

In Fleet Testing of Fuel Saving Measures

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10/05/2010Sumon Kumar Sinha
SinhatechSujata Sinha PhD
Rust College

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ABSTRACT

An economical method for reliably determining fleet fuel savings that arises out of the application of a vehicle fuel saving measure is presented. The method relies on testing the device on a random sample of vehicles during normal fleet operations. The sample size is determined by variations in fuel economy inherent in the fleet and the minimum increase in fuel economy needed for a desired return on investment in the device. This reduces the probability that the sample is biased. The sample fuel economy is compared to that of an untreated control group of trucks which can be the rest of the fleet or a subset with certain characteristics, like similar idling percentage. The final results provide a range of fuel economy enhancements at a given confidence level. The method has been applied to validate in operation fuel economy increase of a flatbed tractor trailer fleet due to Sinhatech's Deturbulator aero-drag reducing device.

INTRODUCTION

Truck fleets typically operate with gross profit margins below 5% and fuel accounts for 25-33% of total costs. This means that even a 1% reduction in fuel cost can enhance fleet profitability 5 to 7%. Unfortunately, fleet fuel consumption depends on multiple factors and only a few of these can be controlled. This means the effect on fleet fuel consumption of any fuel saving measure or device is difficult to detect under multi-truck operational conditions. This is true especially if the measure is applied to a few select units within the fleet to evaluate its effectiveness. Eventually, the net overall fuel savings for the entire fleet is what affects the bottom line, and extrapolating from sample results is deemed unreliable. Decision makers usually rely on well controlled industry

standard tests on a single vehicle against a control vehicle. These results however have to be extrapolated if the measure in question is applied to all units within a fleet. Such extrapolation requires ad-hoc corrections to account for “uncontrolled” factors. Results from a SAE [J1321](#) test for example are often discounted 50% or more ad-hoc to estimate fleet fuel savings. This unfortunately increases the likelihood that a device performing well in controlled single-vehicle tests fails to deliver expected savings when applied across the entire fleet. Conversely, a promising device or method maybe not even be considered.

We are therefore proposing a statistically based [1,2] in-operation multi vehicle test which any fleet can conduct without disrupting operations in any significant way. The tests take into account variations resulting from the duty cycle or actual operational conditions of the particular fleet which may not be exactly replicated in other fleets. The procedure relies upon determining the number of trucks to be treated based on the variability inherent in the fleet fuel consumption data. The untreated fleet can be used as control. While, the statistical techniques are well established [1], applying these to truck fleets in this manner is new [3].

This procedure does not replace existing tests, such as the SAE [J1321](#), which indicates the efficacy of a fuel saving device under defined standard controlled conditions. The intent of this procedure is to reduce the risk for fleets by enabling them better estimate the return on investment (ROI) of a fuel saving device in their fleet. Fleets typically monitor truck fuel economy by downloading data from truck mounted units periodically. The only “risk” is the added cost of applying the devices to a small sample of trucks and the cost of processing the downloaded data. If devices are damaged or

compromised during normal operations the test data automatically reflects this. Hence this procedure yields an actual in-fleet efficacy of the fuel saving device being evaluated.

PROCEDURE SUMMARY

1. The procedure requires monthly or weekly averaged “miles per gallon (mpg)”, or “km per liter (kpl)” data (designated as X_i for tractor number i) for all tractors (or powered units) in the fleet. Tractor numbers i range from 1 to N , where N is typically 100 or more.

2. From the above data the Fleet Average mpg or kpl “ μ ” are computed along with the Fleet Standard Deviation “ σ ” in mpg or kpl for the fleet of size N .

$$\mu = \frac{1}{N} \sum_{i=1}^{i=N} x_i$$

$$\sigma = \sqrt{\left[\frac{1}{N-1} \sum_{i=1}^{i=N} (x_i - \mu)^2 \right]}$$

A large N allows assuming the distribution of mpg or kpl values to be Normal. This follows from the “Central Limit Theorem” of statistics [1,2]. Based on the recommendation of ref [2], μ can be assumed to be the population mean provided $N \geq 20$, and σ can be assumed to be the population standard deviation provided $N \geq 50$.

3. A set of “ n ” randomly selected trucks ($n < N$) is then treated with the fuel saving device or measure. Typically n is less than 10 to begin with.

4. We record the *Before-Treatment* fuel economy of the trucks X_{i-BT} (mpg or kpl) for the month or week prior to treatment. We also record the Fleet Average fuel economy $\mu = \mu_{BT}$ during this period.

5. The trucks are then driven as per normal commercial operations within the fleet for another month or week (depending on how frequently mpg or kpl data is downloaded).

6. The *After-Treatment* fuel economy of the trucks X_{i-AT} (mpg or kpl) for the month or week after treatment is then recorded along with the Fleet Average fuel economy $\mu = \mu_{AT}$ during this period.

