



Advantage I-75 Mainline Automated Clearance System

Final Report

Part 2 of 5: Motor Carrier Fuel Consumption Individual Evaluation Report

Prepared for

The Advantage I-75 Evaluation Task Force

Submitted to

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Motor Carrier Fuel Consumption

Final Report

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Introduction

With over 600 commercial vehicle inspection stations across the USA and the increasing emphasis on safety inspections for commercial vehicles, there are numerous occasions on 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. Presently, along the Interstate 75/Highway 401 corridor, there are approximately 4,500 trucks equipped with transponders to communicate with AVI (Automated Vehicle Identification) readers located near the 29 weigh stations on the corridor. The AVI readers then identify the transponder equipped trucks and their credentials. Weigh stations equipped with mainline weigh-in-motion (WIM) scales can also verify compliance with truck size and weight regulations. When the information is read and verified, the trucks receive a signal, both visual and audible. The signal directs the operator to either by-pass the weigh station or to enter the station (for a random inspection). The elapsed time of this communication from the truck to the weigh station, back to the truck, is less than one second. By electronically screening commercial vehicles on the mainline, thereby permitting compliant vehicles to bypass the weigh station, enforcement officials can better focus their resources on non-compliant commercial vehicle operations. This specific test was to evaluate the effect of electronic clearance on motor carrier fuel consumption along the Interstate 75/Highway 401 corridor.

Project Scope

The purpose of this part of the evaluation 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 would then either stop or slow 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.

Summary of Findings

The fundamental hypothesis tested was that reduction or elimination of stops at weigh stations by transponder equipped truck will result in measurable fuel savings for each transponder equipped vehicle. Fuel savings estimates were measured at five sets of weigh stations along the corridor. These five sets of weigh stations represent the three main weigh station design types. They are: The static scale design type, the ramp weigh-in-motion (WIM) design type, and the high speed ramp WIM design type. The estimated fuel savings were different for each weigh station design type. The static scale design type

provided the most substantial fuel savings. Bypasses at Knoxville, Tennessee and Findlay, Ohio, provided measurable savings of 0.16 (0.61 liters) and 0.18 gallons (0.69 liters) per vehicle per station bypassed respectively. The fuel savings accrued at the ramp WIM scales are less dramatic. The savings in Monroe, Michigan were estimated at 0.11 gallons (0.42 liters) per vehicle per station bypassed. The savings in Monroe, County, Georgia, however, were estimated at 0.06 gallons (0.23 liters) per station. Finally, the savings accrued in Charlotte County, Florida, at the high speed ramp WIM, were 0.05 gallons (0.19 liters) per vehicle per station bypassed. A small study of fuel consumption in queues suggests that the fuel savings for static scales may be as much as twice the values given here when trucks are in stop-and-go driving conditions averaging 4 mph (6.4 kph). As this was a controlled experiment, the fuel savings realized were minimal savings. The principal conclusion, however, is that there are measurable fuel savings obtained by electronic clearance. The value of these savings, however, depends upon the number and nature of stations electronically cleared.

purpose of the test

The purpose of this test was to evaluate the effect the Advantage I-75 Mainline Automated Clearance System (MACS) has on the fuel consumption of participant motor carriers.

The detailed data collected as part of the Motor Carrier Fuel Consumption Individual Evaluation Test were used to provide data on fuel usage of heavy trucks at weigh stations.

Evaluation Test description

On the basis of the results of the previous evaluation activities and pilot studies, this test was designed to determine the potential fuel savings attributable to electronic clearance of weigh stations at selected sites along the Advantage I-75 corridor.

This test was based upon applying accepted fuel consumption test procedures to determine the differences in fuel consumption between two nearly identical commercial vehicles under defined scenarios (scripts) in the vicinity of selected weigh stations on the I-75 corridor. The scripts were designed such that one of the trucks simulated electronic clearance by driving past the weigh station at mainline speeds while the other truck simulated routine weigh station processing by driving through and stopping or slowing (as the weigh station design dictated) at the weigh station. At the selected test sites, the two trucks were equipped with special 15-gallon (56.775 liter) fuel tanks and given specific instructions concerning speed and route for a loop of interstate highway containing two weigh stations (one each direction). The trucks used in this test were nearly identical in specifications, equipped with identical loads and used the same drivers throughout the test procedure. Also, the trucks began their test runs within one minute of each other to control as much variability in fuel consumption as possible. The fuel consumption was measured according to the procedures defined in the SAE Type II Fuel Consumption Test (SAE J1321). This test was conducted under controlled conditions. Thus, the tests were run with the weigh stations closed, in order to control the variability in fuel consumption associated with queues.

Hypothesis Tested

Hypothesis One: "Reduction or elimination of stops at weigh stations by participant transponder equipped trucks will result in measurable energy (fuel) savings for each equipped truck." (Detailed Evaluation Plan, May 10, 1996.)

Recap of 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 consumption 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.

It should also be noted that Mr. Claude Travis of Claude Travis & Associates was instrumental in developing these test procedures. Mr. Travis played a key role in the Pilot Tests and provided much needed expertise and advice throughout the evaluation procedure.

Scenarios of Fuel Consumption Tests

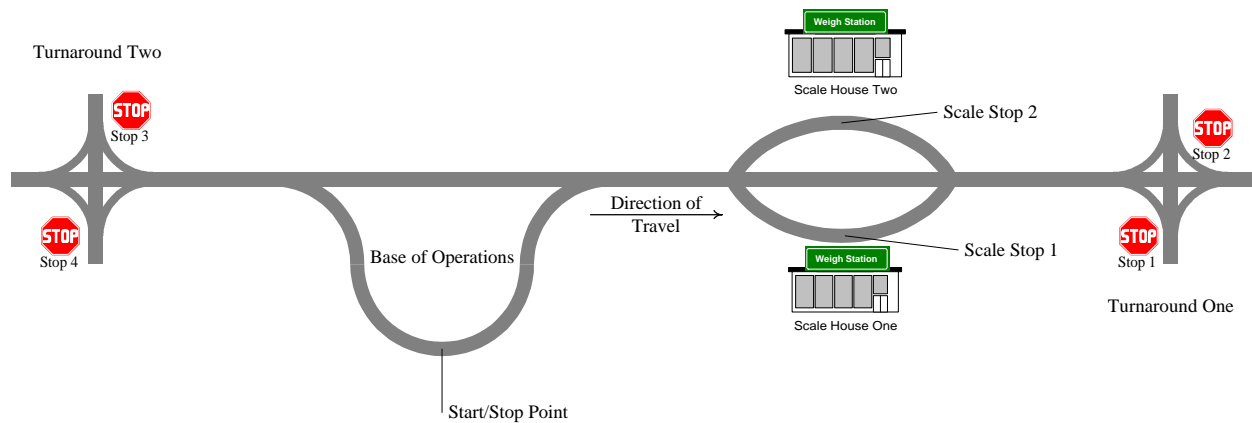
The following describes the scenarios, scripts and procedures for performing the Fuel Consumption Tests. These are the scenarios as described in the Detailed Evaluation Plan, submitted on May 10, 1996.

As previously stated, two identically equipped trucks, one termed the control truck and one termed the test truck, complete test runs on defined loops of the interstate highway following defined scripts. The defined interstate highway loops, illustrated in Figure One, consist of two weigh stations, two turnaround points, and one base of operations. The trucks complete the appropriate number of baseline runs whereby both of the trucks follow the control script. These runs are used to establish baseline fuel consumption differences between the two trucks. The trucks then complete the appropriate number of test runs whereby one truck follows the control truck script and the other truck follows the test truck script. The trucks were dispatched on the runs within 30 seconds of each other, so that they would be running in identical conditions. The number of baseline runs and test runs is dependent upon weigh station design. (Detailed Evaluation Plan, pp. 22 - 23, May 10, 1996).

The drivers complete each test run according to the following scripts. Separate scripts are provided for the control truck and the test truck. The route of a typical test run is provided in Figure 1.

Figure 1: Typical Test Route

Script for the Control Truck



1. Upon entering the truck cab, close the vent window and side window, reset the cumulative stop timer to zero, release the parking brakes (hold the vehicle in place using the foot brake pedal), and wait for the start signal from the data collection team leader.
2. When the data collection team leader signals the start of the run, start the engine, exit the base of operations, and begin the test run.
3. Accelerate to 60 miles per hour (mph) (97 kilometers per h[kph]), enter the mainline and engage the cruise control.
4. Bypass Weigh Station One and proceed to the exit designated as turnaround one.
5. Come to a complete stop at the base of the turnaround one exit ramp (see stop point one) and depress the start button of the cumulative stop timer.
6. Turn left, pull away from stop point one when traffic permits, and depress the stop button of the cumulative stop timer.
7. After crossing over the interstate highway, come to a complete stop at a point opposite the top of the interstate entrance ramp (see stop point two), and depress the start button of the cumulative stop timer.
8. Turn left onto the interstate exit ramp when traffic permits and depress the stop button of the cumulative stop timer.
9. Accelerate to 60 mph (97 kph), re-enter the interstate highway, and engage the cruise control.
10. Bypass Weigh Station Two, and proceed to the exit ramp designated as turnaround two.

11. Come to a complete stop at the base of the turnaround two exit ramp (see stop point three) and depress the start button of the cumulative stop timer.
12. Turn left, pull away from stop point three when traffic permits, and depress the stop button of the cumulative stop timer.
13. After crossing over the interstate highway, come to a complete stop at a point opposite the top of the interstate entrance ramp (see stop point two) and depress the start button of the cumulative stop timer.
14. Turn left onto the interstate exit ramp when traffic permits and depress the stop button of the cumulative stop timer.
15. Accelerate to 60 mph (97 kph), re-enter the interstate highway, engage the cruise control, and proceed to the exit ramp at the base of operations.
16. Upon arriving at the base of operations start/stop point set the parking brake and put the transmission in neutral.
17. Observe the cumulative stop timer and idle the engine for the period of time necessary to equal 60 seconds total stop time. For example, if the cumulative stop timer indicated 27 seconds, the engine would be idled for 33 seconds to equal 60 seconds total stop time.

