



Advantage I-75 Mainline Automated Clearance System

Final Report

Part 3 of 5: Weigh Station Individual Evaluation Report

Prepared for

The Advantage I-75 Evaluation Task Force

Submitted to

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Introduction

This document is the third of five evaluation reports for the Advantage I-75 Mainline Automated Clearance Systems (MACS) on the performance and productivity of weigh stations along the I-75/Highway 401 corridor between Ontario and Florida. The vision of the Advantage I-75 program is to incorporate existing technologies into an ITS operational setting that will provide an initial step in the process of adapting the nation's highway systems to accommodate the increased demands placed on it. A field operational test entitled *Mainline Automated Clearance Systems* (MACS) was designed and implemented for the Advantage I-75 program. The objective of the MACS operational test was to allow transponder-equipped trucks to travel any segment of the entire length of I-75 and Highway 401 at mainline speeds with no more than a single stop at a weigh station.

Project Scope

The purpose of this part of the evaluation is to determine if mainline electronic clearance produces significant travel time savings for motor carriers. The data collection procedure used to make this determination was designed by Iowa State University. The prescribed method was to position recorders at the entrance point of the weigh station, at the static scale, and at the exit point of the weigh station. The recorders, equipped with stop watches, then recorded the time each truck crossed the specific point. Mainline speeds were also recorded. The difference in time between the commercial vehicle in the weigh station, and one on the mainline was the estimated time savings attributable to being electronically screened on the mainline.

Findings

The fundamental hypothesis tested was that reduction or elimination of stops at weigh stations by participant transponder-equipped vehicles will result in travel time savings for that truck. Travel time estimates were measured at 19 sets of weigh stations along the corridor. These 19 sets of 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 time savings were different for each weigh station design type. Travel time savings were most substantial at the static scale design types. At the static scales in Knoxville, Tennessee and Findlay, Ohio, vehicle bypasses provided measurable time savings, on average, of 4.86 minutes, and 2.22 minutes, per station respectively. Part of the time difference is the amount of truck traffic at each facility. Trucks entered the Knoxville, Tennessee weigh station at a rate of 450 trucks per hour, while the rate of arriving vehicles at the stations near Findlay, Ohio was 215 trucks per hour. The travel time

savings between driving on the mainline and driving through the weigh-in-motion stations are smaller. Travel time savings at WIM stations such as those in Monroe, Michigan were estimated at 1.33 minutes per station. The time savings accrued in Charlotte County, Florida, at the high-speed ramp WIM, were 1.92 minutes per station cleared to bypass. The principal conclusion from this experiment is that there are measurable time savings obtained by electronic clearance. The value of these savings, however, depends on the number and nature of the stations being electronically cleared.

PURPOSE OF EVALUATION

The purpose of the weigh station throughput evaluation is to determine the effect of the Advantage I-75 MACS project on travel time for commercial vehicles on the I-75 corridor. Specifically, the difference in time required by commercial vehicles traveling through Advantage I-75 MACS weigh stations and the time required by vehicles that are electronically cleared to bypass the same weigh stations was measured.

EVALUATION DESCRIPTION

The evaluation procedures, as described in the Weigh Station Individual Evaluation Test Plan, submitted to the Task Force on May 10, 1996, is based on the results of the previous evaluation activities and pilot studies. The test is designed to determine the potential time savings attributable to being cleared to pass weigh stations at selected sites along the Advantage I-75/Highway 401 corridor. Comparisons of travel times for vehicles electronically cleared to bypass selected weigh stations on the mainline and for vehicles routinely processed through the same weigh stations were established by collecting explicit vehicle throughput data during multiple time periods. The throughput data consisted of vehicle identification and arrival times collected at three locations within the weigh station for all vehicles entering the station during the prescribed time periods. The three locations were:

- w Point One: Upstream base of the weigh station approach ramp (Point of Entry).
- w Point Two: Static scale or primary monitoring facility at the center of the weigh station.
- w Point Three: Downstream base of the weigh station departure ramp (Point of Exit).

Two research assistants were positioned at each of the three locations and manually recorded the vehicle identification and arrival time for each arriving vehicle during the scheduled observation time period. Data were collected in 66 minute increments at the beginning of the tests. The six additional minutes of data were required to ensure that all measurements were obtained for each vehicle arriving at Point One during the first 60 minutes. On the basis of Pilot Study Two results, six minutes was an adequate time for approximately 99 percent of the arriving vehicles from Point One to Point Three. Later collection sessions gathered the data in two-hour increments. The use of two-hour periods proved to be more helpful for constructing a weigh station simulation program, which was required for other aspects of the evaluation.

The arrival time data at Points One, Two and Three were used to calculate the mean interarrival time and processing time at each of the weigh stations. The mean interarrival time is a measure of how frequently vehicles arrive at a specified point (e.g., Point One). For example, a mean interarrival time of 8.5 seconds at Point One, indicates that, on average, one vehicle is arriving at Point One every 8.5 seconds. Processing time is a measure of the time required for vehicles to be processed from the beginning point of the weigh station (Point One) to the ending point of the weigh station (Point Three). Travel time savings were established by subtracting the mainline travel time from Point One to Point

Three at observed highway speeds from the weigh station processing time. The results of the evaluation are presented in a tabular listing of the typical travel time savings at each of the selected Advantage I-75 weigh stations. The nature and extent of vehicle inspections were determined by recording vehicle processing data for each vehicle arriving at the static scale or central processing point (e.g. Point Two) during the scheduled time periods. The data recorded are an identifier code used to designate pre-defined inspection scenarios and processing time. On the basis of the results of Pilot Study Two, the following three inspection scenarios were used for this test:

- w Stop at Scale: Routine processing, in which the vehicle is immediately released to the mainline after the weight and credentials have been examined.
- w Level One: Brief inspection, in which the vehicle is first directed to park on the scale (not pulled out of queue) for a brief credential check and then released to the mainline.
- w Level Two: Detailed inspection, in which a vehicle is pulled out of queue and directed to park at a designated inspection and parking area for further inspection or credential check.

The data were recorded simultaneously with the identification and arrival time information by the research assistants stationed at Point Two.

For each selected test site, the inspection information is presented in a tabular format providing the number of vehicles entering the weigh station, the number of vehicles that stopped at the scale, and the number of Level One and Level Two inspections that occurred during the scheduled collection periods.

As the design of some of the weigh stations is such that not all the stations require that the vehicles entering the stations arrive at the static scale, (e.g. Ramp WIM and High-Speed Ramp WIM stations), the collected data are also useful in determining the probabilities of being directed to the static scale (Point Two) at these stations.

Hypothesis Tested

- w "Reduction or elimination of stops at weigh stations by participant transponder-equipped trucks will result in travel time savings for those trucks."