7. The increase in Fuel Economy ΔX_i of a treated truck i during this period attributable to the treatment is given by:

$$\Delta X_i = (X_{i-AT} - X_{i-BT}) - (\mu_{AT} - \mu_{BT})$$

8. We then calculate the average increase in mpg or kpl of the sample of n trucks and the standard deviation of these values:

$$\bar{\Delta x} = \frac{1}{n} \sum_{i=1}^{i=n} \Delta x_i$$

$$s = \sqrt{\left[\frac{1}{n-1} \sum_{i=1}^{i=n} (\Delta x_i - \bar{\Delta x})^2 \right]}$$

9. The Uncertainty U in $\bar{\Delta x}$ is then calculated as follows [2,4]:

$$U = \pm \frac{t.s}{\sqrt{n}}$$

Where, the t-distribution statistical variable “ t ” corresponds to an assumed confidence level “ c ” (likelihood that estimate is correct) and “degrees of freedom” $df = (n-1)$). This assumes sampling from a Normal distributed population [1,2,4] Generally c is between 80% and 99%. For $c = 95\%$ (a commonly used default), t can be found as:

Sample Size n	Degrees of freedom Df	t
2	1	12.7
3	2	4.3
4	3	3.18
5	4	2.78
6	5	2.57
7	6	2.45

The Estimate for Improvement in average Fleet Fuel Economy μ is then:

$$\Delta \mu = \bar{\Delta x} \pm \frac{t.s}{\sqrt{n}}$$

The probability that the improvement $\Delta \mu$ lies within the

bounds $\bar{\Delta x} + \frac{t.s}{\sqrt{n}}$ and $\bar{\Delta x} - \frac{t.s}{\sqrt{n}}$ is the confidence level c . What this estimate does not account for are:

a). The possibility that the n -truck sample is biased (i.e., too good or too bad and not truly representing the fleet) and does not account for all truck to truck operational variability in the entire fleet. Such variability can be due to driver behavior, load, idling, terrain, traffic, maintenance and model of truck.

b). The possibility of large changes with time due to weather changes, or damage and degradation of the device with extended use.

10. We then select the minimum increase “ m ” in Fleet Average mpg or kpl which the fuel saving measure or device needs to deliver in order to be considered. The device cost and desired payback period should be considered in figuring m .

11. The minimum improvement in Fleet Fuel Economy $\Delta\mu_{\min}$ which the device or measure delivered in the estimate of Step 9 is computed as:

$$\Delta\mu_{\min} = \Delta\bar{x} - \frac{t.s}{\sqrt{n}}$$

If $\Delta\mu_{\min}$ is greater than or equal to m , the measure or device should be considered. The average $\Delta\bar{x}$ can be used to estimate fleet fuel savings. However, for reducing the possibility of erroneous conclusions due to bias in the sample, the sample size n should be increased. The procedure for estimating this is shown below:

12. Determine the minimum number of trucks to be treated “ n ” in order to detect a change of m in Fleet Average mpg or kpl without encountering bias in the sample:

$$n = \left(\frac{z\sigma}{m} \right)^2$$

Here, σ is assumed to be population mean. The standard deviation in mpg or kpl from a fleet size N of 50 or more [2] can be used as per Step 2. This also meets the criterion of assuming Normal distribution of mpg or kpl values in the fleet. The Normal Distribution parameter z is therefore selected based on an assumed Confidence Level “ c ”. The Confidence Level signifies the likelihood that the estimate in Fleet Average improvement in mpg or kpl falls within $\pm m$. The following values may be used:

Confidence Level “ c ”	Normal Distribution Parameter “ z ”	Comments
99%	2.576	Extremely Stringent
95%	1.96	Commonly used default
90%	1.645	A 5% chance of obtaining mpg or kpl increase less than m
80%	1.282	A 10% chance of obtaining mpg or kpl increase less than m

APPLICATION OF PROCEDURE TO A FLATBED FLEET

Table 1 shows an application to a 540 tractor flatbed fleet operated by Western Express. A set of 6 tractors in this fleet were treated with an aero drag reducing device, the “Dolphin Skin Deturbulator” as shown in Fig 1.



Fig 1. Deturbulator Strip (Bottom) and installation on Flatbed Tractor (Top)

The Deturbulator consists of flexible-surface strips adhesively bonded to the body of a flatbed hauling tractor (Fig 1). It reduces turbulence found in the separated region behind the tractor converting it into a bubble encasing the trailer and its load [5] as shown in Fig 2. SAE J1321 tests have indicated the ability of the Deturbulator to reduce the tractor trailer gap drag when applied to the tractor and front corners of the trailer [6,7]. Since load shapes on a flatbed affect aerodynamics a SAE J1321 with a specified shape was seen to have limited utility for truck fleets. Also, a tractor mounted device makes it easier to monitor individual truck fuel mileage, further justifying in-fleet evaluations.

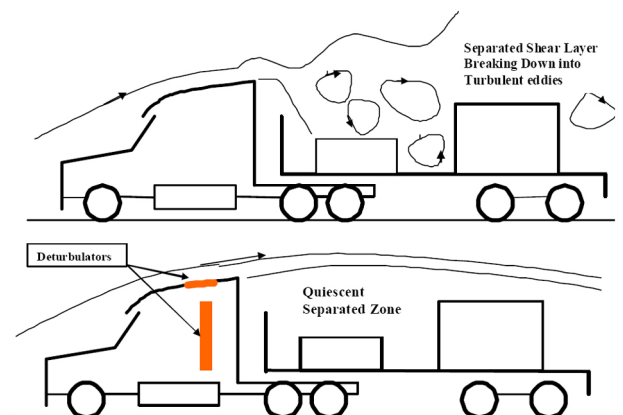


Fig 2. Effect of Deturbulator on Flatbed Aerodynamics

It was decided that a minimum 0.10 mpg increase in fleet fuel economy was needed to justify the ROI needed for adopting the Deturbulator for this fleet.