



Advantage I-75 Mainline Automated Clearance System

Detailed Evaluation Plan Part Two: Motor Carrier Fuel Consumption Individual Evaluation Test Plan

Prepared for
The Advantage I-75 Evaluation Task Force

Submitted to
The Kentucky Transportation Center

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May 10, 1996



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PURPOSE OF THE TEST

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

OVERALL TEST RESPONSIBILITY

As evaluation manager for this individual test plan, the Center for Transportation Research and Education is responsible for the following duties:

- Select appropriate test sites
- Recruit motor carriers to participate in the fuel consumption test
- Recruit staff to assist with conducting the tests
- Procure test equipment (portable fuel tanks and scales, and communications equipment)
- Prepare a data management plan
- Perform the tests
- Conduct the statistical analysis
- Conduct limited data collection to determine how measured fuel consumption differences are affected by congestion (queues)
- Prepare a written report summarizing the findings

EVALUATION TEST DESCRIPTION

Using the results of previous MACS project evaluation planning activities termed Pilot Study One, this test was designed to determine the potential fuel savings attributable to bypassing weigh stations at selected sites along the Advantage I-75 corridor.

This test is based on applying accepted fuel consumption test procedures to determine differences in fuel consumption between two nearly identical trucks operating under defined scenarios (scripts) in the vicinity of selected I-75 corridor weigh stations. The scripts have been designed such that one of the trucks simulates electronic clearance by driving past the weigh station at mainline speeds while the other truck simulates routine weigh station processing by driving through and stopping or slowing (as the weigh station design dictates) at the weigh station. At the selected test sites, two trucks will be equipped with special 15-gallon 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 will have identical loads and the same drivers, be nearly identical in specifications, and begin their test runs within one-minute of each other to control as much variability in fuel consumption as possible. The fuel consumption will be measured according to the procedures defined in the SAE Type II Fuel Consumption Test (SAE J1321). The tests will be conducted at closed weigh stations to control the variability in fuel consumption associated with queues.

The effect of weigh station queues on fuel consumption will be determined by conducting additional tests, termed weigh station queue fuel consumption tests. These tests will be conducted under

controlled conditions in which the test trucks will complete defined loops (approximately 3,500 ft in length) with repetitive starts and stops at specified intervals. The results of these controlled tests will then be used to estimate the effect of various queue lengths (e.g., one truck, two trucks, five trucks, and etc.) on fuel consumption.

Hypotheses to be 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.”

Evaluation Approach to be Used

The fuel consumption test is an experiment comparing electronically cleared trucks’ fuel consumption to that of trucks processed normally at a weigh station. Two trucks are used for the experiment. One truck, termed the control truck, always bypasses the weigh station. The other truck, termed the test truck, alternates between control runs in which the weigh station is bypassed and experimental runs in which the weigh station is visited. At the end of the test runs at a given site we will have measured baseline fuel consumption differences between the two trucks (when both bypass the weigh station) and experimental fuel consumption differences between the two trucks (when one bypasses the weigh station and one stops/slows at the weigh station). This evaluation approach includes two forms of control. On each run the control truck and test truck encounter almost identical conditions and therefore any observed difference are due to experimental or vehicle differences. The use of baseline test runs allows us to estimate fuel consumption differences due to vehicle differences (tire tread, engine performance) and therefore provide a control for the experimental runs.

Statistical Methods to be Used to Analyze the Data

The data collected at each site will be analyzed separately. At the end of each run we will measure the difference in fuel consumption between the two vehicles. Then the differences observed during baseline runs will be compared to the differences observed during experimental runs. The difference between the mean experimental fuel difference and the baseline fuel difference is an estimate of the fuel savings attributable to bypassing the weigh station. This difference can be tested using two-sample t-testing procedures to determine whether the savings are significantly different than zero on average. Additional information will be provided in the form of a confidence interval for the mean fuel savings. Results will be reported as fuel savings in gallons of fuel per weigh station bypassed with a standard error.

Test Scheduling

The test schedule is contingent on close coordination with the test participants and test locations. The following paragraphs provide an overview of the contact names, addresses, phone, and fax for each key test participant and test location.

Test Participants

The test participants include the evaluation manager and coordinator, data collection team, and motor carrier. Table One provides the key contact, address, phone/fax and role of each test participant.

Table One: 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 Coordinator	Mr. Jim York	Center for Transportation Research and Education 2625 N. Loop Drive Suite 2100 Ames, Iowa 50010-8615	(515) 294-9501 (515) 294-0467
Data Collection Team	Mr. Ed Powe	Regional Entrepreneurial Institute Kentucky State University 415 Hathaway Hall Frankfort KY 40601	(502) 227-6172 (502) 227-6763
Motor Carrier	Mr. Richard Honeycutt	Collins and Aikman Corporation P.O. Box 521 New London NC 28127	(704) 985-1202 (704) 985-1216

Scheduling commitments should be made to members of the data collection team six weeks prior to commencement of testing. Scheduling commitments should be made to the motor carrier three weeks prior to commencement of testing

Test Locations

The primary test location scheduling consideration is coordination with the weigh stations included in the test runs. The key contact name, addresses and phone/fax numbers are provided in Table Two for each test location. A detailed discussion of site selection is provided on pp 19–21.

Table Two: 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
Hancock/Wood, 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, GA	Capt. Cliff Tackett	Georgia Dept. of Transportation 276 Memorial Drive Atlanta, GA 30303	912-994-1278
Charlotte, 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 officials are to be notified by phone and in writing approximately one month and one week prior to commencement of the fuel consumption tests.

However, several scheduling concerns must be resolved prior to conducting the fuel consumption tests at two test locations. First, the Hancock, Ohio weigh station is scheduled for building renovation beginning on or about June 1, 1996. As currently planned, the existing weigh station building will be demolished and replaced with an updated facility.¹ However, current plans do not specify removal of the scale platform or renovation of the entrance or exit ramps. Ideally, the tests at this location should be conducted prior to commencement of construction activities. However, the tests could be conducted during construction activities providing that they do not interfere with construction personnel.

Second, the Forsythe, Georgia, test location will experience abnormal traffic conditions as a result of the 1996 Summer Olympics. Additionally, because of its close proximity to Atlanta, Georgia, many of the lodging facilities have been reserved by event attendees and other support personnel. As a result, fuel consumption tests will not be scheduled at this location within one month of the commencement of the Summer Olympics.

¹ According to a telephone interview with Sgt. Jim Bennett of the Ohio Highway Patrol.

Required Support

The weigh station personnel at the selected test sites would be required to agree with the provisions of the fuel consumption tests. Specifically, the weigh station personnel would be required to close the each weigh station for brief periods of time (e.g., five minutes or less) on each test run.

Test Location and Duration

The tests will be conducted at defined interstate highway loops near Monroe, Michigan, Findlay, Ohio, Knoxville, Tennessee, Forsythe, Georgia, and Ft. Meyers, Florida. The duration of the tests at Findlay, Ohio, and Knoxville, Tennessee, will be 5 days each, the duration of the tests at Monroe, Michigan, and Forsythe, Georgia, will be 7 days each, and the duration of tests at Ft. Meyers, Florida, will be 9 days.

Additional fuel consumption testing will be conducted at the Charlotte, Florida test location. These tests will be conducted at scheduled times (e.g., one or two hours daily) under controlled conditions at the Charlotte Scales. The purpose of this additional testing is to gather the needed data for estimating the effect of various weigh station queues on fuel consumption.