Script for the Test Truck

1. Upon entering the truck cab, close the vent window and side window, reset the cumulative stop timer to zero, release the parking brakes (hold the vehicle in place using the foot brake pedal), and wait for the start signal from the data collection team leader.
2. When the data collection team leader signals run start, start the engine, exit the base of operations, and begin the test run.
3. Accelerate to 60 miles per hour (97 kph), enter the mainline, and engage the cruise control.
4. Instruct the run observer, seated in the passenger seat to notify Weigh Station One at a point 4 miles (6.4 km) upstream from the weigh station entrance ramp.
5. Slow to the designated weigh station approach speed at the beginning of the weigh station entrance ramp and continue to the static scale.
6. Come to a complete stop for 15 seconds at the static scale (***do not engage the cumulative stop timer***).
7. Pull away from the static scale, and re-enter the mainline.
8. Accelerate to 60 mph (97 kph), engage the cruise control, and proceed to the exit ramp designated as turnaround one.
9. Come to a complete stop at the base of the turnaround one exit ramp (see stop point one) and depress the start button of the cumulative stop timer.
10. Turn left, pull away from stop point one when traffic permits, and depress the stop button of the cumulative stop timer.
11. After crossing over the interstate highway, come to a complete stop at a point opposite the top of the interstate entrance ramp (see stop point two) and depress the start button of the cumulative stop timer.
12. Turn left onto the interstate exit ramp when traffic permits and depress the stop button of the cumulative stop timer.

13. Accelerate to 60 mph (97 kph), re-enter the interstate highway and engage the cruise control.
14. Instruct the run observer, seated in the passenger seat, to notify Weigh Station Two at a point 4 miles (6.4 km) upstream from the weigh station entrance ramp.
15. Slow to the designated weigh station approach speed at the beginning of the weigh station entrance ramp and continue to the static scale.
16. Come to a complete stop for 15 seconds at the static scale (*do not engage the cumulative stop timer*).
17. Pull away from the static scale, and re-enter the mainline.
18. Accelerate to 60 mph (97 kph), engage the cruise control and proceed to the exit ramp designated as turnaround two.
19. Come to a complete stop at the base of the turnaround two exit ramp (see stop point three) and depress the start button of the cumulative stop timer.
20. Turn left, pull away from stop point three when traffic permits, and depress the stop button of the cumulative stop timer.
21. After crossing over the interstate highway, come to a complete stop at a point opposite the top of the interstate entrance ramp (see stop point two) and depress the start button of the cumulative stop timer.
22. Turn left onto the interstate exit ramp when traffic permits and depress the stop button of the cumulative stop timer.
23. Accelerate to 60 mph (97 kph), re-enter the interstate highway, engage the cruise control, and proceed to the exit ramp at the base of operations.
24. Upon arriving at the base of operations start/stop point set the parking brake and put the transmission in neutral.
25. Observe the cumulative stop timer and idle the engine for the period of time necessary to equal 60 seconds total stop time. For example, if the cumulative stop timer indicated 27 seconds, the engine would be idled for 33 seconds to equal 60 seconds total stop time.

Procedures

The following paragraphs provide a discussion of the setup procedure for the test trucks and the base of operations. Following that, the test run procedure provides a discussion of the data collection team procedure for each of the test runs.

Setup

Upon arriving at the selected test location, the test trucks must be equipped with the appropriate fuel lines and fuel tanks, and the base of operation must be set up.

- { **Test Truck Fuel Lines:** First, the trucks must be equipped to accept the portable fuel tanks and quick disconnect fuel lines. This is completed by installing quick-connect fittings on the fuel draw and fuel return lines. Secondary fuel draw and fuel return lines with in-line fuel coolers are then run from the engine to the location where the portable fuel tank will be mounted. The quick connect fittings will allow the truck to be fueled by either the portable 15 gallon (56.775 liters)

fuel tanks (during the test runs) or the existing 150 (567.75 liters) gallon fuel tanks (traveling to and from lodging facilities).

{ Test Truck Fuel Tanks: Second, the portable fuel tanks are installed in a location that allows quick access and secure mounting. These tanks are held in place with cargo securement straps. Generally, the fuel tanks can be mounted on the deck plates behind the truck's sleeper cab. These deck plates are typically used by drivers when coupling or uncoupling trailers and would provide adequate support for the 150-pound (68.1 kilograms) portable fuel tanks. Using the experience gained in Pilot Study One, six hours should be an adequate time period to equip the two trucks (test truck and control truck). It should be noted that the truck setup procedure needs only to be done once at each test location.

Figure 2: Placement of Portable Tanks



{ Test Truck Fan Hubs: The automatic fan hubs are disabled by disconnecting the positive power lead to the air solenoid. This eliminates variability in fuel consumption that is attributable to the engagement and disengagement of the fan hub. It should be noted that engine operating temperatures will be closely monitored. Should operating temperatures approach manufacturers recommended maximums, test runs will be suspended or the fan hubs will be set to constant run (always engaged).

{ Base of Operations: The base of operations is a site located on the test route that provides an adequate safe working area at each test location. This working area is used for installing and

removing the portable fuel tanks before and after each test run and fueling and weighing an extra set of tanks while the trucks complete test runs. As part of the setup activities, the scales used to weigh the fuel tanks must be set up and leveled at a location that is shielded from wind and rain. The recommended method is to use an enclosed 6 foot × 12 foot (1.82 m x 3.66 m) trailer with a sturdy floor that can be detached from a towing vehicle and leveled. This trailer would house the scale used for weighing the tanks and a one-day fuel supply.

{ Other Setup Activities: The base of operations was well marked with orange-safety cones and warning signs during setup. For tests scheduled during nighttime hours, the base used auxiliary lighting utilizing a portable generator with a light stand.

Test Runs: The data collection team procedure for each test run is detailed in the following paragraphs:

1. The portable fuel tanks are filled, weighed, with the weights recorded on the data collection sheet (one sheet per run), and loaded on the trucks. The odometer reading for each truck is also recorded on the appropriate location on the data collection sheet at this time.
2. The drivers go to their trucks, close the vent windows and side windows, release the parking brakes, hold the vehicle in position with the foot brake pedal, and wait for the start signal.
3. The data collection team leader signals the control truck to start the engine and begin the test run according to the prescribed script.
4. The data recording person notes the control truck start time (HH:MM:SS) on the data collection sheet.
5. Between 30 and 45 seconds after the control truck begins its run, the data collection team leader signals the test truck to start the engine and begin the test run according to the script.
6. The data recording person notes the test truck start time (HH:MM:SS) on the appropriate data collection sheet.
7. A member of the data collection team observes and records the wind speed and direction and temperature within one minute after the test truck has departed the base of operations.
8. The extra set of tanks are weighed (empty weight from previous run), filled, and re-weighed (loaded weight for next run) while the control truck and test truck complete their test runs.
9. As the trucks approach the base of operations after completion of their test runs, the data collection team positions themselves to direct traffic. This is necessary to prevent unplanned stops or starts for the test truck and control truck as they re-enter the base of operations.
10. The data recording person notes the engine stop time (HH:MM:SS) when each truck has been parked and the engine has been shut down.
11. The data recording person then interviews the drivers and notes any significant deviation from the defined script (unplanned stops or starts or other factors that might skew the fuel consumption).
12. The fuel tanks are changed (empty tank replaced with full tank) and the trucks are readied for the next run.
13. The drivers go to their trucks and ready for the next test run (ideally within five-seven minutes).

14. After the test trucks have departed the base of operations on the next test run, the data collection team leader computes the fuel consumed and notes the T/C ratio¹ for the previous run.

Planning and Scheduling

The test schedule was contingent upon close coordination with all test participants. The following tables list the names, organizations, addresses, and telephone numbers for each of the participants involved in the test:

Table 1: Test Participant Contacts by Project Role

Role	Key Contact	Address	Phone/Fax
Evaluation Manager	Mr. Bill McCall	Center for Transportation Research and Education 2625 N. Loop Drive Suite 2100 Ames, Iowa 50010-8615	(515) 294-9501 (515) 294-0467
Evaluation Coordinators	Mr. James York, Mr. Dennis Kroeger	Center for Transportation Research and Education 2625 N. Loop Drive Suite 2100 Ames, Iowa 50010-8615	(515) 294-8103 (515) 294-0467
Data Collection Team	Mr. Ed Powe	Entrepreneurial Development Institute (EDI) Kentucky State University 415 Hathaway Hall Frankfort KY 40601	(502) 227-6172 (502) 227-6763
Motor Carrier	Mr. Richard Honeycutt	Collins and Aikman Corporation PO. Box 521 New London NC 28127	(704) 985-1202 (704) 985-1216

Scheduling commitments were made with participants approximately six weeks prior to commencement of actual testing. Events such as the 1996 Summer Olympics in Atlanta, Georgia and highway construction projects caused changes in the original schedule. We proceeded with the tests in other locations and returned to the Georgia test site following the conclusion of those special events.

¹ The T/C ratio is defined as the ratio of test truck fuel consumption (pounds of fuel consumed) to control truck fuel consumption (pounds of fuel consumed). This ratio is computed in the field to verify that test run consistency meets defined SAE standards for data collection. A detailed description of the field data and required field data reduction method is provided in Appendix One pp. 48-49 of the Evaluation Recommendations. *Detailed Evaluation Plan Part One: Evaluation Recommendations*. The Iowa Transportation Center. October 18, 1995.

