USDOT Region V Regional University Transportation Center Final Report

TECHNICAL SUMMARY

NEXTRANS Project No. 172OSU2.2

DOCUMENTING AND DETERMINING DISTRIBUTIONS, TRENDS, AND RELATIONS IN TRUCK TIMES AT INTERNATIONAL BORDER CROSSING FACILITIES

by

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Documenting and Determining Distributions, Trends, and Relations in Truck Times at International Border Crossing Facilities

Introduction

Documenting the times trucks incur when crossing an international border facility is valuable both to the private freight industry and to gateway facility operators and planners.
Members of the project team previously developed and implemented an approach to document truck activity times associated with crossing an international border by using technologies that are already in use by truck fleets. The approach relies on on-board GPS-enabled data units, virtual perimeters called geo-fences that surround areas of interest, and a mechanism for data transmission. The project team has been teaming with a major freight hauler whose trucks regularly traverse two of the busiest North American freight border crossings – the privately owned Ambassador Bridge, connecting Detroit, MI, and Windsor, ON, and the publicly owned Blue Water Bridge, connecting Port Huron, MI, and Sarnia, ON– to determine times associated with the multiple activities associated with using the facilities at these border crossing sites.

In the study reported here, additional geofence data were collected, new processing codes were written and implemented, new geofences were implemented to respond to changes in physical infrastructure at the border crossings, and data were processed into queuing and inspection times and summarized in tables and figures that would be useful for quarterly reports of important statistics.

Findings

The new processing codes produced results that were similar and almost identical to results that had been produced with previous codes. The new codes were successfully used to produce new queuing and inspection time information in forms that would be useful for regular, quarterly updates. Some difficulties with newly implemented geofences were discovered and corrected. Corrections were derived that could be applied to Michigan-to-Ontario data collected at the Blue Water Bridge facilities as a result of changes in the locations of inspection facilities.

Recommendations

A wealth of data has been collected over the years on times trucks incur in inspection and when queuing before inspection in both directions at the Ambassador Bridge and Blue Water Bridge border crossing facilities, two of the busiest and most highly valued land border crossings in North America. The geofence approach has proven advantageous in that it takes advantage of hardware and communication systems already in use on many truck fleets and requires no additional roadside infrastructure. As a result, it was equally easy to collect data at the privately owned and operation Ambassador Bridge facilities as it was to collect data at the publicly owned and operated Blue Water Bridge facilities. The data appear to be unprecedented in the detail and length of time during which the data were collected. As such, the data can be used to indicate trends and to investigate behavioral relations. The tables and figures presented in this report illustrate the types of quantitative, systematic reporting that could be produced. However, data collection efforts were made possible because of relations with well situated individuals in a large trucking company, and because of likely retirements and changes in the company, it is unlikely that systematic data collection can continue as in the past. Nevertheless, the data that have been collected can be used in future studies.

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1. Introduction

Documenting the times trucks incur when crossing an international border facility is valuable both to the private freight industry and to facility operators and planners. Private carriers and shippers can benefit from having objective travel time measures for trip planning and scheduling. By monitoring trends in the documented travel times, facilities operators and planners can detect when conditions have sufficiently changed to warrant changes in infrastructure or operations. In addition, developing, calibrating, and validating predictive models of how travel times respond to alternate infrastructure configurations or operations policies requires extensive and valid data on crossing times.

Elsewhere (*1*,*2*), we described a geofence based approach we had previously developed to determine the times trucks incur in various activities when crossing international borders, as well as the implementation of the approach at two of the busiest and highest valued North American land border crossings – the Ambassador Bridge connecting Detroit, MI, and Windsor, ON, and the Blue Water Bridge connecting Port Huron, MI, and Sarnia, ON. The approach takes advantage of onboard position, timing, and communication systems that are already installed on many truck fleets. Data records with precise time stamps are triggered when the unit crosses the boundary of a virtual geofence, the coordinates of which are communicated remotely to the truck units. By designing the coordinates of the geofences so that the boundaries correspond to strategic locations, the truck times associated with multiple activities can be determined. Our implementation allowed us to produce unprecedented distributions of truck times at these border crossing facilities (*1*,*2*).

In this project, we continued to collect and process truck location and timing data obtained from a fleet of private trucks using the Ambassador Bridge or Blue Water Bridge facilities with the geofences previously implemented and with revised geofences. Data collection protocols were described in *(2)*. In this project, we continued to collect data after the dates reported there through 12/31/2016.

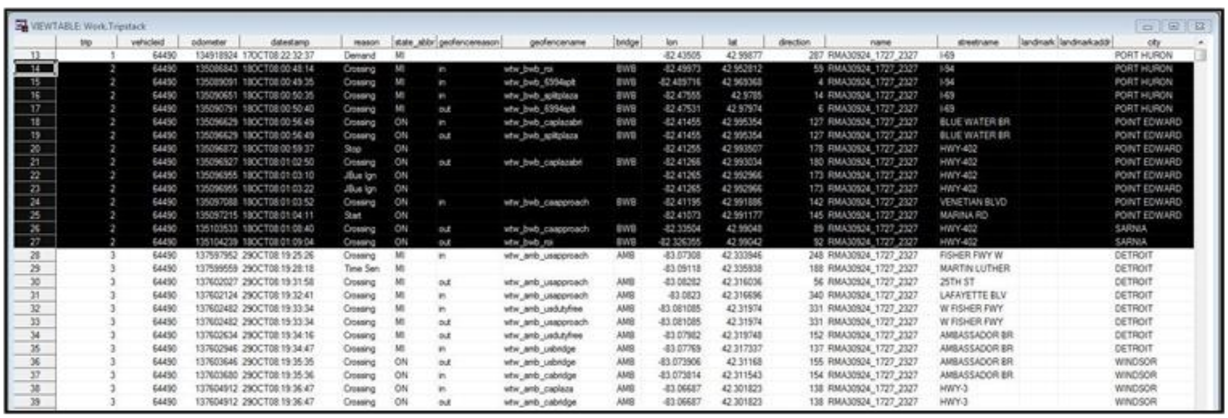
Because of change in project personnel and computer infrastructure, we rewrote codes for processing the collected data into empirical queuing and inspection times. We describe the logic of these codes in Section 2. In Section 3 we describe several issues encountered with changes of physical inspection facilities and newly implemented geofences. In Section 4, we present empirical summaries of queuing and inspection times in formats that would be conducive to regular reporting. In the final section we conclude that our efforts have led unprecedented data on times trucks incur at two major international land crossings. The data can lead to analyses such as those presented in *(2)*. We also conclude that the geofence approach can provide such data with minimal additional infrastructure investments.