Key Conditions

None

Key Assumptions

None

Key Constraints

None

Security Considerations and Provisions Specific to the Evaluation Test Plan

None

Safety Considerations Affecting the Design of the Test

The tests shall be conducted within the provisions of the federal motor carrier safety regulations. Specifically, test personnel and equipment shall comply with all of the provisions in 49 CFR parts 382, 383, and 390–397. For example, drivers shall operate within the hours-of-service provisions of 49 CFR part 395.

The test personnel (e.g., fuel tank handlers and note keepers) shall be trained in routine motor carrier operating practices to lessen the chance of accidents during refueling between test runs.

The base of operations shall be lighted if the tests are conducted during periods of darkness.

Privacy Considerations

None

Potential Impacts on the Operational System

The tests require that the weigh stations be closed for brief periods as the test truck approaches and travels through the weigh station. This is required to control the variability in fuel consumption that is attributable to queues. These weigh station closures will be minimized by utilizing truck to weigh station communications (e.g., cellular telephones) to limit weigh station closures to approximately five minutes per test run. This would provide enough time to eliminate existing weigh station queues as the test truck approaches the station and allow the test truck to complete the appropriate script without disruptions from other traffic. The weigh stations would then re-open after the test truck left the station.





TEST SCHEDULE

The test is scheduled to begin in mid May, 1996 and be completed approximately three months after the end of the MACS operational test in March, 1998. An overview of the major test activities is provided below.

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

A Gantt Chart illustrating the above schedule is provided in Figure One. Data collection and analysis for this test will be done in conjunction with the Weigh Station Test Plan. A detailed data collection schedule for the fuel consumption tests and weigh station throughput timing tests is provided in Appendix One. This schedule illustrates a monthly overview of the combined data collection schedules for the Fuel Consumption Test Plan and the Weigh Station Test Plan.

Figure One: 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	May, 96  June, 96																																			
Data Collection	June, 96  September, 96																																			
Data Analysis	October, 96  October, 97																																			
Report Preparation													November, 97  March 98																							

REFERENCES

The material presented in this document is a result of several preliminary planning activities. A brief review of those preliminary plans is provided in the following paragraphs.

The General Evaluation Work Plan, prepared and submitted to the Evaluation Task Force in December, 1993, furnished a summary of the potential project goals, objectives, and measures of effectiveness derived from sources including initial project proposals, concept papers, or presentations. Additionally the document ranked the priority of these objectives as primary, secondary, and candidate based on their potential for being credibly evaluated and presented a “best-guess” budget for evaluating each of the objectives.

The Scope of Work for the Detailed Evaluation Work Plan, prepared and submitted to the Evaluation Task Force in April, 1994, grouped the primary goals and objectives established in the *General Evaluation Work Plan* into sets of objectives and preliminary hypothesis tests based on their expected effects on the project stakeholders (motor carriers, weigh stations, and the various jurisdictional agencies along the Advantage I-75 corridor). The result of this grouping was five Individual Evaluation Test Plans that could be further developed to assess the effects of the MACS project on the stakeholders involved. These Individual Evaluation Work Plans are shown below:

- Motor Carrier Individual Evaluation Work Plan
- Weigh Station Individual Evaluation Work Plan
- Motor Carrier Safety Individual Evaluation Work Plan
- Jurisdictional Issues Individual Evaluation Work Plan
- Credential Compliance Individual Evaluation Work Plan
- System Individual Evaluation Work Plan

Using the November, 1993 edition of the FHWA’s Operational Test Guidelines as a model, this document presented preliminary test hypotheses, test concepts, test methodologies, and budgets for developing each of the above individual evaluation work plans.

The Hypotheses Validation and Test Methodology was prepared and submitted to the Evaluation Task Force in January, 1995. The purpose of this document was to present testable hypotheses and initial test methodologies, grouped by individual evaluation work plan, for sixteen selected goals and objectives related to the services provided by the MACS project and six selected goals and objectives related to the performance of the MACS system hardware and software. The development of the initial test methodologies revealed that some of the selected project objectives were similar in meaning and intent and would thus require duplicate evaluation efforts. For example, Hypotheses Seven (i.e., reduced queue lengths) and Hypothesis Ten (i.e., reduced instances of “queue overflows onto the mainline”) were viewed as similar in their required test methodology and therefore combined into a single hypothesis concerning the overall impact of the MACS project on weigh station queues. The development of initial test methodologies also revealed that other objectives were too vague to develop an economically feasible method of conducting a credible evaluation. For example, Hypothesis Four

(i.e., improved productivity of motor carriers attributable to the efficient administration of weigh stations) was eliminated because a more direct assessment of motor carrier productivity was already contained in Hypotheses One (i.e., energy savings attributable to the MACS project) and Hypothesis Two (i.e., travel time savings attributable to the MACS project).

The Pilot Studies were developed at the direction of the Evaluation Task Force to assist in the planning of the two-year evaluation. Two pilot studies were carried out. The first focuses on the Motor Carrier Individual Evaluation Work Plan and the second focuses on weigh station conditions to be evaluated in the Weigh Station Individual Evaluation Work Plan. Not included in the *Scope of Work for the Development of the Detailed Evaluation Plan*, these studies were prepared between January and July, 1995, and submitted to the Evaluation Task Force and Policy Committee in August, 1995. The purpose of these studies is summarized below:

- Obtain information about the amount and variability of fuel consumption for various weigh station processing scenarios with and without electronic clearance.
- Determine the key predictors of certain variables of interest such as weigh station throughput, queue length, merges and lane change, and traffic congestion.
- Determine the sample size required for a credible two-year evaluation.
- Conduct preliminary analysis using the statistical methods that are likely to be used in the full-scale evaluation.
- Determine whether the proposed statistical methods are appropriate for assessing the effect of electronic clearance.
- Provide the evaluation team with experience in data collection conditions likely to be encountered during the two-year evaluation.

Similar to other preliminary planning activities, the intention of these studies was the continued refining of the two-year evaluation as a method of providing the most credible operational test evaluation for the least cost.

Detailed Evaluation Plan Part One: Evaluation Recommendations was prepared to provide members of the Evaluation Task Force with data-based recommendations concerning methodology and a preliminary budget for the two-year evaluation of the Advantage I-75 Mainline Automated Clearance System (MACS). Notes on statistical methodology were included to assist in the interpretation of the recommendations. The information provided in that document was intended to assist the Evaluation Task Force in assessing and approving a credible evaluation plan that appraises the impacts of the MACS project on the various stakeholders effected by the electronic clearance services provided.

PRE-TEST ACTIVITIES

This test plan is based on the results of an extensive pilot study that was conducted at four locations along the Advantage I-75 corridor during September, 1995. The planning for the pilot study is

discussed in a documents entitled *Pilot Studies*. The results of the pilot study are provided in a document entitled *Detailed Evaluation Plan Part One: Evaluation Recommendations*.²

EVALUATION TEST ACTIVITIES

Description of the Fuel Consumption Tests

This following paragraphs provide a detailed description of the scenarios, scripts, and procedures for the fuel consumption tests. A separate description of the weigh station queue fuel consumption tests to be conducted at the Charlotte, Florida test location is provided on page 14.