Recap of Test Procedures

This test compared the travel time required for vehicles proceeding through the weigh station to that of vehicles bypassing the station at observed mainline speeds. We then calculated expected travel time savings resulting from electronic clearance at selected Advantage I-75 MACS weigh stations. The data, referred to as throughput processing time data, were collected at scheduled one- and two-hour time periods that coincided with both peak and non-peak traffic conditions. The test output is listed in tabular format stating the mean and standard deviation of travel time savings, and intervals describing the travel time savings for 95% of the truck population for each of the selected test sites.

The evaluation also incorporated a survey of the nature and extent of existing inspection and credential monitoring conditions at selected Advantage I-75 MACS weigh stations. The study documented the number and type of inspection and credential monitoring that occurred during the scheduled time periods. The results of this part of the study are listed in Table 5. The information provided is the number of inspections or credential verifications during the specified time periods.

Statistical Methods Used to Analyze the Data

The statistical methods used were consistent with the various aims of this data collection effort. The first part of the statistical analysis of the data was error checking and editing. The experience from the pilot studies proved accurate; approximately one-to-two percent of the data records contained data entry or recording errors. Some of these errors were easily discovered; for example, a truck recorded as having reached Point Three prior to reaching Point One.

The principal method of analysis was simply to record summaries of the data. To measure time savings the mean amount of time required for a truck to pass through the weigh station (based on a large sample) is reported. A smaller sample of speed measurements is used to assess the time required for trucks that bypass the weigh station to travel a similar distance. The difference between the two means is a measure of travel time savings. The median is an alternative measurement that is not affected by outlying errant values. In addition to reporting the mean savings, a measure of variability (the standard deviation) and an interval that describes the experiences of the middle 95 percent of the population of commercial vehicles (with others excluded as possible errors or evidence of unusual driving) is also reported. In addition, the recorded data will provide information about the frequency and duration of inspections under the current system. This information is most useful for others to assess the possible impact of electronic clearance on credential monitoring and other violations.

A second aim of the data collection was to provide data for building and validating simulation models. The tables described above were essential to that effort, but the simulation requires additional data about the probability distribution of various random phenomena (i.e., the interval between consecutive truck arrivals or the service time for an inspection or static weighing). Standard distributions like the exponential distribution for arrival times (or its generalized version, known as the gamma distribution) and normal distributions for processing times or speeds were also considered. The parameters of these distributions were chosen to match the observed mean and standard deviation of the data.

Evaluation Schedule

The evaluation schedule was contingent upon close coordination with the test participants and test location. The following tables list the contact names, addresses and telephone numbers for the key participants and research locations.

Key participants included the evaluation manager, evaluation coordinators, data collection team, and statistical analysis team. Table 1, provides the key contact, telephone numbers, fax numbers, and role of each key participant.

Table 1: Evaluation 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, IA 50010-8615	(515) 294-9501 (515) 294-0467
Evaluation Coordinators	Mr. Dennis Kroeger	Center for Transportation Research and Education 2625 N. Loop Drive Suite 2100 Ames, IA 50010-8615	(515) 294-7164 (515) 294-0467
Data Collection Team	Mr. Ed Powe	Entrepreneurial Development Institute Kentucky State University 415 Hathaway Hall Frankfort, KY 40601	(502) 227-6172 (502) 227-6763
Statistical Analysis	Dr. Hal Stern	121 Snedecor Hall Iowa State University Ames, IA 50011-1210	(515) 294-5582 (515) 294-4040

Evaluation Locations

Because many weigh stations only operate during certain hours of the day, the evaluation was extremely dependent on close coordination with weigh station personnel. Table 2 provides the key contact names, addresses, telephone and fax numbers for each of the weigh stations included in the test. Every effort was made to contact the weigh station both by telephone and in writing approximately one month prior to commencement of the throughput data collection. The weigh station personnel were cooperative during the test procedures. Also, the data collection team made sure not to disturb the stations' operations while collecting the data.





Table 2: Weigh Station Contacts by Test Location

Test Location	Key Contact	Address	Phone/Fax
Halton, Ontario (Trafalgar North and South)	Mr. John Cowan	Ministry of Transportation 1182 North Shore Blvd. East P.O. Box 5020 Burlington ON, L7R-3Z9	(905) 637-4108 Ext. 252 (905) 637-4114
Middlesex, Ontario (Putnam North and South)	Ms. Kathie Costello	Ministry of Transportation 659 Exeter Road London, ON N6E-1L3	(519) 649-3004 (519) 649-3086
Essex, Ontario (Windsor North and South)	Mr. Duncan Calder	Ministry of Transportation 2740 Dougall Avenue Windsor, ON N8X-1T2	(519) 972-7349 (519) 973-1492
Monroe, MI (Erie East and West)	Lt. Thomas Kenney	Michigan State Police 300 Jones Avenue Monroe, MI 48161	(313) 242-3500 (313) 242-8928
Hancock/Wood, OH	Sgt. Jim Bennett	Ohio Highway Patrol 3201 North Main Avenue Findlay, OH 45840	(419) 423-1414 (419) 423-9179
Kenton, KY	Lt. Jim Sutter	Kentucky Transportation Cabinet Motor Vehicle Enforcement: P.O. Box 109 Walton, KY 41094-0109	(606) 356-1111 (606) 356-0862
Scott, KY (Georgetown)	Lt. William Carter	Kentucky Transportation Cabinet Motor Vehicle Enforcement P.O. Box 760 Georgetown, KY 40324	(502) 863-4559 (502) 863-2124
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 (Forsyth)	Capt. Cliff Tackett	Georgia Dept. of Transportation 276 Memorial Drive Atlanta, GA 30303	(912) 994-1278 (912) 993-3017
Lowndes Co., GA (Valdosta)	Capt. Charles Purvis	Georgia Dept. of Transportation 276 Memorial Drive Atlanta, GA 30303	(912) 244-6863 (912) 245-4331

Charlotte Co., FL (Punta Gorda)	Maj. Bill Mickler	Florida Dept. of Transportation 605 Suwannee Street Mail Station 99 Tallahassee, FL 32399-0450	904-488-7920 904-221-6627
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The data collection schedule was originally designed to be in concert with the fuel consumption tests, and to be completed during the summer of 1996. The schedule was revised due to several factors:





- w At the time of the data collection, the weigh stations at Halton and Middlesex, Ontario, due to staff constraints, were only operating 30 - 40% of the time.
- w At Hancock, Ohio the weigh station building was undergoing renovation during June and July 1996, and was closed for 90 days due to the construction.
- w The crews at the Monroe and Lowndes, Georgia stations were reassigned to Atlanta, Georgia for parts of July and August 1996 to assist with traffic control and security for the 1996 Summer Olympic Games.
- w Following the Olympics, these stations then underwent construction improvements and were

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
Evaluation Preparation	May 96  June 96																																			
Data Collection	June 96  October 96																																			
Data Analysis	October 96  October 97																																			
Report Preparation													November 97  March 98																							

closed for periods of time during the fall. The data collection was delayed until December 1996.