2. Logic of New Processing Codes

Because of changes in project personnel, programs that had previously been compiled in different languages using different processing systems had to be transferred to new systems. We determined that it was easier to rewrite the programs in a new operating system. This task was successfully implemented. Several sets of old data were processed with the new programs to ensure that new results corresponded to old results. We iterated with the new programs until we were satisfied with the results. We explain the logic of the new programs here and present more detailed structure in Appendix A.

2.1 Trip Chaining Algorithm

The data arrive in sequential order (see Figure 2.1), with unique identifiers for individual trucks (vehicle ID), precise time and locational information, a ‘geofence name’ tag (i.e. the name of the geofence that the truck crossed when triggering the record to be written), and a ‘geofence reason’ tag. The geofence reason tag indicates the ‘direction’ of the truck, relative to the geofence, and is either ‘in’, meaning that the truck entered the geofence at that time/location, or ‘out’, indicating that the truck exited the geofence.



VIEWTABLE: Work.Tripstack

	trip	vehicleid	odometer	datestamp	reason	state_abbr	geofencereason	geofencename	bridge	lon	lat	direction	name	streetname	landmark	landmarkaddr	city
13	1	64490	134918924	17OCT08:22:32:37	Demand	MI				-82.43505	42.95877	287	RMA30924_1727_2327	I-69			PORT HURON
14	2	64490	135086843	18OCT08:00:48:14	Crossing	MI	in	wtw_bwb_roi	BWB	-82.49973	42.952812	59	RMA30924_1727_2327	I-94			PORT HURON
15	2	64490	135089091	18OCT08:00:49:35	Crossing	MI	in	wtw_bwb_6994eplt	BWB	-82.489716	42.969368	4	RMA30924_1727_2327	I-94			PORT HURON
16	2	64490	135090651	18OCT08:00:50:35	Crossing	MI	in	wtw_bwb_splitplaza	BWB	-82.47555	42.9785	14	RMA30924_1727_2327	I-69			PORT HURON
17	2	64490	135090791	18OCT08:00:50:40	Crossing	MI	out	wtw_bwb_6994eplt	BWB	-82.47531	42.97974	6	RMA30924_1727_2327	I-69			PORT HURON
18	2	64490	135096629	18OCT08:00:56:49	Crossing	ON	in	wtw_bwb_caplazabri	BWB	-82.41455	42.995354	127	RMA30924_1727_2327	BLUE WATER BR			POINT EDWARD
19	2	64490	135096629	18OCT08:00:56:49	Crossing	ON	out	wtw_bwb_splitplaza	BWB	-82.41455	42.995354	127	RMA30924_1727_2327	BLUE WATER BR			POINT EDWARD
20	2	64490	135096872	18OCT08:00:59:37	Stop	ON				-82.41255	42.993507	178	RMA30924_1727_2327	HWY-402			POINT EDWARD
21	2	64490	135096927	18OCT08:01:02:50	Crossing	ON	out	wtw_bwb_caplazabri	BWB	-82.41266	42.993034	180	RMA30924_1727_2327	HWY-402			POINT EDWARD
22	2	64490	135096955	18OCT08:01:03:10	JBus Ign	ON				-82.41265	42.992966	173	RMA30924_1727_2327	HWY-402			POINT EDWARD
23	2	64490	135096955	18OCT08:01:03:22	JBus Ign	ON				-82.41265	42.992966	173	RMA30924_1727_2327	HWY-402			POINT EDWARD
24	2	64490	135097088	18OCT08:01:03:52	Crossing	ON	in	wtw_bwb_caapproach	BWB	-82.41195	42.991886	142	RMA30924_1727_2327	VENETIAN BLVD			POINT EDWARD
25	2	64490	135097215	18OCT08:01:04:11	Start	ON				-82.41073	42.991177	145	RMA30924_1727_2327	MARINA RD			POINT EDWARD
26	2	64490	135103533	18OCT08:01:08:40	Crossing	ON	out	wtw_bwb_caapproach	BWB	-82.33504	42.99048	89	RMA30924_1727_2327	HWY-402			SARNIA
27	2	64490	135104239	18OCT08:01:09:04	Crossing	ON	out	wtw_bwb_roi	BWB	-82.326355	42.99042	92	RMA30924_1727_2327	HWY-402			SARNIA
28	3	64490	137597952	29OCT08:19:25:26	Crossing	MI	in	wtw_amb_usapproach	AMB	-83.07308	42.333946	248	RMA30924_1727_2327	FISHER FWY W			DETROIT
29	3	64490	137599559	29OCT08:19:28:18	Time Sen	MI				-83.09118	42.335938	188	RMA30924_1727_2327	MARTIN LUTHER			DETROIT
30	3	64490	137602027	29OCT08:19:31:58	Crossing	MI	out	wtw_amb_usapproach	AMB	-83.08282	42.316036	56	RMA30924_1727_2327	25TH ST			DETROIT
31	3	64490	137602124	29OCT08:19:32:41	Crossing	MI	in	wtw_amb_usapproach	AMB	-83.0823	42.316696	340	RMA30924_1727_2327	LAFAYETTE BLV			DETROIT
32	3	64490	137602482	29OCT08:19:33:34	Crossing	MI	in	wtw_amb_usdutyfree	AMB	-83.081085	42.31974	331	RMA30924_1727_2327	W FISHER FWY			DETROIT
33	3	64490	137602482	29OCT08:19:33:34	Crossing	MI	out	wtw_amb_usapproach	AMB	-83.081085	42.31974	331	RMA30924_1727_2327	W FISHER FWY			DETROIT
34	3	64490	137602634	29OCT08:19:34:16	Crossing	MI	out	wtw_amb_usdutyfree	AMB	-83.07982	42.319748	152	RMA30924_1727_2327	AMBASSADOR BR			DETROIT
35	3	64490	137602946	29OCT08:19:34:47	Crossing	MI	in	wtw_amb_usbridge	AMB	-83.07769	42.317337	137	RMA30924_1727_2327	AMBASSADOR BR			DETROIT
36	3	64490	137603646	29OCT08:19:35:35	Crossing	ON	out	wtw_amb_usbridge	AMB	-83.073906	42.31168	155	RMA30924_1727_2327	AMBASSADOR BR			WINDSOR
37	3	64490	137603680	29OCT08:19:35:36	Crossing	ON	in	wtw_amb_cabridge	AMB	-83.073814	42.311543	154	RMA30924_1727_2327	AMBASSADOR BR			WINDSOR
38	3	64490	137604912	29OCT08:19:36:47	Crossing	ON	in	wtw_amb_caplaza	AMB	-83.06687	42.301823	138	RMA30924_1727_2327	HWY-3			WINDSOR
39	3	64490	137604912	29OCT08:19:36:47	Crossing	ON	out	wtw_amb_cabridge	AMB	-83.06687	42.301823	138	RMA30924_1727_2327	HWY-3			WINDSOR