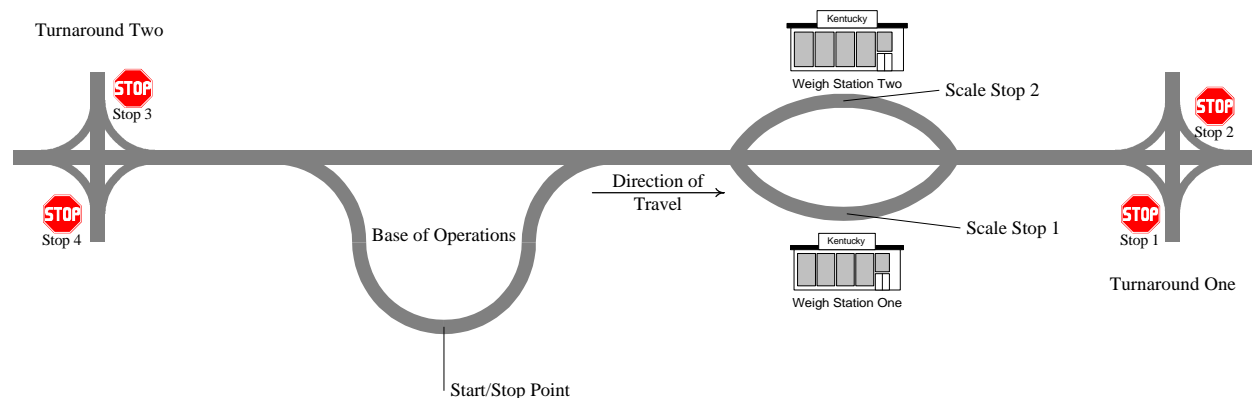
Scenarios

Two identically equipped trucks, one termed the control truck, and one termed the test truck complete test runs on defined loops of interstate highways following defined scripts. The defined interstate highway loops are illustrated in Figure Two and consist of two weigh stations, two turnaround points, and one base of operations. The trucks first complete the appropriate number of baseline runs whereby both of the trucks follow the control truck script. This is accomplished to establish baseline fuel consumption ratios 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 number of baseline runs and test runs is dependent on weigh station design. See discussion of sample size on pp 22–23 for the appropriate number of baseline and control runs for each test location.

Scripts

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 Two.

Figure Two: Typical Test Route



² *Pilot Studies*. Submitted to the Advantage I-75 Evaluation Task Force. Prepared by The Iowa Transportation Center. Ames, Iowa. July 24, 1995. *Detailed Evaluation Plan Part One: Evaluation Recommendations*. Submitted to the Advantage I-75 Evaluation Task Force. Prepared by The Iowa Transportation Center. October 18, 1995.

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 55 miles per hour, 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 55 mph, 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 55 mph, 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 55 miles per hour, 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 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 55 mph, 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 55 mph, 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 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 55 mph, 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 55 mph, 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 first 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 setup.

- **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 fuel tanks (during the test runs) or the existing 150 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 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.
- **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 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 must also be well marked with orange-safety cones and warning signs during setup. When tests are scheduled during periods of darkness

and the base of operations is not adequately illuminated, auxiliary lighting should be setup prior to conducting test runs.

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 to the trucks. The odometer reading for each truck is also noted 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 pervious 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 ratio for the previous run.³

³ 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 methods 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. pp.48–49.

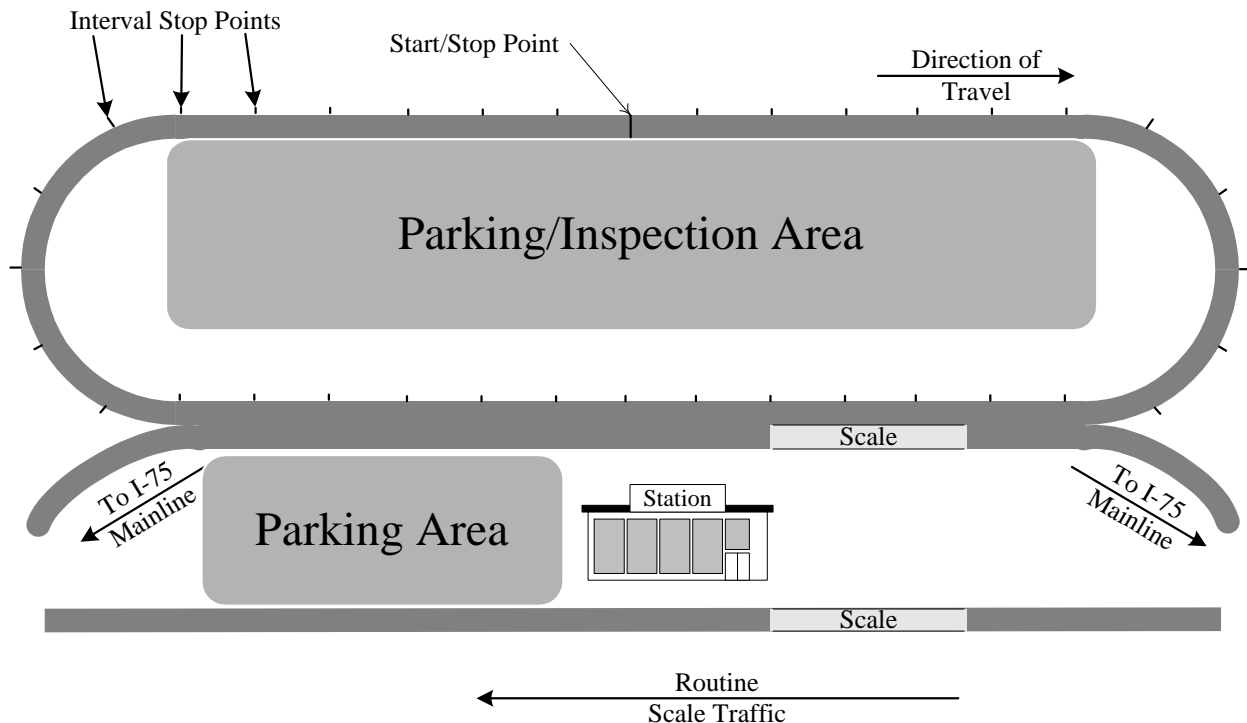
Description of the Weigh Station Queue Fuel Consumption Tests

Separate fuel consumption tests will be conducted at one of the Charlotte, Florida weigh stations to gather data for estimating the effect of weigh station queues on fuel consumption. Brief descriptions of the scenario, scripts, and procedures for these tests are provided below.

Scenarios

Two identically equipped trucks, one termed the control truck, and one termed the test truck complete test runs on defined loops, as illustrated in Figure Three, located in large parking/inspection areas at the Charlotte, Florida weigh stations. The trucks first complete the appropriate number of baseline runs whereby both of the trucks follow the control truck script. This is accomplished 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.

Figure Three: Weigh Station Queue Fuel Consumption Tests



Scripts

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 Three.

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.
- 3) Maintain a speed of 15 miles per hour, 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 stop point and accelerate to 5 miles per hour. (An average in-queue speed was 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 reaccelerate to 5 miles per hour. (Note, other speeds, such as 10 or 15 mph, will also be used to determine the effect of queue speed on fuel consumption)
- 5) Come to a complete stop at the next interval stop point and remain stopped for a period or 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.

Procedures

See fuel consumption test procedures on page 12.

Resources Needed for Conducting the Test

Hardware

The hardware required for the fuel consumption tests is provided below.

Hardware for the Data Collection Team The following list provides the appropriate transportation equipment, instrumentation, supplies, communications equipment, tools, safety gear, and data collection forms for the data collection team.