Figure 1: Original Data Collection Schedule

The data collection was originally scheduled to begin in mid-May 1996 and to have been completed

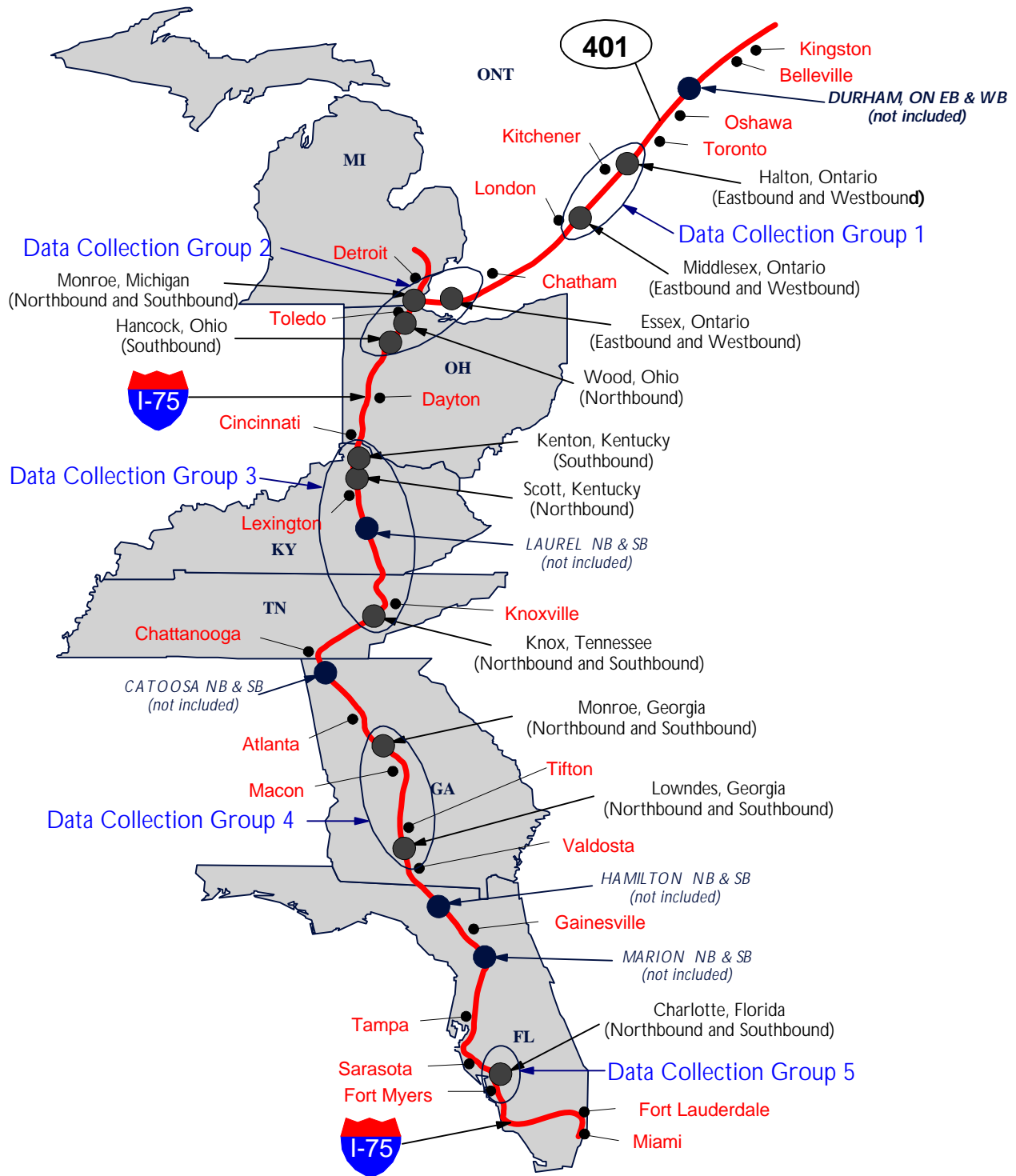
Task Name	1996												1997												1998											
	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12
Evaluation Preparation	May 96  June 96																																			
Data Collection	June 96  December 96																							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

within four months. The data collection was delayed, but was completed by mid-December 1996. Figure 2 shows the revised data collection schedule.

Figure 2: Actual Data Collection Schedule

An overview of the data collection schedule:

w Test Preparation: May - June 1996
w Data Collection: June - December 1996



- w Data Analysis: October 1996 - October 1997
- w Final Report Preparation: November 1997 - March 1998

Figure 3: Data Collection Locations

As Figure 3 indicates, the data collection locations were grouped geographically into Data Collection Groups One through Five beginning with Data Collection Group One in Ontario, moving South to



Group Two stations in Michigan and Ohio. Data Collection Group Three contained the stations in Kentucky and Tennessee. Data Collection Group Four included the stations in Georgia, and Data Collection Group Five included the stations in Florida.

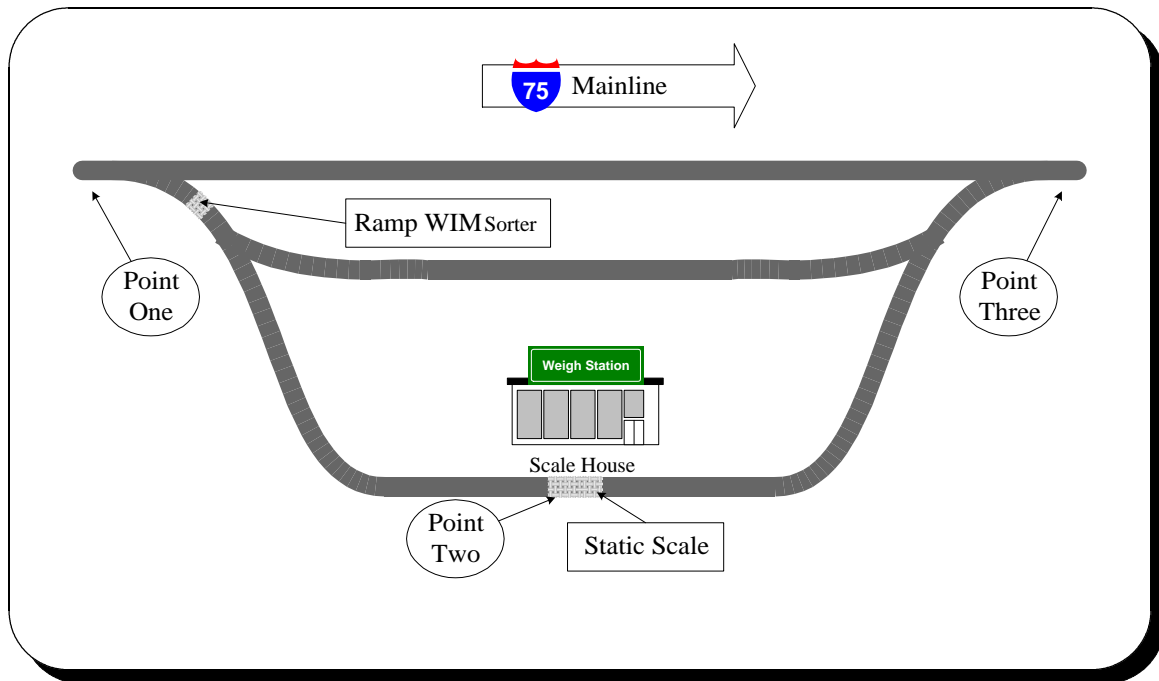
Figure 4: Weigh Station Queue at Findlay, Ohio