Figure 2.1. Sample Data Stream

Trip chaining is the process by which individual truck trips crossing the border are identified in the stream. In the best-case scenario, individual trips are identified by corresponding ‘in’ and then ‘out’ geofence reasons on a given geofence name that has the suffix ‘_roi’ attached. The ‘_roi’ suffix indicates one of two large geofences that have been set up to enclose one of the two bridges. In the highlighted example shown in Figure 2.1, row 14 shows that truck 64490 entered (‘in’) the Blue Water Bridge ‘ROI’ (‘wtw_bwb_roi’) at 12:48 am on October 18, 2008, and row 27 shows that truck 64490 exited (‘out’) the Blue Water Bridge ‘ROI’ (‘wtw_bwb_roi’) at 1:09 am on October 18, 2008. From these geofence reasons, it can be inferred that all of the data records (also known as ‘pings’) that occur between those two records (rows 14 and 27) are all a part of the same trip as truck 64490 crossed the Blue Water Bridge going from Michigan to Ontario. Therefore, the set of records from row 14 to 27 are treated as an ‘individual trip’ in the data stream.

Unfortunately, not all trips are identifiable by '_roi' 'in' or 'out' pings. At times, some expected pings are not recorded. To account for these anomalies, additional steps are taken to identify individual border crossings. Note that all the records in the data stream are sorted by vehicle ID, and then by date and time. Therefore, in some cases, a missing '_roi' 'in' can be identified by having the preceding record being an '_roi' 'out' – as the '_roi' 'out' indicates that the previously recorded trip had ended. Similarly, a missing '_roi' 'out' can be identified by having the following record in the stream being an '_roi' 'in' – as the '_roi' 'in' indicates that the next recorded trip has begun.

Additional steps are taken to account for further anomalies – such as sequences of observed records that are missing '_roi' 'in' or 'out' pings. Some anomalous trips can be identified by checking for changes in vehicle ID, as *individual border crossings* can only occur by an individual truck (so a switch in vehicle ID necessarily means that a new crossing is occurring). Similar logic can be applied to consecutive records that are too far apart, either in terms of distance or time. Therefore, additional steps for identifying a new trip or 'closing' a previous trip are enforced if two consecutive records occurred either more than an hour apart, or if the truck traveled more than 10 kilometers. (These thresholds had previously been determined and implemented in previous codes.)

Each individual border crossing trip is given a sequential integer that identifies all the pings/records associated with the trip (field 'trip' in Figure 2.1). It is then straightforward to assign the bridge direction to each trip. Bridge name is indicated by the field 'bridge' and state/location is indicated by the field 'state_abbr' in the stream. The trip highlighted in Figure 2.1 is designated Trip 2 and is a trip in which truck 64490 crossed the Blue Water Bridge, travelling from Port Huron, MI to Sarnia, ON. Trips that don not actually cross the border are removed. Trips are chained in this way to produce four sets of trips – one for each of the four bridge directions (AMB MI-ON, AMB ON-MI, BWB MI-ON, and BWB ON-MI). Further analysis is then conducted on each bridge-direction separately.

2.2 Time Estimation

To determine the times that trucks in the database spent in the customs and inspection process and in the queue leading up to the customs and inspection process, times between the appropriate geofence boundaries are subtracted. Inspection times are estimated via the time spent traveling between one geofence boundary upstream of the inspection area and another geofence boundary downstream of the inspection area. As an example, Figure 2.2 shows the inspection stream along the Ambassador Bridge in the Ontario to Michigan direction. The large, light-blue geofence – here labeled 'amb_usplaza' – ends just before the trucks enter the inspection booth. (Red arrows indicate the direction of truck travel.) This is the upstream geofence. The light-purple geofence labeled 'amb_ustoll' is the downstream geofence. The time it takes an individual truck to travel from 'amb_usplaza' (exit the geofence) to 'amb_ustoll' (enter the geofence) is the estimated time of inspection based on the geofence approach.

