The Importance of Measuring Fuel Consumption In Evaluating Electronic Clearance

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Electronic screening of commercial vehicles at weigh stations is important to enforcement agencies and motor carriers as it allows both parties to use their resources more efficiently. This paper studies the effects of electronic screening on reducing the fuel consumption for motor carriers. The hypothesis that we tested was that a reduction or elimination of stops at weigh stations by participating transponder-equipped trucks will result in measurable fuel savings for those transponder-equipped trucks. The experiment demonstrates the impact of electronic screening on motor carriers by actually measuring fuel consumption between two trucks in the field under controlled conditions. The obtained results show that there are measurable fuel savings attributable to electronic screening. Key words: electronic screening, fuel consumption.

INTRODUCTION

With over 600 commercial vehicle inspection stations across the USA and the increasing emphasis on safety inspections for those vehicles, there are numerous occasions in which a commercial vehicle driver faces delays en route. Many of the nation's fixed inspection facilities were constructed 20 to 30 years ago. Consequently, the explosive growth in truck traffic has exceeded the station design specifications at many of these inspection stations. As truck arrivals exceed these stations' operational capacities, queues develop and drivers are delayed. Often, the backups require stations to close to avoid safety risks.

The national Intelligent Transportation System (ITS) program is designed to address these safety and productivity concerns along with focusing advanced technology on commercial vehicle operations (CVO). One part of this overarching program is to enhance mainline electronic clearance of CVO at the weigh stations. Several electronic clearance systems are in currently in operation across the country. These systems equipped with Automated Vehicle Identification (AVI) readers then identify the transponder-equipped trucks, verifying their size, weight, and credentials. When the information is read and verified, the trucks receive a signal, both visual and auditory. The signal directs the operator to either by-pass the weigh station or to enter the station (if there is a discrepancy in the size, weight, or credential information). The elapsed time of this communication from the truck to the weigh station, back to the truck, is less than one second. By electronic screening commercial vehicles on the mainline, thereby permitting compliant vehicles to bypass the weigh station, enforcement officials can better focus their resources on the non-compliant commercial vehicle operations. This paper describes the importance of measuring the fuel consumption of commercial vehicles as part of an overall evaluation of measuring the effects of electronic clearance at weigh stations.

This paper documents the application of a fuel consumption experiment. The paper illustrates the fuel consumption experiment through a case study of six typical weigh stations located on an interstate with high truck traffic volume. Although only six weigh stations were used in the case study, we have used the experiment to analyze electronic screening at for other weigh station designs.

METHODOLOGY

Our experiment is to determine if mainline electronic clearance produces significant fuel savings for motor carriers. The test used to make this determination applied accepted Society of Automotive Engineers' (SAE) guidelines. The prescribed method directed one truck to stay on the mainline and a second truck to enter the weigh station. The second truck then either stops or slow down at the scale, depending on the design of the weigh station. The fuel used by each truck was then precisely measured to determine the fuel used by each vehicle. The difference in fuel used was the estimated savings of fuel attributable to a truck bypassing a weigh station.

Test Procedures

The fuel consumption test was based upon the Society of Automotive Engineers Recommended Practice (SAE Type II Fuel Consumption Test). This experiment was performed to determine if the reduction or elimination of stops at weigh stations by trucks equipped with transponders results in measurable fuel savings for each participant truck. One truck, termed the control truck, always bypassed the weigh station. The other truck, termed the test truck, alternated between control runs in which the weigh station was bypassed, and experimental (or test) runs in which the weigh station was entered. At each of the test sites, the baseline fuel con-

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sumption difference between the two trucks was measured (when both trucks bypassed the weigh station.) Then the experimental fuel consumption difference was measured between the two trucks (when one truck bypasses the weigh station and one stops or slows at the weigh station.) This procedure includes two forms of control. First, during each run the control truck and test truck encountered almost identical conditions, therefore any observed differences were due to experimental or vehicle differences. Second, the use of baseline runs provided estimates of the fuel consumption differences due to vehicle variances (tire tread, engine performance, etc.) The baseline runs, therefore, provided a control for the experimental runs. For the purposes of consistency and reliability, the same equipment and drivers are used through out the duration of the experiment.

In an attempt to obtain "real-world" results as closely as possible, standard issue equipment was used for these fuel consumption experiments. The only modifications made to the vehicles were the addition of the portable fuel tanks, utilized for the precise measurement of the fuel usage. Prior to beginning the tests, the tractors were equipped with "quick-connect" fittings by the motor carrier, permitting the easy installation and subsequent removal of the portable fuel tanks and fuel coolers. No other alterations were made to the tractors or trailers.

There were three basic weigh station design types used for the fuel consumption experiment: the static scale design, the ramp weigh-in-motion (WIM) design, and the high-speed ramp WIM design. These are the most common design types encountered by commercial vehicle operators. To gain the most from the experiment, we decided to use the most efficient and least efficient design types in order to determine a proper range of fuel consumption. To that end, two static scale design types were chosen, two ramp weigh-in-motion design types were chosen. Finally, high-speed ramp WIM design was selected. To recap the site location decisions, these sites were chosen based upon their topographical layouts, varying traffic volumes, and efficiency in design. One set of static scales has flat terrain and contains moderate traffic volume. Conversely, the second set of static scales is hilly with very heavy volume of vehicle traffic. Likewise, the first set of ramp WIM scales is laid out on flat terrain, with heavy volume of traffic. Meanwhile, the second ramp WIM scale layout is hilly with a moderate amount of traffic. The high-speed ramp WIM design is the most efficient design layout of the group. It is on flat terrain with a light to moderate traffic volume. This design was termed "High-Speed" Ramp WIM because the design allows trucks to use the bypass lane at speeds of up to 45 mph (72 kph), which is considerably higher than other bypass lanes at other facilities.