The transportation equipment consists of:

- 15 passenger van or extended cab pickup with sufficient towing capacity
- Enclosed six foot by 12 foot cargo trailer with swing doors and a sturdy floor
- Jacks and leveling equipment for leveling the cargo trailer

The instrumentation consists of:

- Portable scale (preferably digital readout) with a 30 inch square working surface capable of weighing 200 pounds with an accuracy of ± 0.1 pounds.
- Wind speed gauge capable of reading wind speed to the nearest 2 miles-per-hour
- Thermometer capable of reading temperature to the nearest degree Fahrenheit

- Compass or other device to measure wind direction to the nearest 5 degrees of arc.
- Where appropriate and feasible, a hand held terminal for downloading and resetting trip information from the electronic engine management system.
- Laptop computer (or hand held calculator) for recording and computing T/C ratios to verify test run consistency

The supplies consist of:

- Four 55 gallon drums and a manual transfer pump for refueling the portable fuel tanks
- One small spill-back reservoir for catching excess fuel (from the manual transfer pump)
- Supply (approximately 500 to 1000 sheets per test location) of paper wiping towels to be used for wiping excess fuel from the surface of the fuel tanks prior to each tank weighing.
- Supply (approximately 100 per test location) of plastic wire ties for securing the temporary fuel lines
- One dozen extra “O” rings for the quick disconnect fuel lines
- One dozen sharpened lead pencils
- 3 clipboards
- Six large hand held stop watches with digital readout (two for recording total run time, two for recording cumulative stop time, and two for backup)

The communications equipment consists of:

- Two cellular phones (one for regular use and one as backup) for communicating from the test truck to the weigh station
- One citizens band radio for communicating from the base of operations to the test trucks.

The tools consist of:

- Wrench set ranging from 3/8 inch to 1 1/4 inch for installing the quick disconnect fuel lines on the test trucks
- One-half inch drive socket wrench and socket set with sockets ranging from 3/8 inch to 1 1/4 inch
- Miscellaneous tools consisting of wire cutters, pliers, phillips-head, and straight-head screw drivers, miniature carpenter's level, black electrical tape, ignition wrench set, and “O” ring pick

The safety equipment consists of:

- Fifteen orange fluorescent safety cones for demarcating parking and working areas at the base of operations
- Five orange fluorescent safety vests (one for each member of the data collection team)
- Six pair of cotton work gloves per test location
- Portable generator and auxiliary lighting equipment for inadequately lit base of operations used for conducting test runs during periods of darkness

The data collection forms consist of the Fuel Measurement Form and Test Vehicle Specifications Sheet that are illustrated below. One fuel measurement form is used for each test run, and one test vehicle specifications form is used for each test location. Extra forms or a method of duplicating blank forms should be available.

Hardware for the Test Trucks The hardware for the test trucks consists of fuel lines, quick disconnect fittings, fuel tanks, and in-line fuel coolers.

The fuel lines consist of:

- Six short (6 ft long) sections of number ten aeroquip fuel line with female swivels on each end (used for rerouting the existing fuel draw lines to convenient locations)
- Six long (12 ft long) sections of number ten aeroquip fuel line with female swivels on each end (used for connecting the existing re-routed fuel draw lines to the portable fuel tanks)
- Six short (6 ft long) sections of number four, six, or eight (check with fleet manager for appropriate size) aeroquip fuel line with female swivels on each end (used to reroute existing fuel return lines to convenient locations)
- Six long (12 ft long) sections of number four, six, or eight (check with fleet manager for appropriate size) aeroquip fuel lines with female swivels on each end (used to connect the re-routed existing fuel return lines to the portable fuel tanks)
- Four number ten aeroquip unions for rerouting existing fuel draw lines
- Four number four, six, or eight (check with fleet manager for appropriate size) for rerouting existing fuel return lines
- Ten sets of quick disconnect fittings
- An assortment of pipe thread to aeroquip fitting brass fitting adapters

The fuel tanks consist of:

- Two portable 15 gallon fuel tanks for the control truck (painted green and marked “C-1” and “C-2”)
- Two portable 15-gallon fuel tanks for the test truck (painted blue and marked “T-1” and “T-2”)
- Two cargo winch straps with “C-hooks” and quick releases for securing the fuel tanks to the truck deck plates and frame rails

The in-line fuel coolers consist of:

- Two air-cooled line coolers plumbed with one-half inch pipe-thread inlets and outlets and containing approximately 2 square feet of cooling surface area.
- Eight 2 inch square rubber pads for mounting surface protection
- 16 extra wide wire ties for mounting the aftercoolers to the truck frames

Software

An accepted spreadsheet and/or database package (e.g., Lotus 123 and Lotus Approach or Microsoft Excel and Microsoft Access) is recommended for field recording the test run data and verifying the consistency of the T/C ratios. This package would then be used to export the field data as an ASCII file to a statistical package (e.g., SAS or MINITAB) for analysis.

Consumable Items

The primary consumable item is number two diesel fuel. Based on Pilot Study One results, the test trucks will each consume an average of 5.06 gallons of fuel per test run.

Staff and Responsibilities

The test will require a staff of six individuals, consisting of one data collection team leader, three data collection team members, and two drivers. The data collection team leader is responsible for conducting the test according to the specifications defined in this test plan. Specific data collection team leader responsibilities include:

- Supervising the setup procedures
- Training drivers and data collection team members as needed
- Conducting the appropriate number of test runs (e.g. control runs in the baseline condition and test runs in the experimental condition)
- Transcribing the recorded field data from data collection sheets for each test run to a spreadsheet package on a laptop computer
- Computing the T/C ratio for each test run on a spreadsheet package
- Following the safety procedures to ensure the welfare of the drivers and members of the data collection team

The data collection team is responsible for performing the required support activities. Specific data collection team member responsibilities include:

- Setting up the base of operations according to the direction of the data collection team leader
- Performing the test runs according to the procedures defined on pp 11–13
- Recording the appropriate information on the data collection sheets
- Keeping the base of operations clean and free of debris

The drivers are responsible for the safe operation of their vehicles and completing the test runs according to the scripts defined on pp 9–10.

Test Duration

The current schedule specifies 33 days of fuel consumption testing based on the schedule in Appendix One. In addition, approximately one-month of test preparation time will be required to assemble the resources needed for conducting the test. Although the fuel consumption tests could be completed in approximately six or seven weeks of continuous testing, the tests will be scheduled in conjunction with

other data collection tasks. Hence, the tests are tentatively scheduled to begin on or about June 8, 1996 and be completed on or about August 21, 1996. Some scheduling adjustments may be required during the course of the data collection period to account for such factors as inclement weather or motor carrier considerations.

Selection of Test Sites

The primary site selection consideration for the fuel consumption tests was weigh station design and topography. The test design developed for Pilot Study One and applied to this test removes the effects of traffic from fuel consumption differences because of the various safeguards similar to those used in the SAE Type II test procedures. For example, the fuel consumption tests will be conducted at closed weigh stations (temporarily closed while the test truck passes through the weigh station) and at off-peak traffic hours. The test procedures also specify using two-identically equipped vehicles with the same drivers and conducting the test runs simultaneously to control variability among the test runs. Therefore, the remaining variability in fuel consumption among selected sites will be primarily attributable to weigh station design and differences in topography. (e.g., hilly vs. level road conditions).

The goal of the site selection was to choose the most and least favorable topographical conditions for each of the three weigh station design types that exist on the Advantage I-75 corridor. Table Three provides the design type and topographical classifications for each of the weigh stations along the I-75 corridor.