Test Locations

With regard to the information learned from Pilot Study One, the goal of the site selection was to choose the most favorable and the least favorable topographical conditions for each of the weigh station design types that exist on the Advantage I-75 corridor. Thus, weigh stations were chosen for their terrain as well as their design and proximity to each other at that location. (See pp. 20-21 of the Detailed Test Plan, submitted May 10, 1996, for a more detailed discussion of site selection.)

The following table lists the test sites that were selected for the tests, and the contact person for that weigh station.

Table 2: Weigh Station Contacts by Test Location

Test Location	Key Contact	Address	Phone/Fax
Monroe, MI	Lt. Thomas Kenney	Michigan State Police 12075 South Telegraph Road Erie MI 48133	313-848-4684 313-848-3603
Findlay, OH	Sgt. Jim Bennett	Ohio Highway Patrol 3201 North Main Avenue Findlay OH 45840	419-423-1414 419-423-9179
Knoxville, TN	Capt. Richard Sayne	Tennessee Dept. of Public Safety 7601 Kingston Pike Knoxville TN 37919	615-966-5071 615-671-1293
Monroe, Co. GA	Capt. Cliff Tackett	Georgia Dept. of Transportation 935 E. Confederate Ave Atlanta, GA 30316-2531	912-994-1278
Charlotte, Co. FL	Maj. Bill Mickler	Florida Department of Transportation 605 Suwannee Street Mail Station 99 Tallahassee FL 32399-0450	904-488-7920 904-221-6627

Generally the above named officials were notified in writing and by telephone approximately one month in advance of commencing the fuel consumption tests. The tests were scheduled and conducted in the following order:

1. Findlay, Ohio
2. Monroe, Michigan
3. Knoxville, Tennessee
4. Charlotte County, Florida
5. Monroe County, Georgia

Test Duration

The duration of the tests was dependent upon weigh station design type. The Findlay, Ohio and Knoxville, Tennessee locations are static scale design. All trucks are directed to the scale and there is no bypass lane. The Monroe, Michigan and Monroe County, Georgia locations are Ramp Weigh-In-Motion (WIM) design, consisting of a static scale and a bypass lane. The weigh station in Charlotte County, Florida contains a higher speed ramp WIM design. The weigh station is equipped with a bypass lane that permits speeds of 45 miles per hour (72 kph), and two scales for weighing trucks. As described in the Detailed Evaluation Test Plan, weigh station types vary in expected fuel savings and in variability from run-to-run. On the basis of the Pilot Study data, tests including 60 runs (30 control runs and 30 test runs) were recommended for the static scales; 100 runs for ramp WIM scales; and 140 runs for the high speed ramp WIM scales. These sample sizes were reduced by half when the studies were carried out because:

- w The time required to perform the tests with the original sample sizes was found to be excessive;
- w The recommended sample sizes were found to be conservative, once the data collection began.

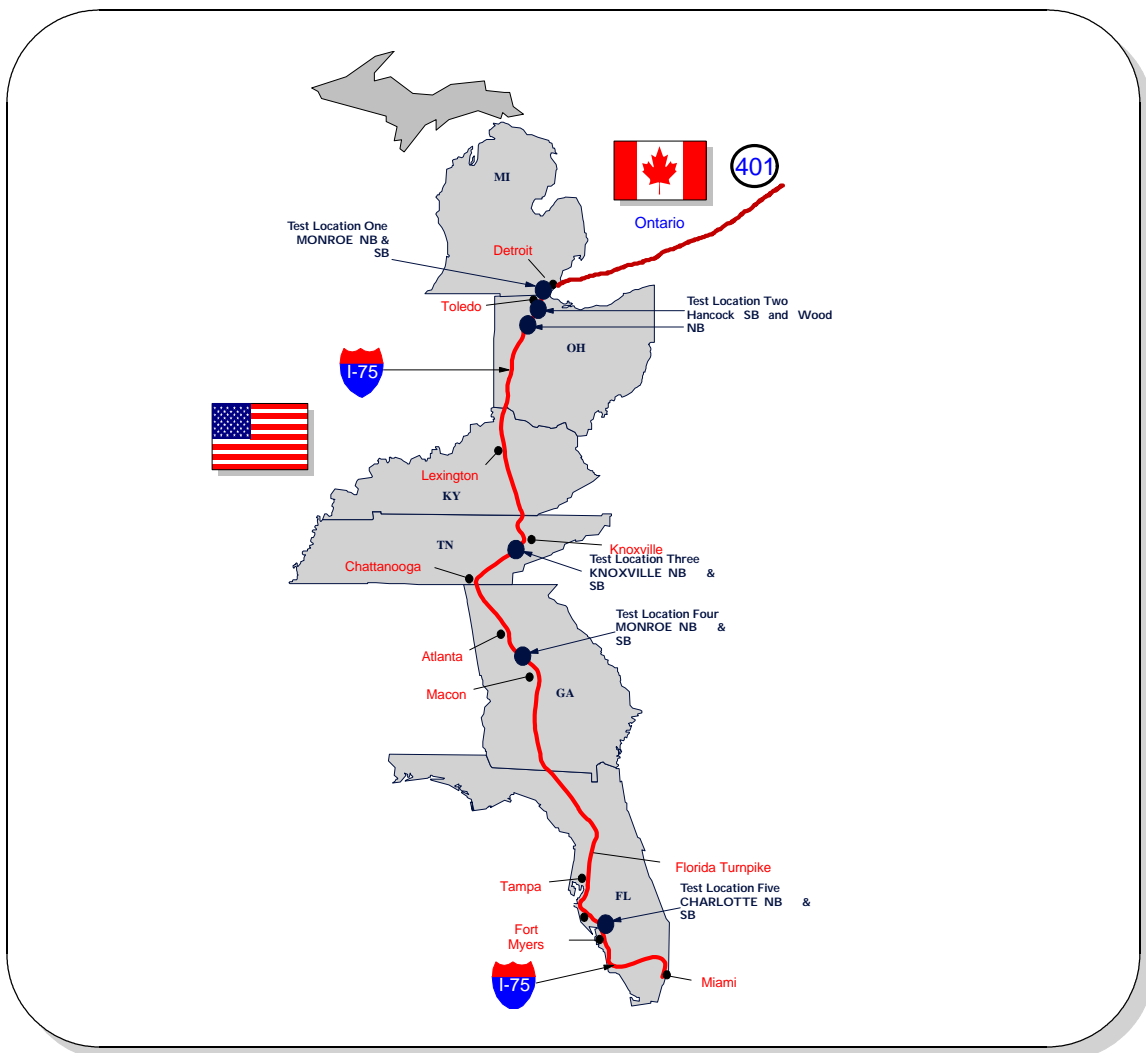
Table 3 lists the test location, scale design and duration of the tests.

Table 3: Test Location, Design Type and Test Duration

Test Location	Design Type	Duration (in Days)	Total Test Runs
Monroe, MI	Ramp WIM	7 Days	50
Findlay, OH	Static Scale	5 Days	30
Knoxville, TN	Static Scale	5 Days	30
Monroe Co., GA	Ramp WIM	7 Days	50
Charlotte Co., FL	High Speed Ramp WIM	9 Days	70

In addition to the tests described above, we carried out additional runs at Charlotte County, Florida to determine the effect of queue length/traffic speed on fuel savings. These runs were conducted using the large parking areas behind the Charlotte County weigh stations where the trucks made repeated stops at measured intervals to simulate queue traffic.

Figure 3: Map of Test Locations



Actual fuel consumption testing began in July 1996. Preparations, however, were being made since immediately after the Pilot Studies concluded in September 1995. Data collection, analysis, and report preparation proceeded through 1996 and 1997, and will be completed at the end of the MACS operational test in March 1998. A test schedule recap is provided below:

- { Test Preparation: September 1995 - June 1996
- { Data Collection: June 1996 - March 1997
- { Data Analysis: October 1996 - October 1997
- { Final Report Preparation: November 1997 - March 1998

Data collection extended beyond the original schedule set forth on May 10, 1996 due to scheduling conflicts. The original schedule stated that fuel consumption testing would begin on or about June 8, 1996 and would be completed on or about August 21, 1996. This target schedule was not met for a number of reasons, including:

w The weigh stations in Georgia closed for a month during the Olympic Games in Atlanta, Georgia. The closures of the weigh stations were done to minimize traffic delays incurred by the huge number of visitors to the Atlanta area. Thus, we could not run the tests at the Monroe County location during July.

w Following the closure of the weigh stations for the Olympic Games, the weigh stations in Georgia closed for construction improvements and the implementation of the Advantage I-75 systems, such as the AVI equipment and mainline WIM scale. The construction improvements at the Monroe County weigh station were not completed until January 1997. The tests were completed at our first scheduled opportunity.

w The tests in Charlotte County, Florida were postponed for two weeks, because in-service training was scheduled for the days that we originally planned for the fuel consumption tests.

A Gantt Chart illustrating the above schedule is provided in Figure 4.