Figure 4 above, shows the arrival of trucks at the weigh station near Findlay, Ohio. The picture clearly illustrates the queue of trucks extending to the mainline highway.

The following table lists the weigh stations for which data were collected, and an indication of their peak hours of operations.

Table 3: Weigh Station Design Description

Station Name	Design Type	Peak Hours	Peak Queue Conditions
Halton, ON	Ramp WIM	7:00–9:00 AM East 9:00–11:00 AM & 3:00–5:00 PM West	Frequently full queues resulting in manual closing as frequently as 6 times/hour during peak periods.
Middlesex, ON	Ramp WIM	7:00AM–3:00PM East 7:00–9:00 AM & 1:00–3:00 PM West	Frequently full queues resulting in automatic station closing as frequently as 3 times/hour during peak periods.
Essex, ON	Ramp WIM: East Static Scale: West	7:00AM–3:00PM East 7:00–10:00AM West	Frequently full queues resulting in automatic station closing as frequently as 6 times/hour during peak periods.
Monroe, MI	Ramp WIM	6:00–9:00 AM North 3:00–6:00 PM South	Frequently 2,000 ft queues during peak hours. No station closings.



Wood, OH	Static Scale	5:00–9:00 AM & 2:00–7:00 PM	Queue overflows onto mainline 5- times per hour during peaks. Manual station closing when notified by CB radio.
Hancock, OH	Static Scale	6:00–9:00 AM & 3:00–6:00 PM	Queue overflows onto mainline 7- times per hour during peaks. Queue monitored by TV camera. Manual station closing when queu fills.
Kenton, KY (southbound only)	Ramp WIM	9:00–11:00 AM	Rarely full queues. No station closings.
Scott, KY (northbound only)	Ramp WIM	6:00–9:00 AM & 3:00–6:00 PM	Rarely full queues. Automatic station closing when queue fills.
Knox, TN	Static Scale	6:00 AM–5:00 PM	Consistently full queues. Vehicle instructed to bypass when full. No station closings.
Monroe, GA	Ramp WIM	11:00 AM–4:00 PM	Seldom full queues. Manual stati closing when full.
Lowndes, GA	Ramp WIM	7:00-11:00 PM South 9:00 AM-4:00 PM North	Seldom full queues. Manual stati closing when full.
Charlotte, FL	High-Speed Ramp WIM	10:00 AM–5:00 PM	No full queues. No station closings.

Recap of Evaluation Procedures

A detailed description follows of the scenarios and procedures for the weigh station throughput evaluation.

Scenarios

While it is important to evaluate the effect of electronic clearance on weigh station performance, the task is complicated by the fact that the traffic conditions at every station are affected by a number of unique factors such as topography and traffic patterns. Additional complications include seasonal variation in traffic volume, special events traffic such as sporting events and conventions, and continuous road construction. With the enormous number of possible scenarios, a comprehensive design that would include data describing every possible traffic condition does not seem possible. Instead we opted to survey the stations during the summer months (when it was easiest to recruit data collection members and stay within the proposed evaluation time frame) at both peak and non-peak travel times. Our aim was to provide information representative of the range of behavior seen at each station. Information about other scenarios (e.g., winter travel) can be obtained by simulation or extrapolation from the results obtained here.

Figure 5: Weigh Station Data Collection Points

Throughput Data Collection Procedures



The procedures used for recording vehicle arrival time and unique vehicle identification information at each of the three data collection points shown in Figure 5 were identical for each selected collection site. (These are the procedures, as described in the Detailed Evaluation Plan, submitted on May 10, 1996).

w Point One: Point One was staffed by three individuals: one arrival observer, one arrival recorder, and one bypass observer/recorder. Prior to the start of the first scheduled one-hour data collection session, the data collection team leader locates and permanently marks the observation point (using a 1"×2"×18" pointed stake or fluorescent paint) at the location shown on the detailed weigh station site plan. (Site plans for each of the selected test sites are provided in Appendix Three.) The distance from Point One to Point Two was then measured using a surveyor's wheel and recorded on the site plan and in the right header of the first hour's Vehicle Arrival/Departure Identification Form. Just prior to the start of each scheduled session, the arrival recorder enters the information, such as site identification and weather information, in the header of page one of the Vehicle Arrival/Departure Identification Form.

As the session began, the arrival observer called out the unique truck identification (first four digits of the prorated plate and arrival time (MM:SS)) to the recorder. For example, suppose that two closely spaced (say 100 feet apart) trucks arrive at Point One shortly after the session began. Now further suppose that the first truck, with prorated plate PR-4564, arrived at Point One at 2 minutes 14 seconds past the hour, and the second truck, with prorated plate RC-8742 arrived at Point One at 2 minutes 26 seconds past the hour. The arrival observer would announce the first truck as "**PR45—02:14**" and the second truck as "**RC87—02:26.**" The arrival recorder would record the first truck on the 2-minute line (i.e., third line from the top) on page one of the Truck Arrival/Departure Identification Form by noting PR45 on the ID line (gray-shaded) and 14 on the Sec. line (not shaded). The second truck would be recorded in the box immediately to the right of the first truck by noting RC87 on the ID line (gray shaded) and 26 on

the time line (not shaded). Figure Six illustrates the above sample entries in an abbreviated version of the Vehicle Arrival/Departure Identification Form. Complete forms are included in the Appendix of the final report.

Figure 6: Abbreviated Vehicle Arrival/Departure Identification Form

Minute	Vehicle Identification and Arrival Time (Seconds)								
0	ID.								
	Sec.								
1	ID.								
	Sec.								
2	ID.	PR45	RC87						
	Sec.	14	26						
3	ID.								
	Sec.								