Table Three: Weigh Station Design and Topographical Classification

Station Name	Design Type	Topography	Description
Halton, ON	Static Scale	Level	
Middlesex, ON	Static Scale	Level	
Essex, ON	Static Scale	Level	
Monroe, MI	Ramp WIM	Level	Flat even terrain with relatively long (1,300 ft), gently curving entrance and exit ramps
Wood, OH	Static Scale	Level	Flat even terrain with nearly straight entrance and exit ramps
Hancock, OH	Static Scale	Level	Slight downgrade transition from downgrade to upgrade on approach ramp due to RR overpass
Kenton, KY (southbound only)	Ramp WIM	Rolling	Moderate upgrade on approach ramp which continues on the mainline
Scott, KY (northbound only)	Static Scale	Level	Gently rolling terrain with scales located at top of small rise
Laurel, KY	Static Scale	Rolling	Scales located on top of small rise with moderate to slight upgrade on approach ramp and downgrade on exit ramp
Knox, TN	Static Scale	Rolling	Long upgrade on and one-half mile pass southbound exit ramp
Catoosa, GA	Ramp WIM	Rolling	Moderate downgrade on southbound approach ramp
Monroe, GA	Ramp WIM	Rolling	Scales located on top of small rise
Lowndes, GA	Ramp WIM	Level	Flat even terrain
Hamilton, FL	Static Scale	Level	Ag inspection station would provide problems for fuel consumption test
Marion, FL	High-Speed Ramp WIM	Level	Flat terrain with extremely long scale entrance and exit ramps
Charlotte, FL	High-Speed Ramp WIM	Level	Flat even terrain with extremely long scale entrance and exit ramps

Ideally, the selected test sites should include two weigh stations (e.g., one weigh station each direction) within the same vicinity to ensure that a measurable difference in fuel consumption occurs between the vehicles (i.e., test vehicle vs. control vehicle) on each test run.

The Kenton County and Scott County weigh stations were excluded because they are not of identical design types and they are located 38 miles apart from each other (Kenton County site is at mile marker 168 southbound and Scott County site is at mile marker 130 northbound). The Canadian sites were excluded based on economic considerations. The design types and topographical conditions of the Canadian sites were not viewed as being significantly different from those in the United States. Upon final evaluation, the team decided that it was more economically feasible not to travel to distant Canadian locations to conduct fuel consumption tests in conditions that are nearly identical to those encountered in the United States.

The Monroe, Michigan, sites were selected as the most efficient Ramp WIM design type because the terrain conditions are nearly level (including entrance and exit ramps) and the exit and entrance ramps are designed to provide minimum disruptions to traffic. The Catoosa, Georgia, and Monroe, Georgia sites were selected as the least efficient Ramp WIM design type because of the rolling terrain conditions and moderate upgrades on the scale entrance ramps. Both of these sites have nearly identical terrain conditions and ramp design. Upon final evaluation, the Monroe, Georgia site was selected because of lower traffic volume and more convenient turn-around locations, resulting in more uniform test conditions.

The Wood County/Hancock County, Ohio, scales were selected as the most efficient Static Scale design type because of the level terrain conditions (including exit and entrance ramps). These two stations are not located directly opposite of each other (the Wood County site is 14 miles north of the Hancock County site). However, the terrain conditions and ramp designs at these sites are nearly identical. Additionally, the rest area just north of the Wood County, site will provide a convenient and safe base of operations for the test runs. The Knox, Tennessee sites were selected as the least efficient static scale sites because of the long upgrade beginning on the southbound scale entrance ramp and exit ramp which continues on the mainline immediately south of the station.

The Charlotte County, Florida sites were selected from the High-Speed Ramp WIM scale type. In keeping with Evaluation Task Force recommendations, only one site was selected from the High Speed Ramp WIM sites. The Charlotte County, Florida, site was selected because the low traffic levels on that section of the interstate highway and the remote site location will provide ideal test conditions.

The Charlotte County, Florida sites were selected for the weigh station queue fuel consumption tests because of the favorable layout and the flat terrain conditions. The large parking/inspection area located immediately behind the weigh station will allow completion of these tests in controlled and safe conditions without interference from other routine scale traffic. It should be noted that topographical considerations were not a site selection factor for these tests because the test vehicles will be operating at slow speeds using the lower ranges of transmission gearing. Varying the exit ramp grades by 1 or 2 percent for these tests would therefore produce little variation in fuel consumption because of the low gear ratios.

Specification of Sample Size

The sample size for each test location was determined using a three-step statistical analysis of the fuel consumption data from pilot study one. The first step was to analyze the Pilot Study One data and determine the magnitude of fuel savings and fuel savings variability. The second step examined the sample size required to obtain estimates with different precisions. The third step was to choose the sample size that gave the most precision for a reasonable cost.

The observed fuel consumption differences from Pilot Study One between the control truck and the test truck during baseline runs and experimental runs for each weigh station design type was computed and used to determine the mean and standard deviation (s.d.) estimated fuel savings resulting from bypassing a weigh station. The results of this first step are shown in Table Four

Table Four: Estimated Mean and Standard Deviation of Fuel Consumption Savings by Weigh Station Design Type

Test Location	Design Type	Mean Estimated Fuel Savings (gal.)	s.d. Estimated Fuel Savings (gal)
Monroe, MI	Ramp WIM	0.05	0.09
Marion, FL	High Speed Ramp WIM	0.01	0.03
Laurel, KY	Static Scale	0.09	0.05
Knox, TN	Static Scale	0.13	0.04

The above table illustrates that the standard deviations are comparable except that the standard deviation at the Monroe, Michigan location was greater than other test locations. As noted in previous documentation, this was partly attributable to heavy traffic conditions.

The confidence interval widths for given sample sizes for each weigh station design type was computed using the following formula:

$$Confidence\ interval = M_b - M_e \pm \left(t_{critical\ value}(s.d.) \sqrt{\left(\frac{1}{n_b} + \frac{1}{n_e} \right)} \right)$$

where:

- M_b = the mean observed fuel consumption differences between the control truck and the test truck during pilot study one baseline runs
- M_e = the mean observed fuel consumption between the control truck and the test truck during pilot study one experimental runs
- s.d.* = the standard deviation of the observed fuel consumption during pilot study one baseline runs and experimental runs
- $t_{\text{critical value}}$ = the t value at the specified confidence interval
- n_b = the number of baseline runs
- n_e = the number of experimental runs

The computed confidence intervals for given sample sizes are shown in Table Five.

Table Five: Computed Confidence Intervals for Selected Sample Sizes by Weigh Station Design Type

Design Type	Std. Dev. (gal)	Confidence Interval Width by Sample Size (gal)			
		10	30	50	70
Static Scale	0.05	0.089	0.052	0.040	0.034
High-Speed WIM	0.03	0.054	0.031	0.024	0.020
Ramp WIM	0.05	0.089	0.052	0.040	0.034
Ramp WIM	0.10	0.179	0.103	0.080	0.068

Two possible standard deviations have been used for the Ramp WIM design type to accommodate the higher-than-expected standard deviation in fuel consumption encountered at the Monroe, Michigan test location.