Figure 4: Evaluation Test Schedule

Task Name	1996												1997												1998											
	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12
Test Preparation	June, 96																																			
Data Collection	June, 96												March, 97																							
Data Analysis							October, 96												October, 97																	
Report Preparation													November, 97												March 98											

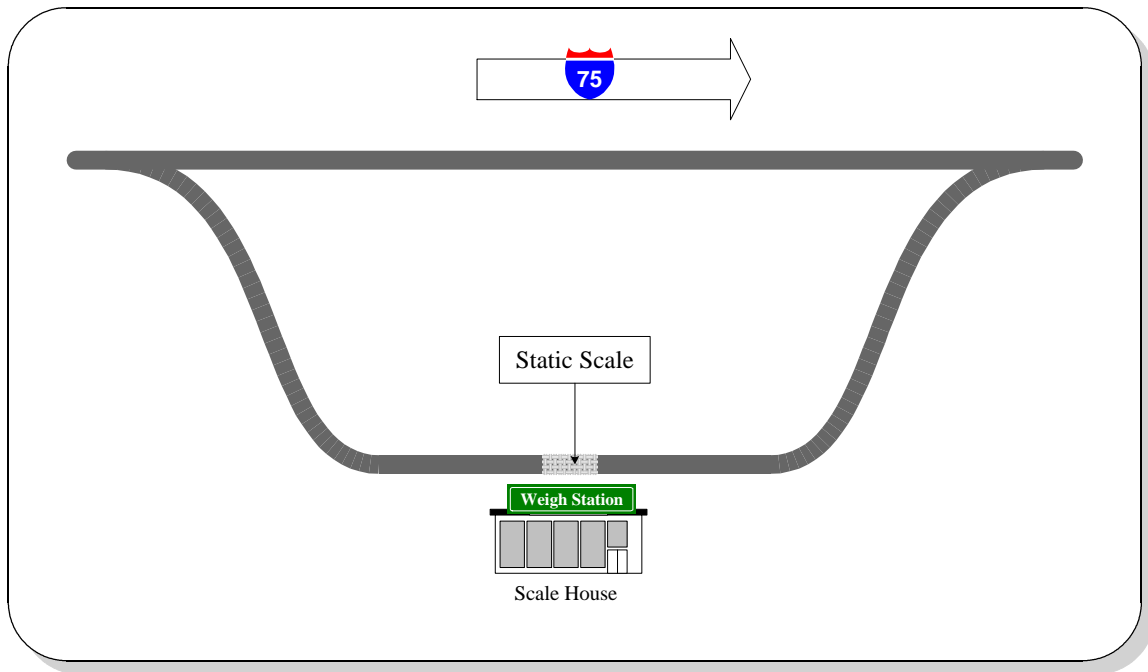
Weigh Station Design

There were three basic weigh station design types used for the fuel consumption experiment. These design types were: 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 participants. During the early phases of the test, the task force decided that the most efficient and least efficient design types be used for the experiment in order to determine a proper range of fuel consumption. To that end, the task force chose the static scale design types at the locations in Ohio and Tennessee. The ramp WIM design was chosen at the locations in Michigan and Georgia. Finally, the task force picked the high-speed ramp WIM design in Charlotte County, Florida. To recap the site location decisions, these sites were picked based upon their topographical layouts, varying traffic volumes, and efficiency in design. The static scales at the Ohio location have flat terrain and contain moderate traffic volume. Conversely, the static scales near Knoxville, Tennessee are hilly with very heavy vehicle traffic. The ramp WIM design near Monroe, Michigan is laid out on flat terrain, with heavy traffic. Meanwhile, the scale layout in Monroe County, Georgia is hilly with a moderate amount of traffic. The high-speed ramp WIM design in Charlotte County, Florida is probably 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 bypass lanes at other facilities.

Because no two weigh station designs are identical, the contrasting design types and locations were chosen by the Evaluation Task Force in order to capture as broad a range of fuel consumption differences as feasible. Thus, the test results will show expected fuel savings at the various weigh station design types that are located on level terrain, rough terrain, heavy traffic, and light traffic.

The following figures illustrate the differing design types. Please be aware that these are not actual scale blueprints, but representations used to illustrate the differences in the weigh station configurations.

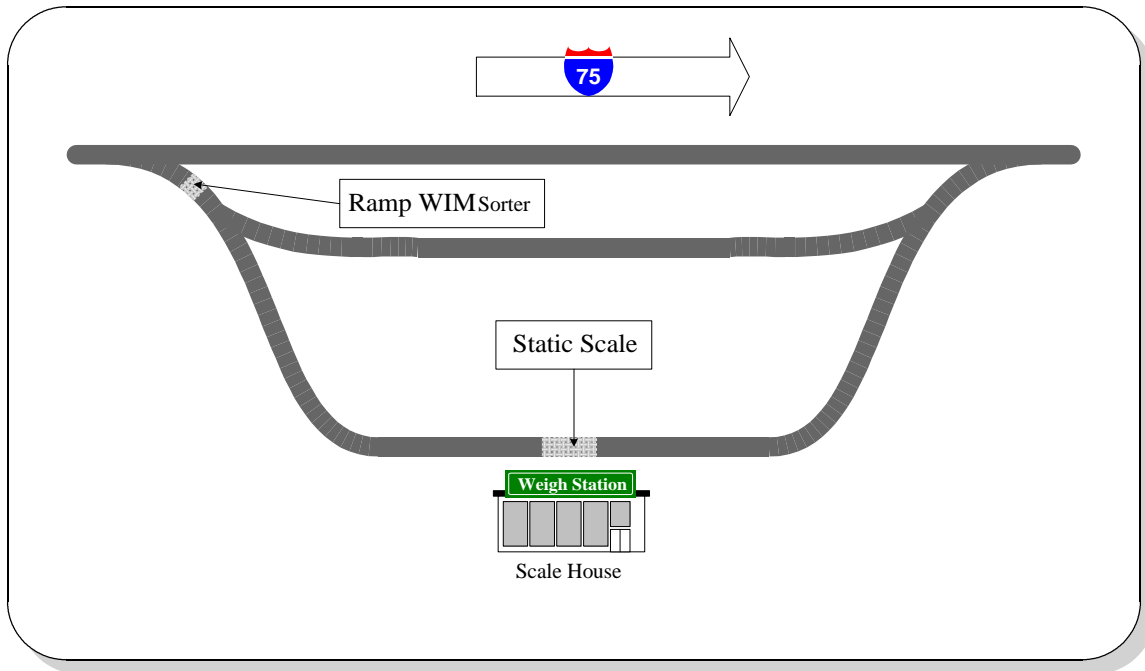
Figure 5: Weigh Station Design Type One, Single Static Scale



Note: Schematic Representation - NOT to Scale

This illustration depicts the type of weigh station layout at the locations in Knoxville, Tennessee and in Findlay, Ohio. The stations use a single static scale that does not allow the use of a bypass lane. All trucks that enter the station are directed to the scale.

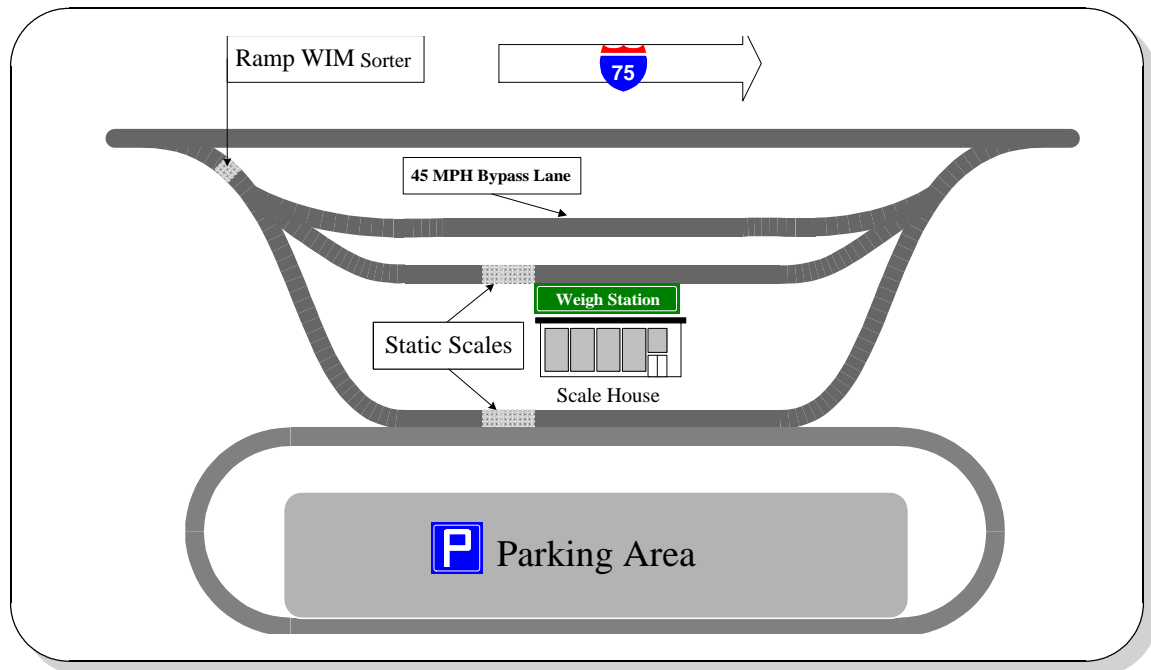
Figure 6: Weigh Station Design Type Two, Ramp WIM, Single Bypass Lane



Note: Schematic Representation - NOT to Scale

This illustration depicts the design used at the locations near Monroe, Michigan and Monroe County, Georgia. This design uses a ramp WIM sorter that permits the use of a bypass lane to sort compliant trucks from those that require a static weight. Trucks are directed to the bypass lane if they weigh under the weigh-in-motion (WIM) threshold weight and no other defects or violations are initially discovered; other trucks are directed to the static scale. For example, State of Georgia regulations requires all over-dimension trucks to report to the static scale for a check. Thus, those trucks requiring an oversize or overweight permit must stop at the static scale in Georgia.

Figure 7: Weigh Station Design Type Three, High-Speed Ramp WIM, Two Static Scales



Note: Schematic Representation - NOT to Scale

This is the weigh station design located in Charlotte County, Florida. This design again uses a ramp WIM sorter that directs compliant trucks to the bypass lane and other trucks to the static scale. This weigh station design also contains two static scales for greater efficiency. The bypass lane allows trucks to bypass the static scale at speeds of 45 mph (72 kph). (That speed is generally 10 mph (16 kph) faster than other stations along the corridor.)