Times for inspection along the other three bridge directions are estimated in similar fashion. Table 2.1 shows the set of upstream and downstream geofences used to construct inspection time estimates for each of the four bridge directions.

The process for constructing estimates of queuing times is analogous to that of the process of construct inspection times. The set of geofences used for queue time estimation are reported in Table 2.2.

Figure 2.2. Illustration of the Ambassador Bridge Ontario to Michigan Inspection Process

Table 2.1 Inspection time estimation geofences

Bridge Direction	Upstream Geofence	Downstream Geofence
Ambassador Bridge Michigan to Ontario	'out' on 'wtw_amb_caplaza'	'in' on 'wtw_amb_huronchrchrd'
Ambassador Bridge Ontario to Michigan	'out' on 'wtw_amb_usplaza'	'in' on 'wtw_amb_ustoll'
Blue Water Bridge Michigan to Ontario	'out' on 'wtw_bwb_caplazabridge'	'in' on 'wtw_bwb_caapproach'
Blue Water Bridge Ontario to Michigan	'out' on 'wtw_bwb_usplazabridge'	'in' on 'wtw_bwb_rte25collect'

In this process the times determined are the times that the trucks take to traverse the roadway between the two geofence boundaries. The actual inspection or queuing time can be better estimated by subtracting the so-called "free flow time" – *i.e.,* the time the truck would take to traverse the roadway if no impediment to travel (inspection process or a queue) was present – from the geofence times. However, the free-flow time would be a constant for a given bridge-direction and activity (inspection or queuing), and subtracting the value would not be necessary for comparative purposes.

Table 2.2 Queue time estimation geofences

Bridge Direction	Upstream Geofence	Downstream Geofence
Ambassador Bridge Michigan to Ontario	'in' on 'wtw_amb_cabridge'	'out' on 'wtw_amb_caplaza'
Ambassador Bridge Ontario to Michigan	'in' on 'wtw_amb_usplaza'	'out' on 'wtw_amb_usplaza'
Blue Water Bridge Michigan to Ontario	'in' on 'wtw_bwb_caplazabridge'	'out' on 'wtw_bwb_caplazabridge'
Blue Water Bridge Ontario to Michigan	'in' on 'wtw_bwb_usplazabridge'	'out' on 'wtw_bwb_usplazabridge'

More detailed descriptions of the scripts written to perform these functions can be found in Appendix A.

3. Data Issues

Two significant issues with data collection and processing were encountered, One occurred on the Ambassador Bridge in the Ontario-to-Michigan direction. The second occurred on the Blue Water Bridge in the Michigan-to-Ontario direction. This section describes these issues and steps taken to address the issues.

3.1 Ambassador Bridge Ontario-to-Michigan Inspection Times

In August of 2014, the project team made adjustments to the geofence definitions near the Ambassador Bridge access and exit locations. After the adjustments were uploaded, a noticeable and systematic southeastern shift in the line of (out) pings along the US Plaza Geofence (**wtw_amb_usplaza**) appeared (see Figure 3.1; north is up in this figure).

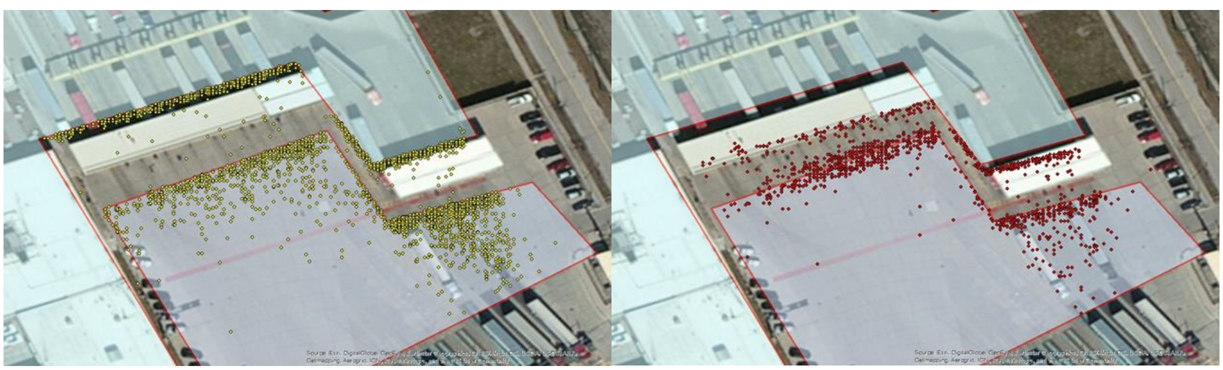


Figure 3.1. Ambassador Bridge 'out' pings along US Plaza and US Toll Geofences; (left) June – August 2014, (right) September – December 2014

It was determined that during the implementation errors were made that caused the Ambassador US Plaza Geofence to extend inward and pass the inspection booth, resulting in the elimination of the gap needed to determine inspection times (see Figure 3.2).

Additionally, this caused the Ambassador US Plaza and US Toll (**wtw_amb_ustoll**) geofences to overlap. Once these issues were detected, and the cause discovered, the geofences were updated (in Webtech Wireless) to reflect a correct set of geofence definitions that closely resemble the previously recommended geofence boundaries. These necessary changes were implemented on January 7, 2016.