Data Analysis

To evaluate the hypothesis that trucks bypassing weigh stations consume less fuel, the fuel consumption has been measured using the test procedures described earlier in this document. The goal is to provide a measure of the expected savings (gallons of fuel per weigh station bypassed) for different weigh station designs. One can formally test the hypothesis of no savings but this is no of much interest here. Instead this experiment focuses on providing a valid estimate along with estimates of the possible variation due to a variety of uncontrolled factors.

Input Data

Data worksheets filled out during the test runs included for each truck: condition (bypass or stop), distance traveled, fuel consumed, time stopped during the run. Wind speed and ambient temperature at the time of each run were also recorded. Analyses of previous pilot data and the present data suggest that wind speed and temperature are not needed for the analysis. This is expected due to the fact that the test and control trucks face the same conditions in each run. The basic measurement that we use for each run is the fuel consumed difference in gallons per weigh station between the control truck and the test truck.

Methods

The approach that is taken here uses two-sample statistical methods (comparing control or baseline runs to experiment runs). Symbols required to carry out the analysis are defined as:

M*b*=the mean observed fuel consumption difference between the control truck and the test truck during the baseline runs

M*e*=the mean observed fuel consumption difference between the control truck and the test truck during the experimental runs

S*b*=the standard deviation of the observed fuel consumption differences between the control truck and the test truck during the baseline runs

S*e*=the standard deviation of the observed fuel consumption differences between the control truck and the test truck during the experimental runs

N*b*=number of baseline runs

N*e*=number of experimental runs

The values are provided in Table 1. Note that if identical trucks were used, then the expected value of M*b* would be near zero. The values observed there are far from zero, which points out the importance of baseline runs for establishing the relative fuel usage of the two trucks. The difference between M*b* and M*e* is a measure of fuel savings due to bypassing trucks. M*b* is lower than M*e* because the test truck is using more fuel in the experimental runs when it stops (or slows) for the weigh station.

The two sample pooled-t-statistic-based methods are used for drawing conclusions. To be specific, the runs are viewed as a sample from a population in which the team is interested (the savings that would be observed in a much bigger experiment involving more trucks). The observed difference between M*b* and M*e* is an estimate of the fuel savings expected. A 95% confidence interval provides a range of plausible values for the expected fuel savings. The formula used to provide the interval is:

$$\textit{Confidence Interval} = (Mb - Me \pm t * S \sqrt{1/Nb + 1/Ne})$$

Where S is a pooled (combined) estimate of variability that uses both the experimental and baseline runs and the t * value is a number that can be obtained from the tables to insure the 95% confidence statement is accurate (the t * value is generally about 2.0). More details about this procedure can be found in a variety of statistics texts including *The Basic Practice of Statistics* by D.S. Moore, W.H. Freeman and Co., 1994. The pooled procedures require that Sb and Se be approximately the same. The are almost identical at four of the five sites. The difference is more substantial high-speed WIM scale type, but still within the range for which pooled procedures are generally applied.

Table 1 Fuel Consumption Baseline and Experimental Results at Each Station

Station	Run Type	Number of Runs	Mean in Gal.	Std. Dev. in Gal.	SE Mean in Gal.
Station #1	Baseline	12	0.2314	0.0399	0.115
Static	Experimental	26	0.0523	0.0390	0.0076
Station #2	Baseline	15	0.1762	0.0399	0.0103
Static	Experimental	15	0.0124	0.0393	0.0101
Station #3	Baseline	23	0.1324	0.0438	0.0091
WIM	Experimental	25	0.0228	0.0402	0.0080
Station #4	Baseline	25	0.0171	0.0601	0.0120
WIM	Experimental	25	-0.0445	0.0648	0.0130
Station #5	Baseline	35	0.1703	0.0364	0.0860
WIM	Experimental	34	0.1184	0.0255	0.0044

Table 2 Estimated Mean Fuel Savings Per Station Bypassed

Station	Station Type	Estimated Fuel Savings in Gallons	95% Confidence Interval in Gallons
Station #1	Static	0.16	0.134, 0.194
Station #2	Static	0.18	0.151, 0.207
Station #3	WIM	0.11	0.085, 0.134
Station #4	WIM	0.06	0.026, 0.097
Station #5	WIM	0.05	0.037, 0.067

It is noteworthy that the sample size and the run-to-run variability (S*b* and S*e*) affect the width of the confidence interval. Sample sizes were chosen with the goal of obtaining confidence intervals sufficiently narrow for accurate inference.

CONCLUSIONS

Table 2 provides the mean fuel savings in gallons per weigh station bypassed and a 95% confidence interval for each site. All confidence intervals exclude the value zero which means that the fuel savings are “statistically significant.” This statement is of limited value since it would seem evident that some fuel savings accrue to trucks that bypass weigh stations. While the results of the experiments are still preliminary, however, we are able to discuss the magnitude of savings.

The static scales provide the most dramatic savings with. The high-speed ramp WIM scale type performs as advertised with minimal fuel savings per station bypassed. The savings accrued at the ramp WIM set of scales are less dramatic. The last result from the ramp WIM station is surprisingly low, even with the hilly terrain surrounding the facility’s area. The confidence interval here is widest because there was a great deal of variability from run-to-run.

The value of bypasses to an individual truck or firm depends on the number and nature of stations passes. For example, suppose a truck bypassed 100 static scale stations over a month. With fuel at $1.11/gallon this would mean savings of approximately $15/month.

Here is another example of expressing the fuel savings: Suppose 100 trucks are electronically cleared to pass a static scale type weigh station, this would mean fuel savings of 16 gallons for those bypasses. Therefore, following these experiments we can say that there are measurable fuel savings attributable to electronic clearance of commercial vehicles at weigh stations.

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