Test summaries

The same equipment and drivers were used throughout the tests, to maintain continuity and uniformity of testing procedures. Two five axle tractor/trailer units from Collins & Aikman Products Co. of New London, North Carolina were used, along with the same drivers. The drivers, Mr. Leon Cox and Mr. Grady Wood, have over 60 years of commercial driving experience between them. Their experience proved to be a great asset during the tests.

In an attempt to obtain "real-world" results as closely as possible, standard issue equipment was used for these fuel consumption tests. The only modification made to the vehicles was the addition of the portable fuel tanks, utilized for the precise measurement of the fuel usage. Prior to the first set of tests in Ohio, 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. The following lists the specifications of the equipment:

1. 1993 Freightliner Conventional Model D120 64ST
2. 400 hp Detroit 60 Series 12.7 Liter engine, equipped with DDECII electronic engine management system
3. Eaton Roadranger 10 speed transmission
4. 210" wheelbase
5. 11 x 22.5 low profile radial tires
6. 48' x 102" enclosed Great Dane trailers
7. Air ride suspension system

Findlay, Ohio

The fuel consumption tests began on August 3, 1996 at the weigh stations near Findlay, Ohio in Hancock and Wood Counties. The Hancock County weigh station is located on the Southbound side of I-75 and the Wood County weigh station is located on the Northbound side of the interstate. To reiterate, the reason for selecting this set of weigh stations, was that these weigh stations are set on flat terrain with moderate traffic levels and there are stations on either side of the interstate. This selection provided an effective contrast to Knoxville, Tennessee that has a hilly terrain and heavy traffic levels.

The static scale design required a minimum of 60 runs, in the original plan: 30 in the "control" condition and 30 in the "test" condition. After completing 12 runs in the control condition and 26 runs in the test condition it was determined that additional runs were not required since existing results provided results at the desired level of accuracy. As a result of this experience sample sizes were reduced for all weigh station designs. To review our experimental design, two trucks drove repeated highway circuits under two different scenarios. To recap the scenarios, the "control" condition is where both trucks remain on the freeway for the experiment to establish the baseline fuel consumption difference between the trucks. The "test" condition is where one truck, termed the test truck, enters the weigh station to simulate the processing of a given vehicle. The other truck, termed the control truck, remains on the freeway and does not enter the weigh station. The fuel consumption difference between a truck entering and slowing (or stopping) at a given weigh station and one that is able to remain on the freeway is

measured. This difference in fuel consumed, after allowing for the baseline differences between the trucks, is the estimated fuel savings attributable to bypassing a weigh station.

Base of Operations

The base of operations for this was a rest area on the southbound leg of the route. During most of the testing the rest area was near full capacity. Because the tests were conducted during the day, testing began at 9:00 AM. Beginning at this hour allowed for the morning rush hour traffic to clear, and for travelers to vacate parking spaces in the rest area. Each morning members of the crew secured three parking spaces at the north end of the rest area (two spaces for the tractor-trailers and one space for the van and equipment trailer.) Securing the first three parking spaces permitted the trucks to enter the rest area unimpeded by other traffic. After refueling the trucks, members of the crew would go out into the rest area and halt traffic until the test trucks had entered the freeway. Stopping traffic in the rest area permitted the trucks to accelerate smoothly and maintain consistent run times.

Figure Eight: Control Truck Entering Base of Operations



Test Route

The test route for this set of tests was a 37 mile (59.5 kilometers) loop, with the north boundary at Exit 179 and the south boundary at Exit 161. The north exit was US. Highway 6, a 4-lane divided highway, with little traffic during the day. The turnaround point on the south exit was a county road with very little traffic.

Traffic

Over the course of the tests in Ohio, the traffic volume varied. Mostly, the traffic was light to moderate. During runs four through seven, however, the drivers described heavy car traffic, which caused the drivers to slow down to 55 mph (88.5 kph) for about 2 miles (3.2 km). Fortunately, the heavy car traffic did not affect the test results. Later in the test, however, the drivers encountered heavy truck traffic. When this situation occurred, the drivers experienced heavy turbulence from the trucks passing the test vehicles. This turbulence caused wider than normal variance in the test results.

Test Conditions

To recap this portion of the Motor Carrier Fuel Consumption Test, the topography at this location in Ohio is flat with wide open spaces. The weather cooperated throughout the test, with no adverse impact on the proceedings. For the four days of testing the temperature averaged in the 80° F (26° C) with little to moderate winds.

For this test, 30,472 lb. (13,834 kg) of freight was obtained from a local warehouse for each truck. Adding the freight to the truck made the gross weight (the weight of the vehicle plus the weight of the freight) of each of the trucks 65,000 lb. (29,510 kg). The evaluation task force determined this gross weight "target" to be the approximate average weight of commercial vehicles operating on the highways. (Please refer to Appendix page 40 for copies of the bills of lading and scale receipts for the actual, certified weight used for the tests.)

Monroe, Michigan

The second round of testing took place at the weigh stations near Monroe, Michigan beginning on August 20, 1996. These stations are located between Detroit, Michigan and Toledo, Ohio, about 35 miles (56 km) south of Detroit. These scales are the ramp WIM (weigh-in-motion) design type, with a weigh-in-motion scale in the entrance ramp and a single static scale for stationary weighing of vehicles and inspection purposes. These are the same weigh stations used in the Pilot Studies in the Summer of 1995.

Base of Operations

The base of operations was an interstate rest area and welcome center on the northbound end of the route. The rest area was continuously full and traffic levels were heavy with both car and truck traffic, requiring testing during nighttime hours. This alleviated some of the traffic congestion on the highway, but the rest area remained filled with trucks and drivers resting before making their rounds the next day.

Three parking spaces were secured at the south end of the rest area prior to each day's testing. Again, securing these spaces permitted the test vehicles to enter the rest area smoothly and park next to the van and equipment trailer for refueling. As was done in the previous set of tests, when the trucks left the rest area, members of the crew halted traffic temporarily to allow the test trucks to enter the highway unimpeded from the other vehicles, in order to maintain consistent run times.

Test Route

The north "border" of the test route was moved north one exit from the Pilot Study, because of the opening of a Pilot Travel Plaza at the exit and the addition of stop lights. The turnaround point was moved north on Interstate 275, Milemarker 2. Moving from I-75 to I-275 was a smooth transition as the highway provided a merge lane to the I-275 Loop at highway speeds. There was no slowdown required until the designated turnaround point at Milemarker 2.

The southbound border of the test route remained Exit 5 of I-75, the Temperance Road exit. This is not a heavily traveled road and there are no stoplights to hinder the vehicles' process.

Moving the north border of the test loop did not extend the test loop too far. The loop was a 34 mile (55 km) round trip, well within the parameters of the test procedures.

Traffic

This stretch of Interstate 75 was streaming with so much traffic that the tests were conducted at night. Nighttime testing was performed in order to maintain consistency in the test results and to alleviate the amount of turbulence caused by other trucks moving around the test vehicles. Even so, at times the test trucks would still encounter "packs" of trucks that would surround them for a period of time. Administering the tests at night, however, lessened the impact of the heavy traffic volume.

Test Conditions

The tests at Monroe, Michigan represent one of the contrasting ramp WIM design types. The topography at this location was flat with wide open spaces. The weather also cooperated during this set of tests. Because these tests were run during nighttime hours, the temperatures were cooler than were experienced in Ohio. The temperatures averaged in the low 70's F °C) and winds remained calm. The mild weather had little or no adverse impact on the research.

For this test 30,920 lb (14,038 kg) of freight was obtained from a local warehouse for each truck. By obtaining approximately the same amount of freight for this set of tests (within 500 lb (227 kg) from the previous set of tests), it was anticipated that the test results would remain consistent. (Refer to Appendix page 40 for copies of bills of lading and certified scale receipts.)

The revised design ramp WIM station required a minimum of 50 runs, 25 in the "control" condition and 25 in the "test" condition. The duration of the testing was seven days, including the placement and subsequent removal of the test equipment on the trucks. This specific set of tests consisted of 48 total runs, 23 in the control condition and 25 in the test condition. A broken water pump on the control truck forced cessation of the testing after the 48th run. It was the next day before repairs were completed. A review of the data collected determined that the preliminary results were within the parameters established by the Evaluation Task Force. Therefore, the team did not return to the field to complete two more runs.

Knoxville, Tennessee

The third round of testing took place at the weigh stations near Knoxville, Tennessee beginning on September 17, 1996. These stations are located about 15 miles (24 km) west of Knoxville, near the junction of Interstates 40 and 75. These static scales are set in hilly terrain with a heavy volume. (At peak operating times, an average 430 trucks per hour enter or bypass the weigh station.) There is a long, steep grade approaching the eastbound scale. This steep hill, coupled with heavy traffic, made this location a natural contrast to the scales in Ohio. As with those scales in Ohio, there is no ramp weigh-in-motion scale to sort traffic at this location. These are the same weigh stations used for the Pilot Studies in the summer of 1995.

Due to the heavy volume of truck traffic, the policies and practices at the weigh stations have been modified by Tennessee Motor Vehicle Enforcement officials. Changes in weigh station procedures were made to reduce the risks of accidents on the interstate. Generally, it is required that all trucks approaching the weigh stations enter the stations. However, if there is a queue of vehicles on the entrance ramp that extends to the interstate, then the next vehicle (or vehicles) can bypass the weigh station without repercussions. This practice of allowing commercial vehicles to continue past the weigh station when the queue is full prohibits vehicles from lining up onto the interstate, which would cause a severe safety hazard.