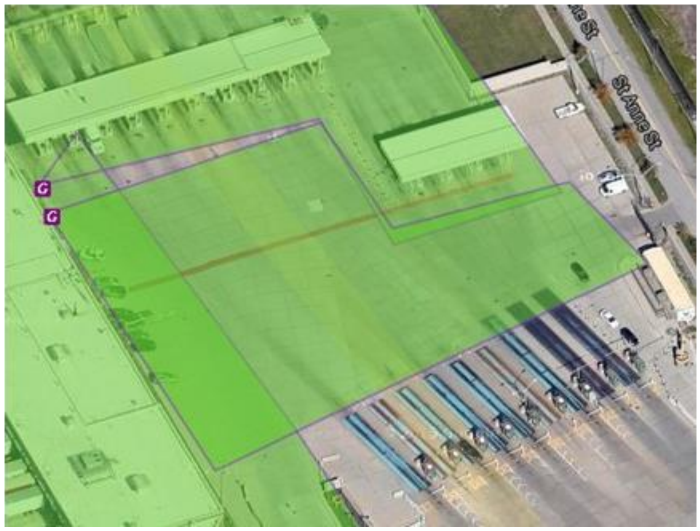


Figure 3.2. Erroneously Implemented Geofences at Ambassador Bridge U.S. Inspection Station

Due to these errors it was not possible to determine Ambassador Bridge Ontario-to-Michigan inspection times while these erroneous geofences were in use, namely, from September 2014 to December 2015.

3.2 Blue Water Bridge Michigan-to-Ontario Inspection Times

A change in the location of Canadian inspection facilities at the Blue Water Bridge resulted in extra roadway length being traversed downstream of the inspection facilities before trucks would cross the geofence boundary intended to record the time the truck finished inspection. The impact of this shift in inspection facilities is illustrated by Figures 3.3-3.6, where pings intended to represent trucks immediately upstream and downstream of the inspection facilities are exhibited for different time periods. The imagery in the figures was obtained after the facilities were moved. (The newer facilities are slightly up and to the left – northwest – of the original facilities.)

Figure 3.3 shows pings between October 2008 and June 20, 2011. The upstream and downstream pings captured by the geofence boundaries align well with the old inspection facilities. Figure 3.4 shows the pings between June 21, 2011 and March 31, 2013. The upstream and downstream pings are crossing the existing geofences at locations that are different than those in Figure 3.3. Apparently, the new inspection facilities (slightly up and to the left) were opened on June 21, 2011. As a result, the trucks were traversing different roadway sections. The change in location was such that the implemented geofences were still recording pings upstream and downstream of the (new) inspection facilities, but they were not recording records immediately upstream and downstream as they were when the facilities were at the original location.

Pings recorded between April 1, 2013 and August 31, 2014 appear in Figure 3.5. We noticed an increase in recorded inspection times beginning in April 2013. Originally, we thought this increase may have been attributable to further changes in travel patterns near the inspection facilities. The pings in Figure 3.5 indicate that similar travel patterns to those during the time period corresponding to Figure 3.4 were occurring during this time. It appears that the recorded increase was a result of real increases in inspection times, and we note that the observed increase occurred around the time of the 2013 Boston Marathon attacks.

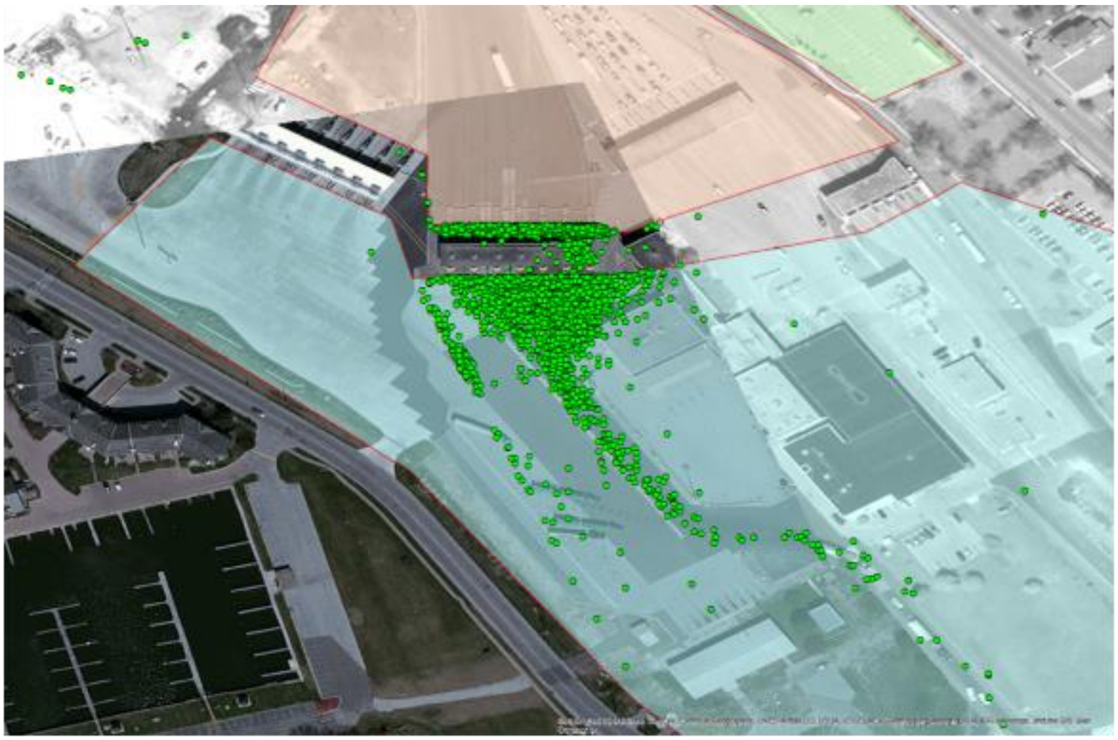


Figure 3.3. Blue Water Bridge Michigan to Ontario Inspection Station, Original Geofences, and Pings: October 2008 to June 20, 2011