Third, sample size was chosen from the above selected sample sizes having acceptable confidence interval widths. For example, a confidence interval width of .05 (that is mean savings plus or minus .025 gallons per station) might be acceptable for a static scale when the expected mean savings is about .10 gallons per station because the confidence interval is approximately 25 percent ($0.025 \div 0.10$) of the expected mean savings. However, the same accuracy would not be acceptable at a high-speed WIM station where the expected savings are smaller. (A confidence interval of plus or minus 0.025 gal for a high speed ramp WIM station with an expected mean saving of 0.013 gal is approximately 200 percent of the expected mean savings.) Final sample size selections depend on both the variability (standard deviation) expected and the mean expected fuel saving. It turns out that the sample size required to obtain a narrow confidence interval for the High-Speed WIM design type is prohibitive and we have therefore selected the largest feasible sample size. Based on the above calculations, we recommend the following sample sizes.

- **Static scales:**
 - » 30 runs in the experimental condition
 - » 30 runs in the baseline condition
- **Ramp WIM:**
 - » 50 runs in the experimental condition
 - » 50 runs in the baseline condition
- **High-speed ramp WIM:**
 - » 70 runs in the experimental condition
 - » 70 runs in the baseline condition

System Conditions

No modifications to the MACS system will be necessary for this test. As previously noted, the only effect of this test on the weigh stations will be the requirement for brief (5 minutes or less) weigh station closures on each test run. Wherever possible, the tests will be scheduled to further limit the need for weigh station closures. For example, the tests could be conducted during times that weigh stations would be normally closed due to staff scheduling.

Traffic Conditions

Pilot Study One revealed that several traffic conditions can affect the outcome of the fuel consumption tests. First, heavy traffic at turnaround point one and turnaround point two (see Figure Two, page 9.) can introduce variability in the fuel consumption test results because the test trucks may have to wait for cross traffic openings for long periods of time before making the left turns at stop points 1–4. Second, heavy truck traffic on the test section of interstate highway may create heavy air turbulence for the test trucks.⁴

One of the objectives in selecting test locations was to minimize the effect of traffic on the outcome of the fuel consumption tests. For example, the weigh station design and topography conditions are nearly identical at the Catoosa, Georgia, and Monroe, Georgia, sites. The Monroe, Georgia site was selected because the traffic conditions should be more favorable to the test runs. However, two of the selected test locations (Monroe, Michigan, and Knox, Tennessee, had unique combinations of weigh station design and topographical conditions and no similar test sites were available. The test runs will be scheduled at non-peak traffic hours (9:00 pm to 6:00 am on weekdays and weekends or 6:00 am to noon on weekends) at these test locations to minimize the effect of traffic.

⁴ The greatest variability in Pilot Study One's test runs occurred at the Monroe, Michigan location. This was partly attributable to the heavy vehicle truck traffic (platooning effect) in the vicinity of the test trucks and partly attributable to heavy cross traffic at the north turnaround point. *Detailed Evaluation Plan Part One: Evaluation Recommendations*. Submitted to the Advantage I-75 Evaluation Task Force. The Iowa Transportation Center. Ames, Iowa. October 17, 1995. pp. 9–10.

Environmental Conditions

Generally, the fuel consumption tests are unaffected by environmental conditions. However, heavy periods of rain can introduce variability in the test results because water on the roadway surface and wind can increase the horsepower requirements, and therefore the fuel consumption, for maintaining set vehicle speed (55 mph). Tests will be suspended during periods of heavy rain to eliminate this variability.

Safety Considerations

Safety considerations have been made for the drivers of the test trucks and the data collection team.

Driver Safety Considerations

The tests are designed to ensure that the drivers will be able to operate within the provisions of the Federal Motor Carrier Safety Regulations contained in 49 CFR parts 382, 383, and 390–397. Additionally, the tests are designed to ensure that drivers can comply with the appropriate company safety procedures. Some of the driver safety considerations specific to the fuel consumption tests are provided below.

- The drivers will operate within the hours-of-service provisions of 49 CFR part 395.
- The final location and mounting of the portable fuel tanks and fuel lines will be subject to the test truck drivers' approval.
- The drivers will not be required to perform any of the heavy lifting associated with installing and removing the portable fuel tanks

Data Collection Team Safety Considerations

Several provisions in the test design have been made to ensure the safety of the data collection team members. First, the base of operations for each test site has been selected to provide minimum traffic hazards. Pilot Study One revealed that the ideal base of operation location is an interstate rest area along the test route because ample parking facilities and slow moving traffic conditions. Interstate rest areas are also generally well-lighted, which will facilitate night time test operations. As Table Six illustrates, interstate rest areas have been selected as a base of operations for four of the five test locations.

Table Six: Base of Operations by Test Location

Test Location	Base of Operation
Monroe, Michigan	Northbound rest area at mile marker 10 (one mile north of South Otter Creek Road exit)
Wood/Hancock, Ohio	Southbound rest area at mile marker 180 (approximately 3 miles south of the Bowling Green, Ohio exit)
Knox, Tennessee	Eastbound interstate parking area on I-40 approximately 6 miles west of the junction of I-40 and I-75.
Monroe, Georgia	To be determined
Charlotte, Florida	Interstate rest area at the turnaround point 2 exit ramp

Other safety considerations for the data collection team include fluorescent orange safety vests, fluorescent orange safety cones, and support belts to assist with portable fuel tank removal and replacement.

Input Data and Sources

The input data is illustrated in the data collection forms shown on the following pages. Input data such as driver name, date, location, temperature, weather conditions, and wind speed are self-explanatory. However, some of the input data such as fuel tank number and weight, scenario and test events is more complex and thus requires further definition. For each of the data collection forms, the following paragraphs provide definitions and data sources for the more detailed input data.

Fuel Measurement Form Input Data

The following index provides definitions and data sources for the fuel measurement form data.

- **Test Run Number:** Sequential number starting at 1 for each test location. The number is assigned by the data collection team leader.
- **Scenario:** The test run scenario (either test or control). Control scenario indicates that the vehicle drives by the weigh station using the script for the control truck. Test scenario indicates that the vehicle enters and processes through the weigh station. The scenario is assigned by the data collection team leader.
- **Fuel Tank Number:** The color and number of the portable fuel tank used for each run. For example, the number “green-2” would indicate that the green tank with the number 2 is used for that run. This is done to eliminate errors during refueling or tank replacement between test runs.
- **Fuel Tank Start Weight:** The weight to the nearest 0.1 pound of the filled fuel tank prior to start of the test run and placement on the test trucks. This weight is read directly from the scale and double checked by two members of the data collection team to prevent measurement error.
- **Fuel Tank Finish Weight:** The weight to the nearest 0.1 pound of the fuel tank after removal from the test trucks at the end of the test run. This weight is read directly from the scale and double checked by two members of the data collection team to prevent measurement error.

- **Fuel Used:** The difference (expressed to the nearest 0.1 pound) between the fuel tank start weight and fuel tank finish weight. The data is calculated using a hand-held calculator or spreadsheet package on a laptop computer.
- **Test Run Events:** Any event that occurred during the run that may attribute to unusual fuel consumption. The test truck driver provides this data during a brief interview following completion of the run. An example of the data is “Had to slow down to 45 mph once because of a slow-moving vehicle.”
- **Test Run Start Time:** The time (HH:MM:SS) that the test truck starts the engine and begins the test run. The data is observed by the data collection team leader.
- **Test Run Finish Time:** The time (HH:MM:SS) that the test truck shuts down the engine following completion of the test run. The data is observed by the data collection team leader
- **Start to Finish Time:** The difference (HH:MM:SS) between the test run start time and test run finish time. The time is useful for maintaining test run consistency and is computed using a hand-held calculator or spreadsheet package on a laptop computer.
- **Vehicle Stopped Time:** The cumulative total of the stopped time at stop points 1–4 plus the idle time at the end of the run. Normally, this time will be equal to 60 seconds. However, the time may occasionally need to be extended to 90 or 120 seconds for test runs with heavy cross-traffic at the turnaround points. Note: If the time must be extended for one test truck, it will also be extended for the other test truck to ensure test run consistency. The source of the data is the test truck driver and the data collection team leader. (The data collection team leader makes the decision to extend the stop time while communicating with the driver as he/she returns to the start/stop point at the base of operations.)
- **Total Number of Stops During Test Run:** The total number of enroute stops (not including stops at the static scale that are defined in the control truck script). Normally the total number of stops will equal four (stop points 1–4). Occasionally, the driver may have more than the required number of stops at the turnaround point because of heavy off-ramp traffic or cross-traffic. The driver provides the total number of stops to the data collection team leader at the end of each test run.
- **Total Time During Stops:** The cumulative stopped time at stop points 1–4 *not including idle time at the end of each run*. The driver provides this time to the data collection team leader at the end of the run.