Using this system, the team can note the ID and arrival time of up to 10 trucks in any one-minute period.

On the basis of the results of Pilot Study Two, secondary vehicle identification procedures were established for those instances when the vehicle's prorate plate is not immediately conspicuous. Conditions encountered during this study indicated that the view of prorate plate is obstructed on approximately 10 percent of vehicles entering the weigh station because the plate is attached to the lower portion of the truck's front bumper on a pivoting bracket which is blown back, covered by an Oversize Vehicle sign, or otherwise not immediately visible. To ensure uniform identification of these vehicles at each of the data collection points, the following order of vehicle identification priority was established:

1. Vehicle prorate plate/identification tag (e.g., first four digits)
2. Vehicle cab color (e.g., blue, green, white, and etc.)
3. Vehicle make (e.g., Navistar, Ford, Kenworth, Peterbilt, and etc.)

We used this procedure to identify vehicles in order to reduce the possibility of erroneous or duplicate vehicle descriptions simultaneously residing in the throughput data set.

The bypass observer/recorder was located in the vicinity of Point One where the bypassing truck traffic can be safely observed. On the basis of the results of Pilot Study Two, the best location for this individual was approximately 200 feet downstream from Point One approximately 10 feet off the road shoulder. Just prior to the start of each session, this individual records the appropriate information in the header of the Truck Bypass Form (see page A-5). As the session commenced, this individual observed and recorded each commercial vehicle bypass event attributable to a queue overflow condition. As each bypass event occurred, this individual placed a dot on the appropriate minute line of the form using a ten-dot tally system. For example, if four vehicle bypasses were observed during minute six of the session, this individual placed four dots on line six of the form.

w Point Two Point Two was staffed by one or two individuals depending on the arrival rates and the arrival speed at the static scale. Generally the arrival speed at these sites was slow enough that one individual could both identify and record the required information.

Prior to the start of the first scheduled one-hour data collection session, the data collection team leader located and permanently marked Point 2 (using a 1"×2"×18" pointed stake or fluorescent paint) at the location shown on the detailed weigh station site plan). (Site plans for each of the selected test sites are provided in Appendix Three.) The distance from Point Two to Point Three was measured using a surveyor's wheel and recorded on the site plan and in the header of the first hour's Vehicle Arrival/Departure Identification Form.

Just subsequent to the start of each scheduled session, the individual assigned to this point enters the information, such as site identification and weather information, in the header of page one of the Arrival/Departure Identification Form.

Figure 7: Recording Data at Static Scale

The individual recorded the unique vehicle identification, arrival time (using the method described for Point One), as each truck arrived at the weigh station's static scale. The processing scenario is observed and recorded based on the key described below in Table 4.

Table 4: Recording Vehicle Processing Scenarios

Processing Scenario	Notation
Stop at scale: Static weigh and exit	None
Level One: Static weigh, credential check (while stopped on scale platform), and exit	Δ
Level Two: Static weigh, inspection, credential check, and exit	+

For example, if a truck is weighed on the static scale and released to return to the mainline, no additional notations are recorded. Suppose, however, that a truck with prorate plate CY-4911 arrived at the static scale at 15:23 past the hour and was stopped on the static scale by an enforcement officer, who walked out of the scale house and asked to see the driver's logbook. Upon examining the driver's logbook, the enforcement officer then released the truck to return to the mainline. This event is then recorded by noting "CY49" on the gray shaded ID line of the 15-minute segment line of page one of the Truck Arrival/Departure Form (i.e., 16 lines from the top), and noting "23D" (the symbol Δ is noted for this processing scenario) on the time line (not shaded). If the truck had been instructed to park and bring the credentials into the weigh station and/or the vehicle was parked for inspection, the

time line portion of the event would be noted as “23+” (the symbol + is used to denote trucks that are static weighed, credential checked, and inspected prior to being released to the mainline).

It should be noted that not all vehicles arriving at Point One will be observed at Point Two for those weigh stations designated as Ramp WIM or High-Speed Ramp WIM design types. Pilot Study Two revealed that the majority of vehicles (77–99 percent of the total vehicles) that enter these weigh stations are immediately directed back to the mainline on a static scale bypass lane. The observer(s) at Point Two at these stations were instructed to only note the vehicle arrival, identification, and processing scenario data for those vehicles that are directed to the static scale.

The process is repeated using pages one, two, and three of the form until the session ends at six minutes past the following hour.

- w Point Three:** As Figure Five illustrates, Point Three corresponds to the point where vehicles exit the weigh station and return to the mainline. However, the term “Vehicle Arrival” is still used at this point to maintain consistency in data terminology. This point is staffed by two individuals, one arrival observer and one arrival recorder. Prior to the start of the first scheduled one-hour session, the data collection team leader located and permanently marked the observation point (using a 1"×2"×18" pointed stake or fluorescent paint) at the location shown on the detailed weigh station site plan.

Just prior to the start of each scheduled session, the arrival recorder entered information, such as site identification and weather information, in the header of page one of the Vehicle Arrival/Departure Identification Form.

As each truck arrived, these individuals noted and recorded the unique vehicle identification and arrival time using the method previously described for Point One. This process continued for each arriving vehicle until completion of the session at six minutes past the following hour.

DATA REDUCTION AND ANALYSIS

Hypothesis and Expected Results

To evaluate the hypothesis that trucks being electronically cleared to bypass weigh stations save time, we measured time savings using the test procedures described earlier in this document. Our goal was to provide a measure of expected savings (time in seconds per weigh station bypassed) for different weigh station designs. One can formally test the hypothesis of no savings, but this is not of much interest here. Instead we focused on providing a valid estimate along with estimates of the possible variation due to a variety of uncontrolled factors.

Input Data

Data recorded for each truck observed included identification information, time at which the truck reached Point One (entry point), time at which the truck reached Point Two (static scale) if it did so, time at which the truck reached Point Three (exit point), and inspection information. Relatively few trucks were submitted to inspections that required extended time delays, so those trucks were omitted from analysis. Only trucks that submitted to a static weigh and/or credential check are described in Table 11. The information was entered into a computer database for further study.