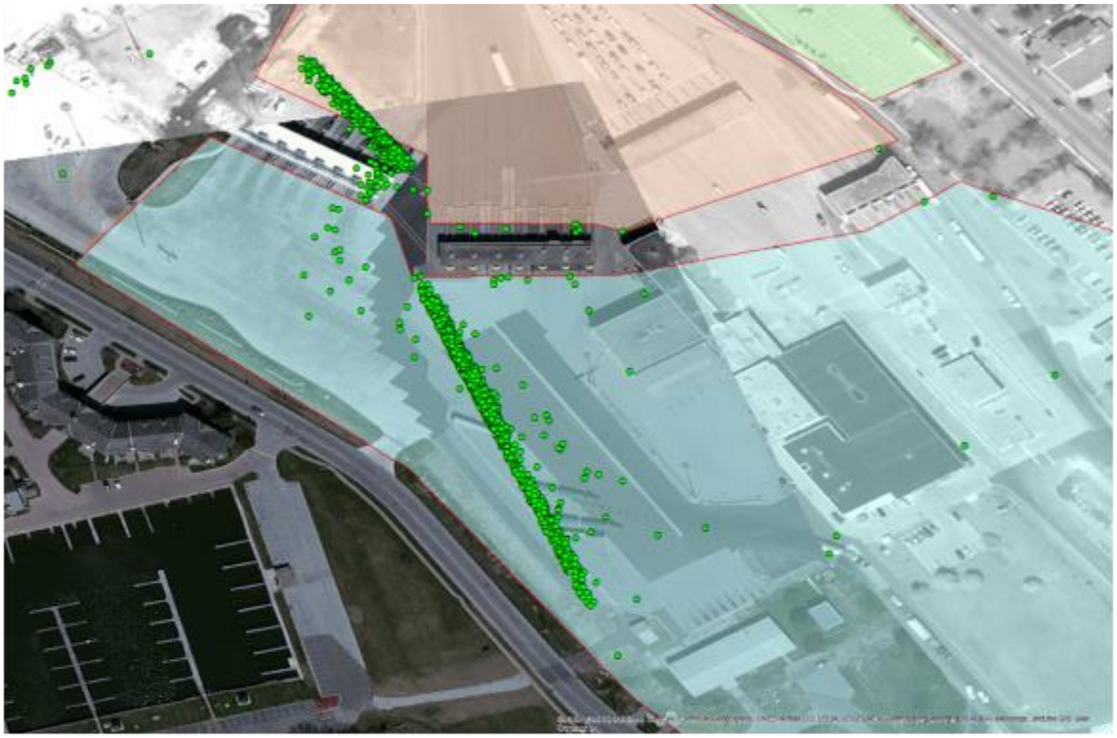


Figure 3.4. Blue Water Bridge Michigan to Ontario Inspection Station, Original Geofences, and Pings: June 21, 2011 to March 31, 2013

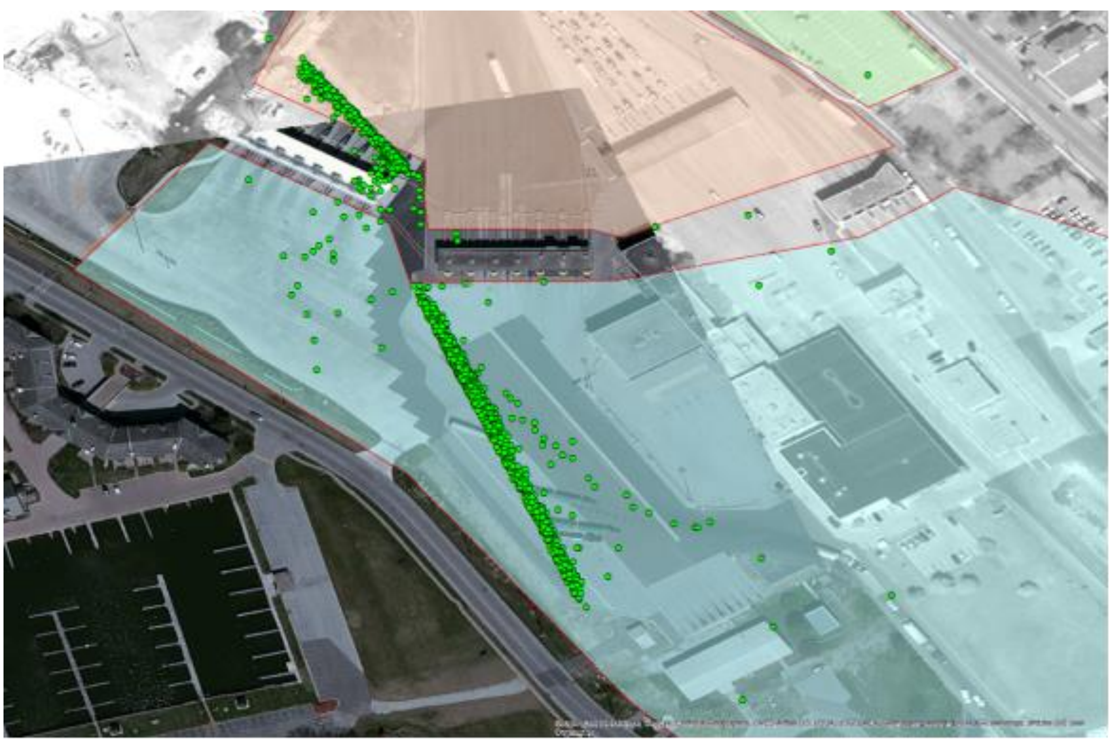


Figure 3.5. Blue Water Bridge Michigan to Ontario Inspection Station, Original Geofences, and Pings: April 1, 2013 to August 31, 2014