Vehicle Identification Form

The data on the vehicle identification form provides the detailed specifications for the test vehicles. An example completed form is provided in Appendix Two, page 50 of *Detailed Evaluation Plan Part One: Evaluation Recommendations*. Most of the data such as make, model, and tire size is provided by the fleet manager. However, the data collection team will be required to collect the following input data.

- **Tire Pressure:** The tire inflation pressure for each tire on the vehicle should be checked prior to conducting any fuel consumption tests to determine that all tires are within a 5 psi tolerance of recommended operating range. Tire pressures that do not fall within that range should be adjusted (e.g., inflated or deflated). Tire pressure should then be recorded.

- **Gross Vehicle Weight:** Gross vehicle weight as determined by a certified public scale should be determined and recorded. The certified scale receipt should be kept as part of the field data records. Ideally, the weight of the control vehicle and test vehicle should be nearly identical and in the range of 60,000–70,000 pounds.
- **Cab to Trailer Gap:** The distance (inches) between the rear of the tractor cab and the front of the trailer. Sliding fifth wheels should be adjusted such that the cab to trailer gap are identical on the control vehicle and the test vehicle.

Figure Four: Fuel Measurement Form

CONTROL TRUCK

Driver Name		Location	
Date		Time of Day (Start)	
Temperature	Weather Conditions		Wind Speed
Test Run Number: _____		Scenario (circle one) Test Control	
Tractor Unit Number: _____		Trailer Unit Number: _____	
Fuel Tank # _____	Fuel Tank Weight	Odometer	Test Run Time
Start			
Finish			
Fuel Used		Test Run Events	
Start to Finish Time			
Vehicle Stopped Time			

Total Number of Stops During Test Run: _____

Total Time During Stops: _____

TEST TRUCK

Driver Name		Location	
Date		Time of Day (Start)	
Temperature	Weather Conditions		Wind Speed
Test Run Number: _____		Scenario (circle one) Test Control	
Tractor Unit Number: _____		Trailer Unit Number: _____	
Fuel Tank # _____	Fuel Tank Weight	Odometer	Test Run Time
Start			
Finish			
Fuel Used		Test Run Events	
Start to Finish Time			
Vehicle Stopped Time			

Total Number of Stops During Test Run: _____

Total Stop Time During Test Run: _____

Figure Five: Vehicle Identification Form

Test Location	Time of Day
Fleet Name	Date
Tractor	Trailer
Unit Number	Unit Number
Make	Make
Model	Model
Year	Year.
Number of Axles	Type (Van, Flat, Tank)
Number Drive Axles	Type of Side
Engine (Make/Model)	Height
Governed Speed	Length
Rated Horsepower	Tire Size
Trans. (Make/Model)	Tire Pressure
Top Gear Ratio	Cab to Trailer Gap
Diff. (Make/Model)	Cargo
Diff. Ratio	Gross Veh. Weight
Fifth Wheel Setting	Number of Axles
Tire Size	
Tire Pressure (Cold)	

Data to Record and Manner of Recording

See previous section

Test Log

See previous section

POST-TEST ACTIVITIES

Participants in Post Test Activities

Center for Transportation Research staff will perform all post test activities.

Debriefings

The data collection team leader shall prepare a written debriefing for each test location that provides a summary of the test events, an overview of the test conditions, and any special circumstances that were encountered during the tests. The purpose of this debriefing is to provide information for data reduction and analysis personnel that highlights any test runs or test conditions that may have resulted in abnormal test results. This debriefing should be completed within one week of completion of test runs at each test site.

Equipment Tear Down

Upon completion of the tests, equipment will be disassembled and returned to the Center for Transportation Research and Education.

Data Retention Plan

As previously discussed, the data will be entered in the field, using a laptop computer, by the data collection team leader following the completion of each run. Nightly backups will be made of the spreadsheet file of the entered field data. Upon completion of the testing, the data file will be forwarded in the appropriate file format for data reduction and analysis.

The original data collection sheets shall be kept in a three-ring notebook and held in archive at the Center for Transportation Research and Education.

DATA REDUCTION AND ANALYSIS

Participants

Data from the fuel consumption test will be input, analyzed, and interpreted by personnel from the Center for Transportation Research and Education (CTRE) at Iowa State University, in consultation with Professor Hal Stern, Department of Statistics, Iowa State University.

Hypotheses or Expected Results

The fundamental hypothesis is that trucks bypassing weigh stations due to electronic clearance will consume less fuel. In addition to addressing this hypothesis, we plan to provide estimates (and error bounds) for the magnitude of the fuel savings at different types of weigh stations.

Input Data

The worksheets filled out during the test runs will be the data source. For each run the following information will be recorded for each truck: condition (bypass or stop), distance traveled, fuel consumed, time stopped during the run, wind speed, temperature. The basic unit of measurement that we will use for each run is the fuel savings in gallons per weigh station (test truck's fuel consumption less control truck's fuel consumption divided by the number of weigh stations).

Methods, Algorithms, and Equations Used for Generating Each Type of Output

The approach that we will take to the data uses two sample statistical methods (comparing baseline runs to experimental runs). The two sample t-test compares the mean fuel savings in baseline runs (which should be approximately zero because both trucks drive the same EXACT route in the baseline scenario) to the mean fuel savings in experimental runs. The t-statistic is computed as:

$$t = \frac{M_e - M_b}{s.d. \sqrt{\frac{1}{n_b} + \frac{1}{n_e}}}$$

where:

- M_b = the mean observed fuel consumption differences between the control truck and the test truck during pilot study one baseline runs
- M_e = the mean observed fuel consumption between the control truck and the test truck during pilot study one experimental runs
- s.d. = the standard deviation of the observed fuel consumption during pilot study one baseline runs and experimental runs
- n_b = the number of baseline runs
- n_e = the number of experimental runs

The value of the t-statistic is compared to a table of the distribution of t (as in The Basic Practice of Statistics by David S. Moore, W. H. Freeman and Co., 1994). Large values of the t-statistic lead us to reject the null hypothesis that there is no fuel savings. We will also consider confidence intervals for the amount of fuel savings based on the same t-statistic. A 95% confidence interval for the mean fuel savings is computed by the following formula:

$$\text{Confidence interval} = \text{Mean}_{base} - \text{Mean}_{xper} \pm \left[t_{critical\ value} (s.d.) \sqrt{\left(\frac{1}{n_b} + \frac{1}{n_e}\right)} \right]$$

where:

all terms are defined above and the $t_{critical\ value}$ is again obtained from an appropriate table.