Base of Operations

A base of operations was established at an undeveloped rest area west of the weigh stations. The use of this facility worked well because there was little traffic around the area. Additionally, this rest area had no toilet or snack food facilities, which probably contributed to the lack of traffic interference in the immediate area. Due to the heavy traffic around the weigh station, however, the tests were conducted at night, to diminish the turbulence caused by the traffic. Each night the parking area was secured for the trucks and testing equipment. As cars and trucks still utilized the area, crew members were dispatched to stop traffic temporarily to allow the test trucks to enter the freeway unimpeded from other traffic.

Test Route

The east border of the test route was moved two exits east from the one used in the Pilot Studies, because of continued road construction to the airport. The turnaround point was moved to Milemarker 375 on Interstate 75/40 near Knoxville. The overpass road did have a metered stoplight. The stoplight, however, did not cause any extended delays, due to a low traffic volume on that road and the time of night that the tests were conducted. The westbound turnaround point remained Milemarker 356 on Interstate 40. This is not a heavily traveled road, and there are no stop lights to hinder the test vehicles' progress.

By moving the east exit of the test route, the loop extended about three more miles, making a 41 mile (66 km) round trip. The length of the trip is well within the parameters of the test procedures.

Traffic

Like Monroe, Michigan, this stretch of Interstate 75 is heavily traveled. The large traffic volume caused the tests to be performed at night in an attempt to diminish the impact of traffic on the test, both in terms of turbulence and possible speed variations. By running the tests at night there was a definite reduction in the amount of automobile traffic. The amount of truck traffic, however, appeared to remain constant. There were times when after the closure of the weigh station was requested to allow the test truck to enter the scale, that the control truck was then in the middle of a "pack" of trucks. While this truck traffic did not adversely affect the overall test, it is noteworthy that the traffic volume of commercial vehicles did not seem to decrease appreciably during the nighttime hours.

Test Conditions

The Knoxville, Tennessee weigh stations were chosen because of the hilly terrain and high traffic volume. This site provided a sharp contrast to the character of the static scales utilized in Ohio, which were located on flat terrain, with a lower traffic volume. By using these contrasting sites, it was hoped to capture a broad range of fuel consumption differences along the I-75 corridor.

The weather did not adversely impact our testing procedures. The weather was cool but humid during the three nights of testing. There was fog during one night of testing. It was not, however, thick enough to suspend testing. The temperature averaged the mid-60's F (16 C) and winds remained calm.

For this test, 31,600 lb (14,364 kg) of freight was acquired for each truck. The gross weight of each truck was virtually identical; within 120 lb (55 kg) of the other. The control truck's gross weight was 65,400 lb (29,692 kg) and the test truck's gross weight was 65,520 lb (29,746 kg) (Refer to Appendix page 37 for copies of bills of lading and certified scale receipts.)

The revised design for the static scale station required a minimum of 30 runs, 15 in the "control" condition and 15 in the "test" condition. This set of tests completed 30 total runs, 15 in each condition.

Charlotte County, Florida

The fourth round of testing was conducted at the weigh stations in Charlotte County, Florida, near the city of Punta Gorda. The testing began on October 2, 1996, and lasted through October 9, 1996. These weigh stations are located about six miles south of the intersection of US 17 and Interstate 75. These scales are termed "high-speed" ramp WIM, because the scale is equipped with a ramp WIM sorter and a bypass lane with a posted speed limit of 45 mph (72 kph). This bypass lane speed is considerably higher than other bypass lanes, hence the term "high-speed ramp WIM." Along with the bypass lane, there are two static scales, one on each side of the scale house, and a large parking lot for inspection purposes. This particular set of scales was not used in the Pilot Studies, although a similar design layout, near Marion, Florida, was included in the Pilot Studies in 1995.

Base of Operations

The base of operations for this set of tests was the shoulder of the road on the south side of the test route. The nearest rest area was not acceptable because there was no direct access to it. The rest area on North Jones Loop Road is about 1/4 mile (0.4 km) off the interstate, and the trucks would have to maneuver around a long circular drive to get to the parking area. Thus, a wide shoulder area on Tuckers Grade Road was utilized for the base of operations. Tuckers' Grade Road is a four lane, divided road, that provided an adequate set-up area. The shoulder proved to be satisfactory, as there was little traffic on this road to interfere with the test procedures. There was also plenty of territory for the trucks to make their turns into the base area. The Florida DOT also supplied the crew with warning flags that were posted alongside the road, to warn any oncoming motorists that a crew was working along the shoulder of the roadway.

As with previous tests, after refueling the trucks, crew members were sent to designated positions to hold back any oncoming traffic and send the trucks on the test route.

Test Route

The north border of the test route was Exit 34. There was very little traffic on this end of the test route. The south border, as stated, was Exit 27, Tuckers' Grade Road. This was a 47 mile (76 km) route. Again, there was little traffic and no traffic signals to interfere with the operations. Given the length of the route, the crew was fortunate to complete 10 runs a day, and remain within the drivers' hours of service limits.

Traffic

Truck traffic was not a hindrance at this location. There was a moderate amount of automobile traffic, however, not enough to cause major problems.

Test Conditions

The tests at the Florida location were conducted at the efficient "high-speed ramp WIM" design. It was a wide open, flat area. There was the Peace River bridge to cross each run, however. The bridge was probably 3/4 mile (1.2 km) long. There were cross winds that the trucks encountered going across the bridge. Temperatures were warm, in the mid-80's F (27 C). There were moderately gusty winds throughout the testing. On the seventh day of testing, Tropical Storm Josephine came ashore north of the test location. While the area did not bear the brunt of the storm, there were strong winds and rain in the area. The turbulent weather conditions forced a delay in testing on two occasions, to allow for the storm to dissipate. However, there was sustained precipitation throughout the day.

For this test 30,240 lb (13,729 kg) of freight was procured for each truck. Again, the gross weight of each was virtually identical, within 80 lb (36 kg). The gross weight of the control truck was 64,840 lb (29,437 kg). The test truck's gross weight was 64,740 lb (29,392 kg). (Refer to Appendix page 40 for copies of bills of lading and certified scale receipts.)

The revised design for the high speed ramp WIM station required a minimum of 70 runs, 35 in each condition. The larger number of runs is a consequence of the smaller fuel savings expected in this type of station. This test completed 70 runs, 35 in each condition.

Monroe County, Georgia

The fifth and final round of testing was conducted at the weigh stations in Monroe County, Georgia, near the city of Forsyth, about 60 miles (96 km) south of Atlanta, Georgia. These scales are the ramp weigh-in-motion (WIM) design type, similar to those in Monroe, Michigan. These scales provide a substantial contrast to the weigh stations in Michigan, as these scales sit on top of a hill. There is a long, gradual incline approaching the static scale at both northbound and southbound weigh stations, in contrast to the scales in Michigan, which sit on flat terrain. Testing began on February 25, 1997 and concluded on March 1, 1997.

Base of Operations

A rest area at the south end of the test route provided the crew with a base of operations. The rest area was continually full and traffic volumes were heavier than anticipated with both automobiles and trucks.

The crew was fortunate each day to secure three parking spaces; keeping the parking spots secured also proved to be a challenge. On several occasions, even after cones were placed in the spots to reserve the space, people would park in those spaces. Crew members frequently asked people to move their vehicles, so the test trucks would have a place to park. As with the other tests, after refueling the tanks, the crew was dispatched to hold back traffic to allow the trucks to enter the freeway without interference.

Test Route

The north end of the test route was Exit 65, High Falls Road. The south end was Exit 58, Bolingbrooke Road. Neither road was heavily traveled and there were no traffic signals to hinder their progress. Utilizing these two exits produced a 41 mile (66 km) test route.

Traffic

This area of Interstate 75 had an ample amount of traffic, both in trucks and automobiles. There was heavier than normal tourist traffic, due to a motorcycle rally in Daytona, Florida the following weekend. Even without the tourist traffic, the test trucks encountered several slowdowns during the runs, due to heavier than expected truck traffic.

Test Conditions

The rolling terrain at this set of weigh stations provided a sharp contrast to the area surrounding the weigh stations in Monroe, Michigan. The test route contained several hills, including long slopes approaching the southbound weigh station and the rest area. The weather also cooperated during the tests. The temperature was moderate, in the 70's F, (°1 C). We did, however, encounter light rain during two of the days of testing.

For these tests, 30,240 lb (13,729 kg) of bricks were acquired. The acquisition of this freight produced a gross weight of 65,280 lb (29,637 kg) for the control truck and 65,520 lb (29,746 kg) for the test truck. Again, the gross weights of the vehicles were very similar, a difference of only 240 lb (109 kg). (Refer to Appendix page 40 for copies of bills of lading and certified scale receipts.)

The revised design for the ramp WIM station required 50 runs to be performed 25 in the control condition and 25 in the test condition. This test completed 50 runs, 25 in each condition, carried out over a period of five days.