METHODS

Data Editing

Real-time data collection efforts of this type are prone to a number of types of data errors. Errors may occur when recording data in the field (not appropriately identifying a truck, times recorded in the wrong line of the entry form, a truck being sent for an inspection but not reported as such, etc.), or when entering the data into the computer database. We ran some consistency checks to ensure, for example, that trucks arrived at Point One earlier than they arrived at Point Two and that trucks arrived at Point Two earlier than they arrived at Point Three. We also looked for instances in which one truck apparently passed a second when that is not possible (in a standard static scale setup for example.) Incorrect data records were corrected after examining the original forms. Even after editing, several unusual observations remain, e.g., trucks requiring 20 or 30 minutes to traverse a station with no evidence of an inspection or credential check, or trucks requiring fewer than 30 seconds to traverse a station, implying incredible speeds. Truck records with travel times below thirty seconds or above 900 seconds (15 minutes) were assumed to be in error and deleted from further analysis

Data Analysis

The analysis approach that we took used simple descriptive statistics to summarize the experience of the commercial vehicle operations. At each station we report:

N = the number of trucks observed arriving and departing the station inspection (after deleting the number of unusual observations);

Mean = the mean time required to travel from Point One to Point Three;

Std. Dev. = the standard deviation of the travel times from Point One to Point Three;

Median = the median travel time from Point One to Point Three (recall the median is the value such that 50% of the trucks had shorter travel times and 50% of the trucks had longer travel times);

(2.5%, 97.5%) = interval describing travel times for the middle 95% of truck traffic (the fastest 2.5% of the trucks and the slowest 2.5% of the trucks are excluded).

All times are given in seconds.

The standard error of the mean is given in some tables. This quantity is computed as the standard deviation divided by the square root of the sample size (n). It is a measure of how accurately the sample mean here reflects the mean that would be observed over the course of a longer time period. This formula for the standard error assumes that the data are independent observations. Although this assumption is not valid because the experience of one truck certainly depends upon other (especially earlier arriving trucks) trucks, the standard errors still do provide some measure of variability. In addition we have computed for some tables the travel speeds that would be required for a truck traveling on the mainline to cover the distance from Point 1 to Point 3. Estimated time savings are the difference between the mean processing time for trucks that enter the station and the mainline travel time.

Some discussion about the measures used here is necessary. It is common to summarize data of this type by the mean and standard deviation. There are, however, several features of these measures that suggest the mean and standard deviation are of limited benefit here. First, as mentioned earlier, the data include outliers. The worst of these have been eliminated but it is likely that others remain. Second, the usual justification for summarizing data by the mean and standard deviation is that data often follow a bell-shaped symmetric (or normal) distribution. In this case the data do not appear to be symmetric since it is easy to obtain processing times much in excess of the mean but there is a limit on how fast a truck will be processed (approximately 30 seconds). For these two reasons we have included as alternatives the median and a 95% interval. The median is comparable to the mean. In these cases the median is generally lower than the mean because the mean is inflated by the few long processing times. It should be emphasized, however, that the mean and median are two different measures neither is

incorrect and both are useful. The mean is useful because multiplying the mean by a number of trips will yield a realistic estimate of total processing time (this is the definition of the mean). The median is useful because it probably better represents the typical trip than the mean does. The 95% interval is just an empirical observation of the processing times of the middle 95% of trucks processed through the weigh station. It should be pointed out that this is not a confidence interval as it does not represent an estimate of the mean of some population.

RESULTS

The results of the evaluation are organized under three headings: Processing Times, Estimated Travel Time Savings, and Inspection Scenarios. Following the discussion of the evaluation results are the general conclusions of the evaluation.

Processing Times

The weigh station processing times are reported separately for weigh stations with different designs. For each station, the total number of trucks recorded (generally over six hours of observation) is given along with the numerical summaries of the distribution time of the elapsed time required to travel through the station. Specific summaries provided are the mean and median processing time, the standard deviation of the processing times, the standard error of the mean (a measure of accuracy associated with the mean), and the 2.5% and 97.5% point of the distribution of processing times. The last two quantities, viewed as an interval, describe the processing times experiences by the 95% of truck traffic through the weigh stations.

As described earlier, trucks with unusually large travel times (more than 900 seconds or 15 minutes) or unusually small travel times (less than 30 seconds) are omitted from analysis. In addition, the results provided do not include those trucks that were required to submit to an inspection (either Level 1 or Level 2) because the time required for an inspection is unpredictable. The number of inspections is relatively small so that we do not have enough inspections to draw reliable conclusions about the time required to perform an inspection.

There are considerable differences in the processing times at the various weigh stations. Naturally, static scales require more time than WIM scales. There is also variability due to a number of other conditions including the length of weigh station, topography of the station, and the vehicle arrival times.

Table 5 provides the results for four weigh stations with static scales. At these scales all trucks entering the weigh station are expected to stop at Point Two; data for a handful of trucks for which no Point Two arrival times was recorded are excluded from analysis. The Knoxville, Tennessee station stands out with a mean travel time of nearly five minutes; the typical travel times range from three minutes to seven minutes.

**Table 5: Processing Times
Static Scales (Trucks Stop at Point 2)**

Station	N	Mean	Std. Dev.	Median Point	SE Mean	2.5%	97.5%
Wood OH NB	1,246	136.8	39.4	133	1.12	79	216
Hancock OH SB	1,309	127.4	34	124	0.94	78	201
Knox TN NB	454	296.2	63	296	2.96	193	423

Knox TN SB	454	285.5	62.2	282	2.92	170	422
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Tables 6 and 6A provide the results for seven weigh stations that are equipped with WIM scales and for which relatively few trucks were observed to stop at the static scale. Table 6 provides the results for all trucks at these stations and those that bypass the static scale whereas Table 6A excludes the trucks that stopped at the static scale. The results are similar because the number of trucks stopping at the static scale is small here, generally fewer than 60. As might be expected the means increase when the number of trucks that stop at the static scale are included, because their processing times are larger than for the trucks that bypass. The mean and standard deviation can be quite sensitive to inclusion of these static-scale stops. The median is much less sensitive. We view the results of Table 6A as being more representative for these stations because of the small number of static scale observations.

**Table 6: Ramp WIM Station with FEW Stops
at Static Scale (Point 2)**

All Trucks (Including stops at scale)

Station	N	Mean	Std. Dev.	Median Point	SE Mean	2.5%	97.5%
Monroe GA SB	1,377	103.9	40.9	95	1.11	71	194
Kenton KY SB	1,243	150.4	23.9	147	0.68	112	205
Lowndes GA NB	851	81.5	34.1	73	1.17	59	191
Lowndes GA SB	795	81	36.4	70	1.29	56	216
Monroe MI NB	1,960	77.9	9.6	77	0.22	64	103
Monroe MI SB	1,892	80.6	45.8	73	1.03	61	140
Scott KY NB	1,324	97.1	34.6	93	0.96	64	139

**Table 6A: Ramp WIM Scales with Trucks NOT Stopping
at Static Scales (Point 2)**

Station	N	Mean	Std. Dev.	Median Point	SE Mean	2.5%	97.5%
Monroe GA SB	1,341	100.1	30	94	0.82	70	150
Kenton KY SB	1,210	149.9	23.6	147	0.68	111	203
Lowndes GA NB	816	77	18.4	72	0.64	59	135
Lowndes GA SB	737	72.6	17.2	69	0.63	56	125
Monroe MI NB	1,960	77.9	9.6	77	0.22	64	103
Monroe MI SB	1,861	75.6	18.8	73	0.44	61	111
Scott KY NB	1,285	95.3	21.4	93	0.59	63	136

Tables 7, 7A, and 7B provide results for eight weigh stations that are equipped with WIM scales for which a significant portion of the population was observed to stop at the static scale. It is noteworthy that Essex, Ontario (Westbound) is included in this last group even though it is identified as a static scale rather than a WIM scale. The reason for this is that the data collection effort observed a substantial number of vehicles that traveled through the station without stopping at the static scales (115 vehicles representing 15% of the traffic).

