincidence. In other words, the fuel efficiency improvement is not statistically significant.

The third analysis covering the entire aggregated dataset showed a 0.4% improvement in fuel efficiency - a slightly larger improvement than the individual trip fuel efficiency.

The supplementary analyses looking at potential correlations of fuel efficiency with various other factors provided further insights. Interestingly, the unit of production (litres delivered) was not strongly correlated to fuel efficiency for similar trip distances. This is likely due to the existing filters (e.g. engine load) adequately controlling for this variation.

It was found that the stopping intensity (average km between stops) had the strongest correlation to L/100km: the longer the distance between stops, the better the fuel efficiency. The trial period was found to have benefited from a slightly favourable stopping intensity. Regression analysis was performed to normalise to a uniform stopping intensity, and that analysis found that the efficiency improvement was even less significant, shrinking from 0.2% to 0.1%.

Lesser correlations were also found; however, these were not incorporated to reduce the risk of “overfitting” the regression model.

5 Conclusion

The truck in this trial showed a negligible improvement after the vortex generator devices were fitted (Figure 8). Statistically, it is likely that the minor improvement is merely a result of random variability. Therefore, it could be inferred that vortex generators provide a negligible fuel efficiency and GHG benefit when used in a B-double tanker application.

Previous case studies by the *Green Truck Partnership* evaluating vortex generators also suggest that the drag reduction is sensitive to the configuration - a conventional semi-trailer was found to have a measurable benefit, while a road train configuration was found to have no benefit.

This trial was also notable for extending the GTP data analysis methodology with other parameters to increase confidence in the test results. In part, this was possible due to additional data systems from the company and the truck itself. However, correlating vehicle fuel consumption with production data and external factors (e.g. weather), are techniques that GTP can use for future trials.

The variation in results using different analysis techniques simply shows different analytical viewpoints, none of which are necessarily more right than others. However, these refinements resulted in an inherently tight grouping of data and allowed a definitive determinations about the effect of the technology itself.

Figure 6

Comparison of vehicle average speed across baseline and trial periods

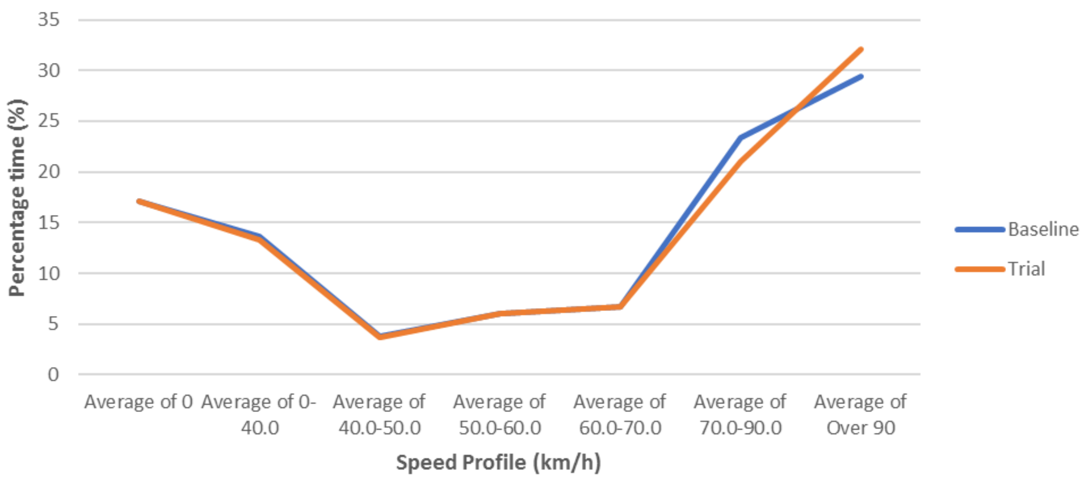


Figure 7
Comparison of vehicle average engine load across baseline and trial periods

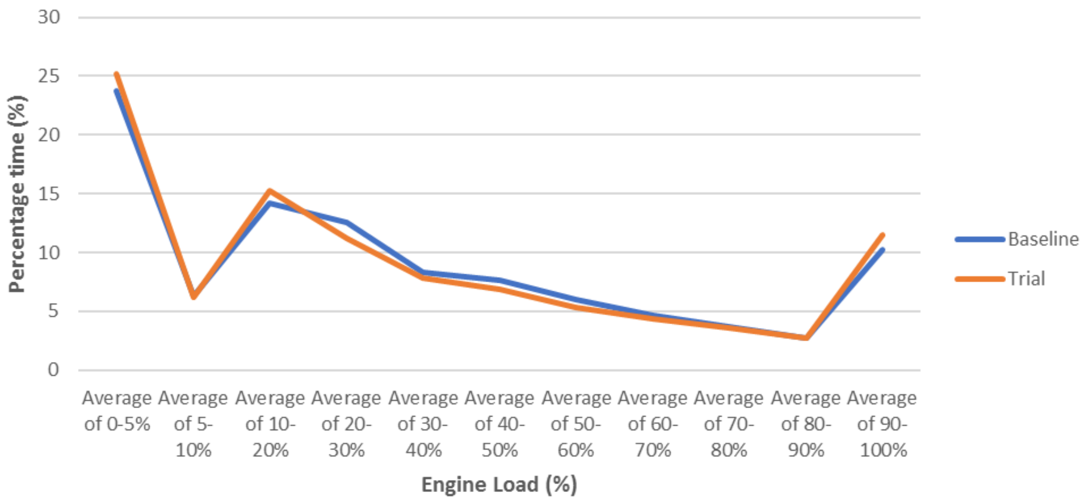
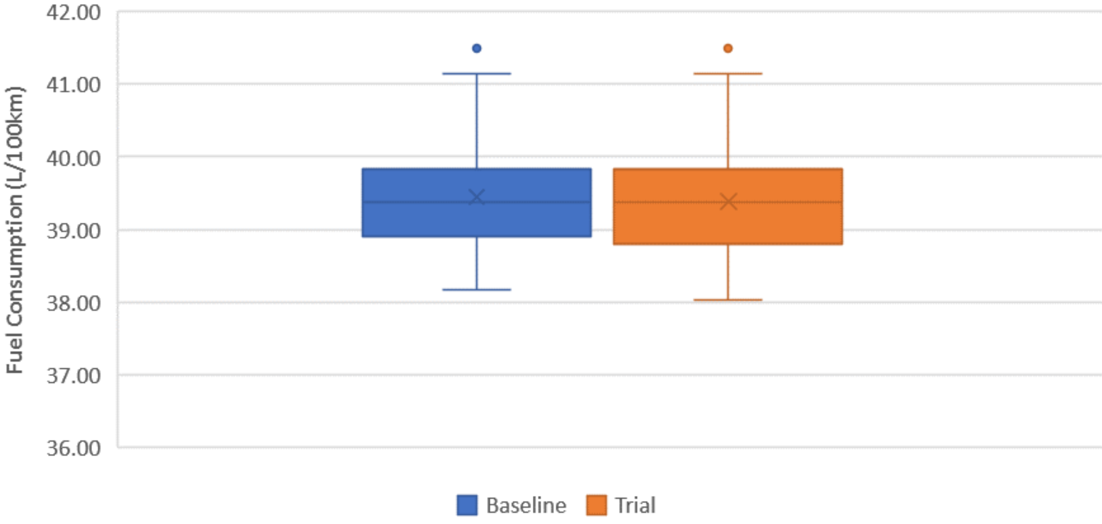


Figure 8
Fuel consumption box and whisker plot



6 References

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7 Document Control

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