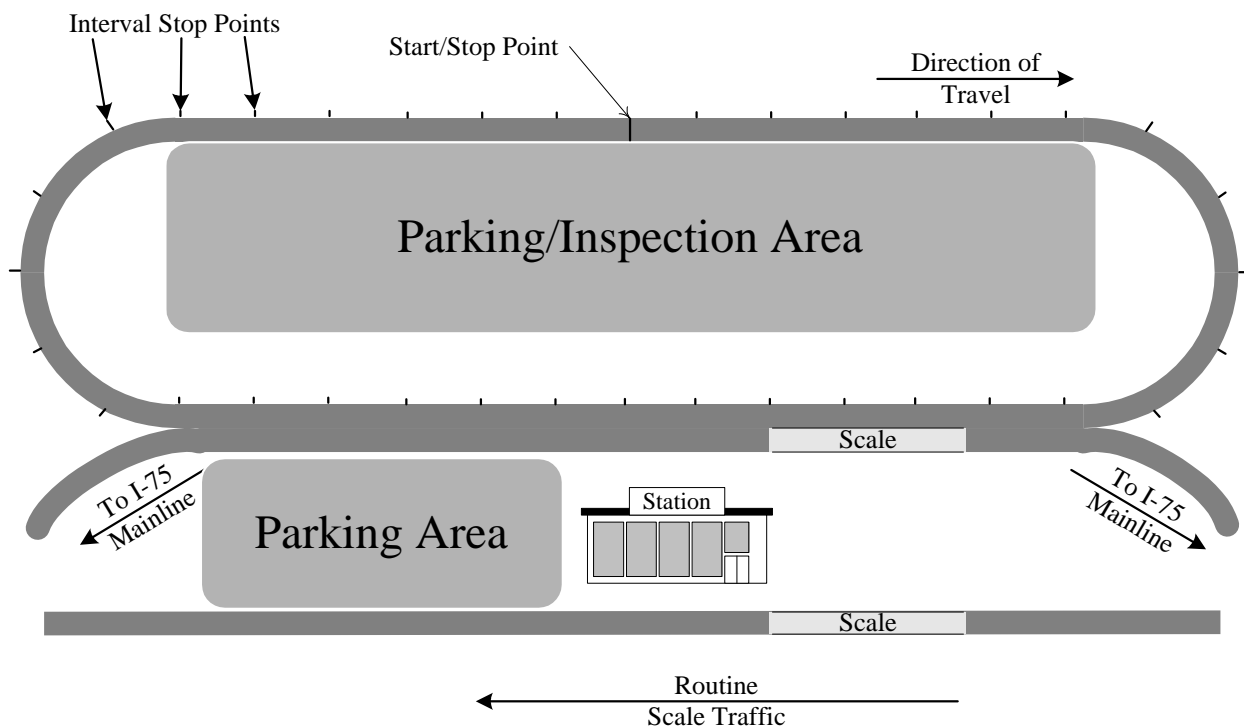
weigh station Queue fuel consumption Tests

Separate fuel consumption tests were conducted at the Charlotte County, Florida weigh stations to gather data for estimating the effect of weigh station queues on fuel consumption. The tests were conducted using similar procedures to those used for the fuel consumption tests at the weigh stations. Some procedures were adjusted to account for the fact that we now had drivers starting and stopping at various intervals. The description of the test procedures went as follows:

Scenarios

Two identically equipped trucks, one termed the control truck, the other termed the test truck complete test runs of defined loops, as illustrated in Figure Nine. These tests were conducted in the large parking and inspection area at the Charlotte County, Florida weigh station. The trucks completed five baseline runs whereby both trucks follow the control truck script. The control truck script established the baseline fuel consumption differences between the two trucks. The trucks then completed five experimental runs in which the test truck stopped each 200 feet, (61 m), and the control truck again followed the control script. The last set of five runs had the test truck stop each 100 feet (30.5 m).

Figure 9: Weigh Station Queue Fuel Consumption Tests



Scripts

The drivers completed each test run according to the following scripts. Separate scripts are provided for the control truck and the test truck.

Script for the Control Truck

1. Upon entering the truck cab, close the vent window and side window, reset the cumulative stop timer to zero, release the parking brakes (hold the vehicle in place using the foot brake pedal), and wait for the start signal from the data collection team leader.
2. When the data collection team leader signals the start of the run, start the engine, depart from the start/stop point, and accelerate to 15 miles per hour (24 kph).
3. Maintain a speed of 15 miles per hour (24 kph), complete two loops of the parking area access road, and return to the start/stop point.
4. Upon arriving at the start/stop point put the transmission in neutral, set the parking brake, and immediately shut down the engine.

Script for the Test Truck

1. Upon entering the truck cab, close the vent window and side window, reset the cumulative stop timer to zero, release the parking brakes (hold the vehicle in place using the foot brake pedal), and wait for the start signal from the data collection team leader.
2. When the data collection team leader signals run start, start the engine, depart the start point and accelerate to 5 miles per hour (8 kph). (This was an average in-queue speed observed during Pilot Study Two's weigh station throughput timing tests.)
3. Come to a complete stop at the first interval stop point and remain stopped for a period of 15 seconds.
4. Depart the first interval start/stop point and accelerate to 5 miles per hour (8 kph).
5. Come to a complete stop at the next interval stop point and remain stopped for a period of 15 seconds.
6. Repeat steps 5 and 6 for each interval stop point, complete two loops of the parking area access road, and return to the start stop point.
7. Upon arriving at the start/stop point put the transmission in neutral, set the parking brake, and immediately shut down the engine.

Hypothesis and Expected Results

To evaluate the hypothesis that trucks bypassing weigh stations consume less fuel, fuel consumption has been measured using the procedures described earlier in this document. The goal is to provide a measure of the expected savings (gallons of fuel per vehicle per weigh station bypassed) for different weigh station designs. One can formally test the hypothesis of no savings but this is of little interest by itself. Instead this experiment focuses on providing a valid estimate of the amount of fuel saved 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 most likely 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 (or liters) per weigh station between the control truck and the test truck.

Table 4: Baseline and Experimental Results for Each Weigh Station

Station	Run Type	Number of Runs	Mean in Gal. (Ltr.)	Std. Dev. in Gal. (Ltr.)	SE Mean in Gal. (Ltr.)
Findlay, OH	Baseline	12	0.2314 (0.8758)	0.0399 (0.1510)	0.115 (0.4353)
	Experimental	26	0.0523 (0.1979)	0.0390 (0.1476)	0.0076 (0.0287)
Knoxville, TN	Baseline	15	0.1762 (0.6669)	0.0399 (0.1510)	0.0103 (0.0389)
	Experimental	15	0.0124 (0.0467)	0.0393 (0.1488)	0.0101 (0.0382)
Monroe, MI	Baseline	23	0.1324 (0.5011)	0.0438 (0.1658)	0.0091 (0.0344)
	Experimental	25	0.0228 (0.0863)	0.0402 (0.1522)	0.0080 (0.0303)
Monroe Co., GA	Baseline	25	0.0171 (0.0647)	0.0601 (0.2275)	0.0120 (0.0454)
	Experimental	25	-0.0445 (-0.1684)	0.0648 (0.2453)	0.0130 (0.0492)
Charlotte Co. FL	Baseline	35	0.1703 (0.6446)	0.0364 (0.1378)	0.0860 (0.3255)
	Experimental	34	0.1184 (0.4481)	0.0255 (0.9652)	0.0044 (0.0167)

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 (measured in gallons (liters) per weigh station).

M_e = the mean average observed fuel consumption difference between the control truck and the test truck during the experimental runs (measured in gallons (liters) per weigh station).

Std. Dev._b = the standard deviation of the observed fuel consumption differences between the control truck and the test truck during the baseline runs.

Std. Dev._e = the standard deviation of the observed fuel consumption differences between the control truck and the test truck during the experimental runs

SEMean = the standard error of the sample mean (this is equal to the standard deviation divided by the square root of the number of runs; it is a measure of the variability of our sample mean measurement).

N_b = number of baseline runs

N_e = number of experimental runs

The fuel consumption values are provided in Table Four for the tests of various weigh stations. The table lists the difference in fuel consumption between the two trucks during the baseline runs (in which both trucks bypass the weigh station) and the experimental runs (in which one truck bypasses while the other pulls into weigh station). The difference between M_b and M_e is a measure of fuel savings due to trucks bypassing weigh station. M_e , the difference between the fuel consumption of a truck bypassing the station and one pulling into the station, is not an accurate measure of the savings in fuel because the observed differences on the experimental runs could be due to variations between the test truck and control truck rather than bypassing the station. This is why we use baseline runs to establish the relative fuel consumption of the two trucks at the time of each test. To elaborate:

Notice that at most locations the control truck (which always bypasses the station) uses more fuel than the test truck (which pulls into the station) during the experimental runs. For example, at the Findlay, Ohio station, the control truck used 0.05 gallons more bypassing the station than the test truck uses when it stops at the static scale. We use the baseline runs to establish the relative fuel consumption of the two trucks at the time of each test. At Findlay, Ohio, when both trucks bypass the weigh station the control truck consumes 0.23 gallons more fuel than the test truck. It is the difference between these two values, $0.23 - 0.05 = 0.18$, that represents the fuel savings. By stopping at the static scale the test truck has consumed additional fuel so that the two trucks are nearly the same in terms of fuel consumed.

The use of baseline and experimental runs would not be necessary if it were possible to use truly identical trucks. For truly identical trucks the mean difference for the baseline M_b would be zero. For this evaluation the mean difference for the baseline runs was positive, the vehicle used as the control truck always consumed more fuel than the test truck during the baseline runs. This can be due to minor variations in engine performance, tire tread, or any number of other possible factors. Since it is not possible to control all of these factors the baseline runs provide the best means of obtaining accurate estimates of fuel savings.

Table Five illustrates the estimated fuel savings per weigh station bypass.

Table 5: Estimated Fuel Savings Per Weigh Station

Location	Weigh Station Type	Estimated Fuel Savings in Gallons (Liters)	95% Confidence Interval in Gallons (Liters)
Monroe MI	Ramp WIM	0.11 (0.42)	0.085, 0.134 (0.322, 0.507)
Findlay OH	Static Scale	0.18 (0.68)	0.151, 0.207 (0.572, 0.783)
Knoxville TN	Static Scale	0.16 (0.61)	0.134, 0.194 (0.507, 0.734)
Monroe Co. GA	Ramp WIM	0.06 (0.22)	0.026, 0.097 (0.098, 0.367)
Charlotte Co. FL	High Speed Ramp WIM	0.05 (0.19)	0.037, 0.067 (0.140, 0.254)

The two sample pooled-t-statistic-based methods are used for drawing conclusions. To be specific, the runs are viewed as a sample from the population of interest (i.e., 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:

$$\text{Confidence Interval} = (M_b - M_e) \pm t^* \cdot S \left(\sqrt{\frac{1}{N_b} + \frac{1}{N_e}} \right)$$

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 S_b and S_e be approximately the same. They are almost identical at four of the five sites. The difference is more substantial in Charlotte County, Florida, but still within the range for which pooled procedures can be applied.