For these eight stations, Table 7 includes the results for all trucks. Table 7A includes only the trucks allowed to bypass the static scale, and Table 7B includes only the trucks stopped at the static scale. As one would expect the trucks required to stop at the static scale have longer processing times than those allowed to bypass the scale. On average it appears to add one or two minutes per station at the static scale.

**Table 7: Ramp WIM Scales With Significant Stops at Static Scale (Point 2)
(All Trucks)**

Station	N	Mean	Std. Dev.	Median Point	SE Mean	2.5%	97.5%
Charlotte FL NB	786	94.8	40	79	1.43	64	197
Charlotte FL SB	791	128.5	68.3	109	2.43	60	271
Essex ON EB	1,054	148.7	56.7	137	1.75	80	280
Essex ON WB	786	147.7	70.3	137	2.51	56	295
Halton ON EB	553	163.9	119.8	126	5.09	54	528
Halton ON WB	841	141.5	108.8	85	3.75	54	457
Middlesex ON EB	1,890	114.7	40	107	0.92	80	207
Middlesex ON WB	1,725	117.2	41.7	109	1.01	82	199

Table 7A: Ramp WIM Scales with Trucks NOT Stopping at Static Scale (Point 2)

Station	N	Mean	Std. Dev.	Median Point	SE Mean	2.5%	97.5%
Charlotte FL NB	631	77.9	12.9	76	0.51	63	106
Charlotte FL SB	647	114.1	55.5	77	2.18	59	205
Essex ON EB	89	101.1	33.1	97	3.51	62	195
Essex ON WB	115	101.7	51.5	86	0.21	34	222
Halton ON EB	332	103.4	70.2	79	3.85	50	275

Halton ON WB	531	83	49.9	72	2.17	51	268
Middlesex ON EB	1,684	106.4	20.7	104	0.51	80	140
Middlesex ON WB	1,557	111.9	35.8	108	0.91	82	156

**Table 7B: Ramp WIM Scales of Trucks
Stopping at Static Scale (Point 2)**

Station	N	Mean	Std. Dev.	Median Point	SE Mean	2.5%	97.5%
Charlotte FL NB	155	163.6	39	157	3.13	117	290
Charlotte FL SB	144	193.3	81.7	161	6.81	111	454
Essex ON EB	965	153.1	56.4	142	1.82	88	286
Essex ON WB	671	155.6	70.1	145	2.71	68	327
Halton ON EB	221	254.9	121.5	227	8.17	95	586
Halton ON WB	310	241.6	109.5	222	6.22	101	523
Middlesex ON EB	206	182.7	77.5	168	5.4	116	394
Middlesex ON WB	168	166.1	57.6	158	4.44	107	518

Estimated Travel Time Savings

Tables 8, 9, and 10 provide a comparison of the observed processing times with an estimate of the time required for trucks that bypass the given station on the mainline highway. The mainline travel time is computed based on the average speed observed for trucks on the mainline in the vicinity of the weigh station. Average time savings per trip ranges from 1.5 - 5 minutes for static scales. For ramp WIM stations the average savings for a truck remaining on the mainline is 30 - 90 seconds against a truck on the WIM-bypass lane, and about 2 - 4 minutes against a truck which is directed to the static scale from a ramp WIM sorter.

There is quite a bit of variability in each case due to the different designs and traffic patterns at each station. In Table Eight it can be seen that among the static scales, the stations in Hancock and Wood Counties in Ohio require less time than the Knoxville, Tennessee station. Tables Nine and Ten show that among the ramp WIM stations, Monroe, Michigan, Lowndes County, Georgia, and Charlotte County, Florida tend to allow the fastest travel times. The station in Halton, Ontario generally requires more time.

**Table 8: Estimated Travel Time Savings Attributable to Electronic Clearance
at Static Scale Type Weigh Stations**

Station	N	Mean Processing Time (Sec.)	Std. Dev (Sec.)	Mainline Travel Time (Sec.)¹	Estimated Time Savings (Sec.)
Wood OH NB	1,246	137.5	44.68	31.82	105.7
Hancock OH SB	1,312	128.04	39.45	31.86	96.18
Knox TN NB	454	295.68	70.15	37.76	257.92
Knox TN SB	457	287.09	75.38	37.76	249.33
Essex, ON WB	794	150.17	81.59	15.92	134.25

¹ Ohio speed limits for commercial vehicles is 55 mph (88 kph). Other states are 65 mph (105 kph).

**Table 9: Estimated Travel Time Savings Attributable to Electronic Clearance
at Ramp WIM Type Weigh Stations**

Station	N	Mean Processing Time (Sec.)	Std. Dev. (Sec.)	Mainline Travel Time (Sec.)¹	Estimated Time Savings (Sec.)
Halton ON EB	567	173.93	142.47	31.92	142.01
Halton ON WB	845	150.84	158.31	30.99	119.85
Middlesex ON EB	1,895	116.13	56.79	50.35	65.78
Middlesex ON WB	1,734	118.63	48.43	47.68	70.95
Essex ON EB	1,055	149.27	58.43	31.37	117.9
Monroe MI NB	1,990	78.33	30.24	42.01	36.32
Monroe MI SB	1,892	81.35	48.72	30.99	50.36
Scott KY NB	1,351	96.53	43.93	26.93	69.6
Kenton KY SB	992	162.06	160.17	51.48	110.58
Monroe GA SB	1,392	104.32	51.5	32.89	71.43
Lowndes GA NB	873	85.48	63.5	33.18	52.3
Lowndes GA SB	814	88.73	83.04	33.18	55.55

¹ Michigan speed limit for commercial vehicles is 55 mph. Other states' limits are 65 mph.