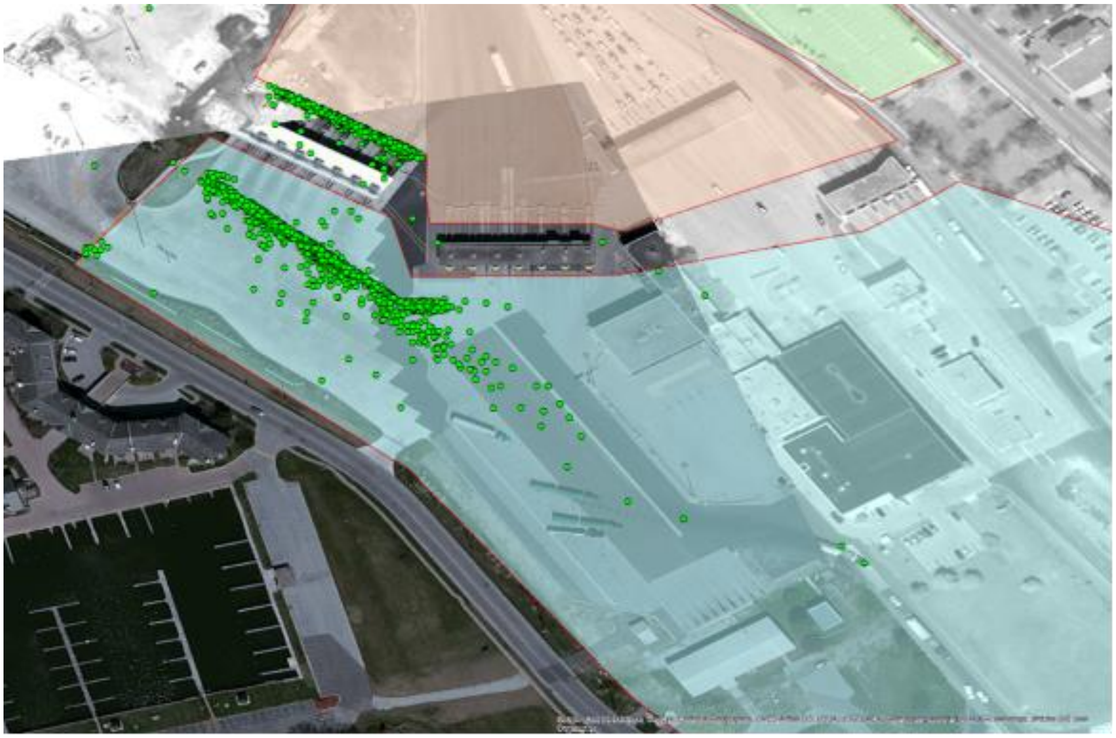


Figure 3.6. Blue Water Bridge Michigan to Ontario Inspection Station, Original Geofences, and Pings: September 1, 2014 to December 31, 2015

As mentioned previously, new geofences were implemented in August 2014. Changes were made in this location to account for the new location of the inspection facilities. The pings beginning September 1, 2014 are shown in Figure 3.6. These seem to track well with location just upstream and just downstream of the new location of the inspection facilities. However, the downstream pings in Figure 3.5 (new inspection facility location and new geofences) appear to be slightly farther from the exit of the facilities than do the downstream pings in Figure 3.3 (original inspection facility location and original geofences). Therefore, for similar real inspection times, the times between the upstream and downstream pings used to estimate inspection times would be longer with the new geofences (after September 1, 2014, Figure 3.6) than before the movement of the new facilities (before June 21, 2011, Figure 3.3). The times would be also be longer after the facilities were moved but before the new geofences were implemented (*i.e.*, for the periods corresponding to Figures 3.4 and 3.5).

To account for these “artificially added times” and to put all inspection time estimates on a basis similar to that which occurred before the inspection facilities were moved, a constant time was subtracted from recorded times between geofence boundaries, depending on the time period. Specifically, a change in time associated with a change in distance travelled because of the inspection locations was estimated. Table 3.1 lists the median times incurred and distances travelled between the two geofence boundaries used for determining inspection times for the time periods associated with Figures 3.3-3.6.

Table 3.1: Median times incurred and distances travelled between geofence boundaries used to determine inspection times for BWB MI-ON trucks for time periods associated with Figures 3.3-3.6

Time Period Associated with	Median Time Incurred	Median Distance Travelled
Figure 3.3	57 seconds	29 meters
Figure 3.4	74 seconds	130 meters
Figure 3.5	89 seconds	136 meters
Figure 3.6	74 seconds	158 meters

Representing the median time to travel between the geofence boundaries as:

$$Median\ Time\ between\ Geofence\ Boundaries = Median\ Inspection\ Time + \frac{1}{Travel\ Speed}\ Median\ Distance\ between\ Geofence\ Boundaries \quad (4.1)$$

the median distances and times from Table 3.1 for pairs of time periods were used to calculate the Travel Speed value (and Median Inspection Time value). When using data for periods associated with Figures 3.3 and 3.4 time periods, the Travel Speed value is found to be 5.9 (m/s). When using data associate with Figures 3.5 and 3.6 time periods, the value is found to be 5.2 (m/s), which is relatively close to the 5.9 (m/s) value. However, when using data associated with Figures 3.4 and 3.5 time periods (where the Median Inspection Time value was believed to changes substantially), the Travel Speed is found to be an unreasonable 0.4 (m/s). Therefore, to compensate for changes in distance between geofence boundaries relative to the original configuration (that corresponding to the time period associated with Figure 3.3), we considered a travel speed for the roadway section after leaving inspection of 5.55 (m/s) (the average of 5.9 and 5.2), determined the additional time associated with the increased median distances for the periods associated with Figures 3.4-3.6, and subtracted these additional times from the recorded times between the pair of inspection geofence boundaries. This led to subtracting 18.2 seconds, 19.3 seconds, and 5.2 seconds, respectively, from times recorded during periods associated with Figures 3.4, 3.5, and 3.6, respectively.