The width of the confidence interval is determined mainly by the standard error of the baseline and experimental means. Although the standard deviations are large, indicating substantial run-to-run variability, the standard errors are much smaller because they account for the sample size. Sample sizes were chosen with the goal of obtaining confidence intervals that are sufficiently narrow for the present purpose.

An alternative method of expressing the value of fuel savings attributable to electronic clearance is in percentage of fuel saved. The following table expresses the fuel savings terms of gallons saved per clearance. These values are expressed as a percentage of the fuel required to complete 1/2 of the loop, i.e. per one station. Table 6 includes an expanded version of the data that led to these conclusions along with notes about computing fuel savings as a percentage. The numbers range from 1.53% to 6.65%.

Table 6: Fuel Savings As a Percentage

Station	Type of Run	Number of Runs	Mean Fuel Used - Control Truck Gal. (Ltr.)	Mean Fuel Used - Test Truck Gal. (Ltr.)	Mean Difference Between Control and Test Truck Gal. (Ltr.)	Savings (%)
Findlay OH (Static Scale)	Baseline	12	2.82	2.59	0.23	
	Experimental	26	2.79	2.74	0.05	6.65%
Knoxville TN (Static Scale)	Baseline	15	2.98	2.8	0.18	
	Experimental	15	2.95	2.94	0.01	5.69%
Monroe MI (Ramp WIM)	Baseline	23	2.62	2.49	0.13	
	Experimental	25	2.57	2.55	0.23	4.33%
Monroe GA (Ramp WIM)	Baseline	25	3.4	3.39	0.02	
	Experimental	25	3.44	3.49	-0.45	1.80%
Charlotte FL (High Speed Ramp WIM)	Baseline	35	3.42	3.25	0.17	
	Experimental	34	3.52	3.41	0.12	1.53%

The percentage of fuel saved is derived by taking the fuel consumed by both trucks per 1/2 loop (one station) and dividing by the mean amount of fuel used by the test truck on that half loop. For example, at Findlay, Ohio the typical savings are calculated by subtracting the experimental fuel used from the baseline fuel used, then dividing by the typical fuel used per half loop. Therefore, fuel savings expressed as a percentage is: $0.18/2.69 = 6.65\%$.

At the Knoxville, Tennessee site, the typical fuel consumption is 2.8765 gallons. The fuel savings is then $0.1638/2.8765 = 5.69\%$.

At Monroe, Michigan the typical fuel consumption is 2.5295 gallons. The fuel savings as a percentage is then calculated as (savings/consumption) $0.1096/2.5295 = 4.33\%$.

At the Monroe County, Georgia site, the typical fuel consumption is 3.414 gallons. The fuel savings as a percentage is then calculated (savings/consumption) $0.0616/3.414 = 1.80\%$.

At the Charlotte County, Florida location the typical fuel consumption is 3.3875 gallons. The fuel savings as a percentage is then calculated (savings/consumption) $0.0519/3.3875 = 1.53\%$.

Results of Weigh Station Queue Tests

These weigh station queue tests were designed to provide some insight into the fuel consumption of commercial vehicles which make repeated starts and stops. These tests were to simulate, as closely as possible, a full weigh station queue. As stated earlier, the test truck made repeated stops at 100 ft. (30.5 m) and 200 ft. (61 m) intervals. During these queue tests the trucks were loaded with 35,000 lb. (15,890 kg) of freight to better simulate actual operations through a given weigh station.

The methods for data analysis and reduction of the weigh station queue tests are the same as for the highway speed versions with one modification. Results are recorded as fuel saved per mile rather than per weigh station since no weigh station bypasses are involved in this test.

Table Seven shows the results for three sets of runs: baseline runs in which both trucks complete a one-mile loop at about 15 mph with no stops, Experimental Condition I (200 ft., 61 m) in which the test truck stops every 200 feet (61 m) for 15 seconds, and Experimental Condition II (100 ft., 30.5 m) in which the test truck stops every 100 feet (30.5 m) for 15 seconds.

The control truck averaged about 13.1 mph (21.1 kph) during its 15 runs. We report the mean difference between the two trucks in gallons saved per mile along with the run-to-run standard deviation and the standard error of the mean. Here, as before, the baseline mean would be zero if it were possible to use identical trucks. The observed difference suggests that the control truck consumes more fuel at 13.1 mph (21.1 kph) than the test truck on the baseline run. In the two experimental conditions the test truck consumes considerably more fuel. The standard deviations of the Baseline and Experimental I runs are extremely similar, however, the Experimental II runs were much more variable. Perhaps the constant stopping and starting made these runs more susceptible to environmental factors. Given the small number of runs we have treated the standard deviations as equal.

Table 7 summarizes the results of the weigh station queue test.

Table 7: Baseline and Experimental Results For Weigh Station Queue Test

Run Type	Approx. Stops ft. (m)	Approx. Speed in mph (kph)	Number of Runs	Mean in Gal. (Ltr.)	Standard Dev. in Gal. (Ltr.)	SE Mean in Gal. (Ltr.)
Baseline	None	13.1 (21.1)	5	0.0697 (0.263)	0.0124 (0.047)	0.0055 (0.021)
Experimental I	200' (61 m)	3.8 (6.1)	5	-0.1897 (-0.718)	0.0127 (0.048)	0.0057 (0.022)
Experimental II	100' (30.5 m)	2.3 (3.7)	5	-0.2960 (-1.120)	0.0233 (0.088)	0.0104 (0.039)

To further explain the Weigh Station Queue Test Results, we go to Table 8. The figures in Table Eight suggest that the stop-and-go driving conditions typical of weigh station queues may increase the expected fuel savings for commercial vehicles electronically cleared past static scales. Our earlier weigh station results suggest that a truck pulling into an empty weigh station, stopping at the scale, and accelerating back to highway speed will consume 0.16 to 0.18 gallons (0.61 to 0.68 liters) of fuel per station. The numbers here suggest that a queue moving roughly at 4 mph (6.4 kph) for a length 0.5 miles (0.8 km) would add another 0.13 gallon (0.49 liters) of fuel to the cost of stopping (0.26 gallons per mile for 0.5 miles) or (0.98 liters per kilometers for 0.8 km).

Table 8: Estimated Fuel Savings and Confidence Interval For Weigh Station Queue Tests
(relative to baseline)

Run Type	Approx. Stops in feet (m)	Speed in mph (kph)	Cost of Stop/Go in gal/mi (ltr/km)	95% Confidence Interval in gal. (ltr.)
Experimental I	200' (61m)	3.8 (6.1)	0.26 (0.98)	0.24, 0.28 (0.91, 1.06)
Experimental II	100' (30.5m)	2.3 (3.7)	0.37 (1.40)	0.34, 0.39 (1.29, 1.48)

Summary and findings

Table 5 (see page 34) provides the mean fuel savings in gallons (or liters) 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. A more important issue concerns the magnitude of savings.

The static scales provide the most dramatic savings with bypasses of Knox, Tennessee and Findlay, Ohio saving 0.16 and 0.18 gallons (0.61 and 0.68 liters) per station, respectively. The high-speed ramp WIM in Charlotte County, Florida performs as advertised with fuel savings of about 0.05 gallons (0.19 liters) per station bypassed. The savings accrued at the ramp WIM set of scales are between these two extremes. The savings in Monroe, Michigan were estimated at 0.11 gallons (0.42 liters) per station. The result from the Monroe County, Georgia station (0.06 gallons (0.19 liters) per station) is surprisingly low, even with the hilly terrain surrounding the Forsyth area. The confidence interval here is widest because there was a great deal of variability from run-to-run.

The estimated fuel savings per station bypassed is somewhat conservative since the experimental runs eliminated traffic within the weigh station. The weigh station queue tests provide some insight into the magnitude of the additional fuel savings due to queue traffic. It appears that the stop-and-go traffic, averaging 4 mph (6.4 kph) consumes an additional 0.26 gallons (0.98 liters) per mile (km) relative to the 15 mph (24 kph) constant travel. A queue moving at 2 mph (3 kph) consumes 0.37 gallons (1.4 liters) per mile (km) relative to the 15 mph (24 kph) constant travel through a given weigh station. The fuel consumption relative to mainline speed is probably a small amount more, but we did not measure this relationship directly. More testing is needed in the area of fuel consumption in queue relative to mainline speeds.

The value of electronic clearance, therefore, depends on the number and nature of stations passed. For example, in societal terms, suppose 100 trucks per hour were cleared to pass a static scale. The clearance of these trucks would mean savings of 16 gallons (61 liters) of fuel per hour (assuming no queue) for those 100 electronic clearances. Assuming a 0.5 mile (0.8 km) queue of stop-and-go traffic, would add another 13 gallons (49 liters) to the savings over those 100 clearances. If those trucks were cleared at a ramp Weigh-In-Motion (WIM) type scale, the fuel savings could range from 6 gallons (22.71 liters) to 11 gallons (41.64 liters) for those 100 trucks being cleared electronically.

Another method of expressing the value of electronic clearance is to state it in economic terms in relation to an individual truck or firm. Therefore, suppose a truck were cleared to bypass 100 static scale stations over a month period. With fuel at \$1.08/gallon² this could mean a fuel savings to the carrier of approximately \$11.00/month per truck. Thus, as a result of these experiments, we can state that there are measurable fuel savings attributable to electronic clearance at weigh stations.

² National Truck Stop (NTS) Average price, week of January 3-9, 1998.