Statistical Tests

The statistical tests are described briefly in the previous paragraph. We do not view tests of the hypothesis that fuel savings are zero to be the relevant question to address. Instead, we plan to focus our effort on providing a 95% confidence interval for the mean savings attributable to electronic clearance at each type of weigh station. We plan to provide separate confidence intervals for each of the weigh stations that we visit.

Output Data

The output will be an estimate of the fuel savings attributable to electronic clearance at each weigh station and confidence interval providing some information about the range of plausible values for the fuel savings. This will be supplemented by information about fuel consumed while in queues of various types. It is our intention that the resulting data could be used by interested parties to estimate per trip or annual fuel savings for particular trucks, trips or routes.

Accuracy Requirements

Sample size has been determined (see earlier section) to provide confidence intervals that are as narrow as possible subject to cost constraints.

Hardware, Software (Including Models)

The statistical software required is modest, any existing statistical software program (e.g., MINITAB and SAS) or spreadsheet program can do the required calculations. A personal computer equipped with such software is the only hardware requirement.

REPORTING REQUIREMENTS

A final report outline will be developed during the course of the research. As part of the analysis and reporting phase, draft final report outlines will be developed and submitted to Evaluation Task Force members for review and comment. The final report outline will reflect the comments and input from committee members.

BUDGET

The budget for conducting the Fuel Consumption Test is provided in Table Seven. This budget provides two separate expense subtotals (e.g., personnel and equipment and travel). The total project budget for this plan is the sum of the personnel and equipment subtotals and the Iowa State University indirect cost. The project term begins on June 1, 1996 and runs through March 31, 1998. The budget has been reviewed and approved, as shown in Exhibit A in the Letter of Transmittal, by the Director of the Center for Transportation Research and the Contracts and Grants Officer for the Iowa State University.

Table Seven: Motor Carrier Fuel Consumption Test Plan Budget

	Time (Hrs.)	Rate/ Hour	Budget
Personnel Budget			
<u>Faculty</u>			
Tom Maze	30	\$55.94	\$1,678
Hal Stern	173	\$35.47	\$6,148
<u>Professional and Scientific</u>			
Jim York	693	\$19.87	\$13,774
Bill Mc Call	60	\$38.20	\$2,292
Marcia Brink	12	\$16.51	\$198
Jan Graham	77	\$18.69	\$1,434
<u>Merit Staff</u>			
Dianne Love	99	\$14.44	\$1,434
Secretary	104	\$13.74	\$1,434
<u>Research Students</u>			
Iowa State University Student (Data Collection)	260	\$14.64	\$3,806
Iowa State University Student Two (Congestion Estimation)	260	\$14.64	\$3,806
<u>Post Doctoral Research Associate</u>			
Dr. Ali Kamyab		\$20.19	
<u>Fringe Benefits</u>			
Faculty Fringe @24.55%		24.55%	\$1,921
Professional and Scientific Fringe @30.8%		30.80%	\$5,451
Merit Fringe @ 39.45%		39.45%	\$1,131
Research Student Fringe @\$625/year		\$178.00	\$356
Post Doctoral Research Associate		16.14%	\$0
Total Personnel Budget			\$44,861
Equipment and Travel Budget			
Supplies			\$250
Equipment (Tanks, Scales, Lines and Fittings)			\$2,000
Phone, postage, equipment rent			\$2,000
<u>Subcontracts</u>			
Collins and Aikman Corp (2 vehicles and drivers)	66	\$545.45	\$36,000
Kentucky State University (3 Research Assistants)	990	\$14.53	\$14,385
Kentucky State University Car	2,646	\$0.22	\$582
Iowa State University Van & Trailer	12,467	\$0.48	\$6,041
Meals and Lodging Expense			\$18,428
Additional Domestic Travel			\$3,180
Total Equipment and Travel Budget			\$82,866
Subtotal Project Budget			\$127,726
Indirect Cost @25%			\$29,182

Total Project Budget

\$156,908

APPENDIX

Data Collection Schedule

The following pages provide a preliminary data collection schedule for both the fuel consumption test plan and the weigh station test plan. The schedule depicts a monthly overview of the dates and locations of data collection activities for two data collection teams. The fuel team consists of one team leader, three research assistants, and two truck drivers. The time team consists of one team leader and six research assistants. The three research assistants on the fuel are also members of the time team.

As the preliminary schedule illustrates, the fuel consumption tests will begin on or about June 8, 1996, in Forsythe, Georgia and be completed on or about September 24, 1996 at the Monroe, Michigan, location. The schedule as currently proposed has been designed to accommodate the weigh station renovation at the Hancock, Ohio scale and the 1996 Summer Olympics at the Monroe, Georgia, scales. For example, fuel consumption testing and weigh station throughput timing is scheduled to be completed at the Monroe, Georgia location approximately six weeks prior to the Summer Olympics.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5	6	7	8 Fuel Team leaves for Monroe, Georgia
Day 1 9	Day 2 10	Day 3 11	Day 4 12	Day 5 13	Day 6 14	Day 7 15
Fuel Consumption Testing in Monroe, Georgia						
16 Fuel Team remains in Monroe Time Team leaves for Monroe	Day 1 17	Day 2 18	Day 3 19	Day 4 20	Day 5 21	22 Both Teams return home
	Weigh Station Throughput Timing: Monroe, Georgia → Lowndes, Georgia (Group 4)					
23	24	25	26	27	28	29
30						

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
				Fourth of July (Holiday)		
7	8	9	10	11	Day 1 12	Day 2 13
				Fuel Team leaves for Charlotte, Florida	(Charlotte)	
Day 3 14	Day 4 15	Day 5 16	Day 6 17	Day 7 18	Day 8 19	Day 9 20
Fuel Consumption Testing in Charlotte, Florida						
21	22	Day 1 23	Day 2 24	25	26	27
Fuel Team remains in Charlotte Time Team leaves for Charlotte		Weigh Station Throughput Timing: Charlotte, Florida (Group 5)		Both teams return home		
28	29	Day 1 30	Day 2 31	Day 3 Aug 1	Day 4 2	
Stay overnight in Kenton, Kentucky		Weigh Station Throughput Timing: Kenton, Kentucky→ Knoxville, Tennessee (Group 3)				

August

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				Day 3 1	Day 4 2	3 Time team returns home Fuel team remains in Knoxville
	Day 1 4	Day 2 5	Day 3 6	Day 4 7	Day 5 8	9 10
(Last 2 Days in Knoxville)						
Fuel Consumption Testing in Knoxville, Tennessee						
	Day 1 11	Day 2 12	Day 3 13	Day 4 14	Day 5 15	16 17
Weigh Station Throughput Timing: Halton, Ontario → Middlesex, Ontario (Group 1)						
Day 1 18	Day 2 19	Day 3 20	Day 4 21	Day 5 22	Day 6 23	Day 7 24
Fuel Consumption Testing in Monroe, Michigan						
25	26	27	28	29	30	31

September

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	Day 1 16	Day 2 17	Day 3 18	Day 4 19	Day 5 20	21
Fuel Team leaves for Findlay, Ohio	Fuel Consumption Testing in Findlay, Ohio					Fuel Team remains in Findlay Time Team leaves for Findlay
22	Day 1 23	Day 2 24	Day 3 25	Day 4 26	Day 5 27	28
	Weigh Station Throughput Timing: Findlay, Ohio→Essex, Ontario (Group 2)					Both Teams Leave
29	30					