Table 10: Estimated Travel Time Savings Attributable to Electronic Clearance at High Speed Ramp WIM Type Weigh Stations

Station	N	Mean Processing Time (Sec.)	Std. Dev. (Sec.)	Mainline Travel Time (Sec.)	Estimated Time Savings (Sec.)
Charlotte FL NB	800	97.59	49.06	47.94	49.65
Charlotte FL SB	799	132.85	82.55	47.98	84.87

Processing Scenarios

As described earlier, part of the data collected for each truck was a record of the type of processing it received. For each truck we record whether it stopped at the static scale, whether it received a Level One inspection, and whether it received a Level Two inspection. For the purposes of this report, and to be consistent with the individual test plan, Level One inspections are walk-around inspections. The Level Two inspections are full vehicle inspections. The data are recorded in Table 11 as vehicle counts and in Table 12 as percentages.

Table 11: Weigh Station Processing Scenarios

Location	N - Number of Trucks Through W.S.	Stop at Scale- Number (%)	Level One Inspections Number (%)	Level Two Inspections- Number (%)
<i>Group One</i>				
Halton, ON EB	609	260	18	0
Halton, ON WB	909	384	4	8
Middlesex, ON EB	1,954	236	3	4
Middlesex, ON WB	1,793	202	6	6
<i>Group Two</i>				
Essex, ON EB	1,075	984	2	5
Essex, ON WB	813	693	4	2
Monroe, MI NB	1,997	5	3	4
Monroe, MI SB	1,904	34	1	3
Wood, OH NB	1,263	1,242	1	10
Hancock, OH SB	1,318	1,313	1	4
<i>Group Three</i>				
Kenton, KY SB	1,332	41	8	6
Scott, KY NB	1,361	44	1	2
Knoxville, TN NB	472	454	6	6
Knoxville, TN SB	461	456	0	0
<i>Group Four</i>				
Monroe, GA SB	1,410	32	0	11
Lowndes, GA NB	884	34	0	15
Lowndes, GA SB	821	58	5	13
<i>Group Five</i>				
Charlotte, FL NB	812	146	12	1
Charlotte, FL SB	815	144	9	2

Table 12: Percentage of Credential Checks and Vehicle Inspections at Weigh Stations on I75 Corridor

Weigh Station	% Stop at Scale	% Credential Check	% Inspection
<i>Group One</i>			
Halton ON EB	42.69	2.96	0
Halton ON WB	42.2	0.44	0.89
Middlesex ON EB	12.08	0.15	0.2
Middlesex ON WB	11.27	0.33	0.33
<i>Group Two</i>			
Essex ON EB	91.53	0.19	0.47
Essex ON WB	85.24	0.49	0.25
Monroe MI NB	0.25	0.15	0.2
Monroe MI SB	1.79	0.05	0.16
Wood OH NB	98.33	0.08	0.79
<i>Group Three</i>			
Kenton KY SB	3.01	0.6	0.45
Scott KY NB	3.23	0.07	0.15
Knox TN NB	96.16	1.27	1.27
Knox TN SB	98.48	0	0
<i>Group Four</i>			
Monroe GA SB	2.27	0	1.06
Lowndes GA NB	3.85	0	1.69
Lowndes GA SB	7.06	0.61	1.58
<i>Group Five</i>			
Charlotte FL NB	17.98	1.48	0.12
Charlotte FL SB	17.67	1.1	0.25

The data were collected during the summer of 1996 and reflect vehicle inspections and credential checks based on zero percent transponder usage (transponders were only available on a limited basis at that time). Note that the observed counts or percentages may reflect variations in enforcement strategies or truck populations. Here we briefly describe the processes that seem to be followed at the different stations. At the static scale stations, enforcement officials screen the vehicles as they approach the scales. The officer can then direct the vehicle to the inspection area if an inspection is required. At those sites with Ramp Weigh-In-Motion capabilities, the ramp WIM is set at a certain threshold, 72,000 lb. for example. At that point, vehicles that exceed 72,000 lb. are directed to the static scale to be weighed, and given a cursory examination. The fact that the vehicle is directed to the static scale

does not mean that the vehicle will automatically be inspected . It only means that a static weight of the vehicles is required. A visual check of the vehicle is performed while it is being weighed. An inspection is possible, if vehicle defects are found during the cursory examination. Because the observed counts or percentages are merely a "snapshot" of station behavior at a particular point in time, they should be viewed for informational purposes only rather than as a formal evaluation of any specific hypothesis.

CONCLUSIONS

On the basis of our survey findings, numerous factors affect the measurement of travel time savings attributable to electronic clearance of commercial vehicles at weigh stations. The nature and amount of traffic, for example, around each weigh station plays a role in the amount of travel time saved (or expended) at each weigh station. For example, it will take vehicles longer to travel through weigh stations equipped with only static scales and no bypass lanes, than through those stations equipped with Ramp Weigh-in-Motion (WIM) scales and bypass lanes to sort compliant vehicles. There is little doubt that mainline electronic clearance of commercial vehicle can play a major role in increasing the productivity of the weigh station, as well as the motor carriers.

To illustrate, suppose a transponder-equipped truck was driven from Detroit, Michigan to Naples, Florida. If that truck were cleared to pass each of the southbound weigh stations, a total of 12 minutes, on average, could be saved by electronic clearance of that vehicle. This is valuable time that can be used by the carrier to make deliveries, and the weigh station personnel can focus their resources on other vehicles that were screened on the mainline.

Summarizing the information from this evaluation is difficult because the time savings that accrue to a particular company or vehicle depend on the number and type of weigh stations encountered. A commercial vehicle that frequently passes the weigh station near Knoxville, Tennessee can save up to five minutes per trip through electronic clearance. A couple of useful summaries are that a vehicle can save approximately 1.5 - 5 minutes for every static scale weigh station by using electronic clearance. Furthermore, approximately 0.5 - 1.5 minutes can be saved for every ramp WIM weigh station that a truck is electronically cleared to pass. An alternative summary can be obtained by considering a single trip over the length of the corridor (approximately 3,200 miles) and evaluating the total time saved. When this is done it appears that a truck can save 0.5 seconds for every mile traveled. A heavily used truck that travels 12,000 miles per month (144,000 miles per year) can save nearly two hours per month (100 minutes) by using electronic clearance. An extra two hours of truck time per month is worth approximately \$96.00 per truck per month (assuming 50 miles per hour and \$1.20 cost per mile. This does not include the fuel savings which are described in a separate evaluation). The evaluation suggests that electronic clearance offers significant benefits for both the motor carriers (time savings) and state officials (more efficient enforcement). While there is no "cookbook" answer for how much time will be saved or how much more efficient enforcement might become, this report takes the first step in determining systematically and comprehensively what the costs and benefits are. Therefore, this report states that there are measurable time savings attributable to electronic clearance of commercial vehicles at weigh stations. States and motor carrier officials can then use this information as part of their decision making process in determining how best to utilize electronic clearance at weigh stations.

APPENDIX