4. Formats for Regular Empirical Summaries

Once the new codes were implemented and corrections accounting for issues described in the previous section were determined, we processed data and summarized results in tables and figures we believed would be appropriate for regular reporting. Our data were collected from a large truck fleet that regularly traveled between Ontario and Michigan. Even so, the number of observations would still be limited when slicing the data by day-of-week and hour-of-day. As such, a compromise needed to be made between the frequency with which reports would be generated and the number of data points leading to summary statistics in the reports. After some experimentation, we decided upon quarterly (*i.e.*, three-month) reports. The following tables and figures illustrate the type of information that would be included in quarterly reports, where Q1 represents the first quarter (January, February, March) of the appropriate year, Q2 represents that second quarter (April, May, June), and similarly for Q3 and Q4.

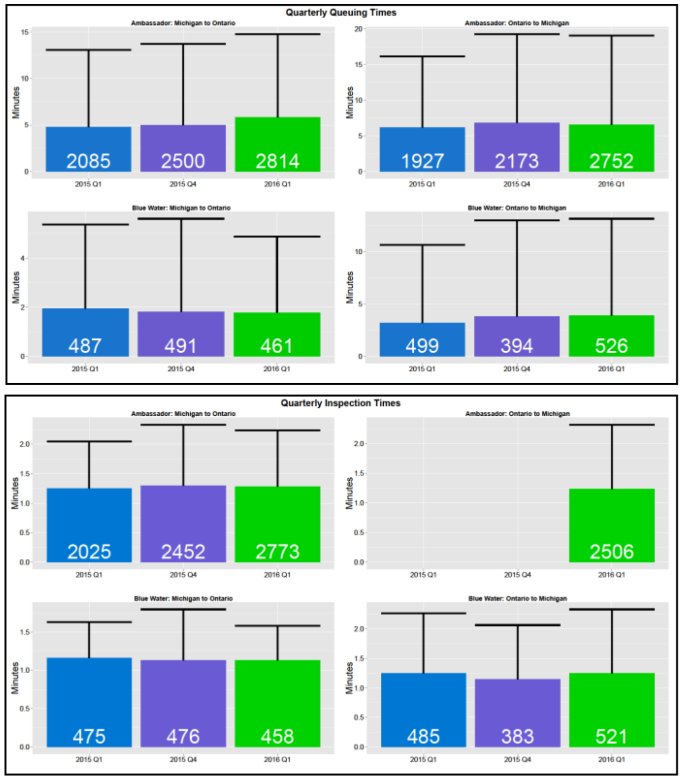


Figure 4.1. Quarterly Queue and Inspection Times.

Figure 4.1 shows the queueing and inspection times represented by bar charts in which the height of each bar represents the quarterly median queuing or inspection time, the height of the whisker associated with each bar represents the 90th percentile, and the observation count is indicated on each bar. Each bridge-direction is represented by three sets of bars: one for the “present” quarter (Q1 2016, in this case), one for the “preceding” quarter (Q4 2015, in this case), and one for the “same quarter of the previous year” (Q1 2015).

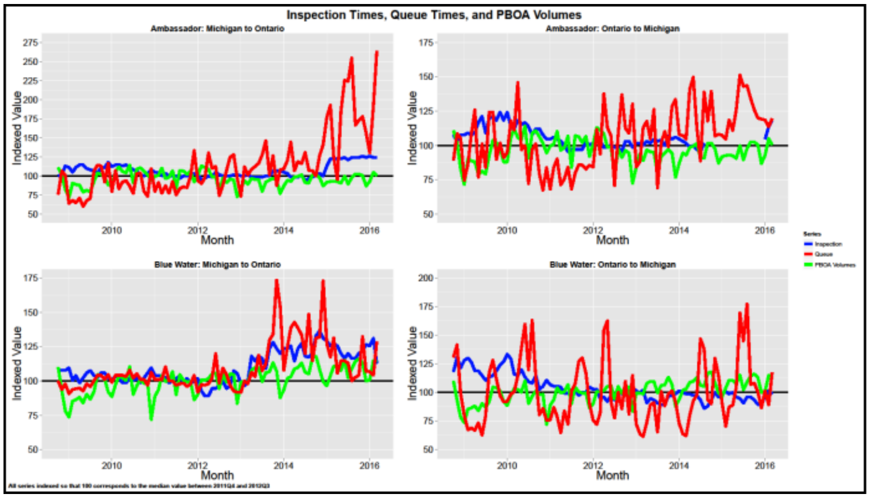


Figure 4.2. Monthly Indexed Inspection and Queue Times with PBOA Volumes.

Figure 4.2 portrays time series plots of monthly median queue and inspection times beginning in October 2008, when data were first collected at this bridge-crossing using the geofence approach. Additionally, average daily truck traffic volumes from the Public Border Operators Association (PBOA) are included. Each time series has been normalized so that a value of 100 corresponds to the series median over the period Q4 2011 and Q3 2012. The time period between Q4 2011 and Q3 2012 was chosen as the reference period because the inspection time and queuing time series were all relatively stable for all four directions during this time. These indexed series plots make observing time trends more easily interpretable and comparable.

Table 4.1: Index values for the different bridge directions when considering all data.

Direction	Measure	Ambassador Index*	Blue Water Index*
MI - ON	Inspection	1.03	0.92
MI - ON	Queue	2.93	1.60
ON - MI	Inspection	1.10	1.25
ON - MI	Queue	5.58	3.82
PBOA	Volume	7101	4061

* Index corresponds to time in minutes (Inspection or Queue) or two-way average daily volume (PBOA)

Table 4.1 provides the reference values used to normalize the individual series that are plotted in Figure 4.2. An index value of 100 in Figure 4.2 corresponds to the values for each series given in Table 4.1. For example, in the top-left plot in Figure 4.2, the red series corresponds to the Ambassador Bridge Michigan-to-Ontario monthly queue time estimates. When this red line crosses the 100 value on the y-axis, then the estimated monthly median queue time for that direction is roughly 2.93 minutes. Note that while the inspection and queue indices reference median times in minutes, the index values for PBOA volumes correspond to the average daily two-way truck counts for each bridge.

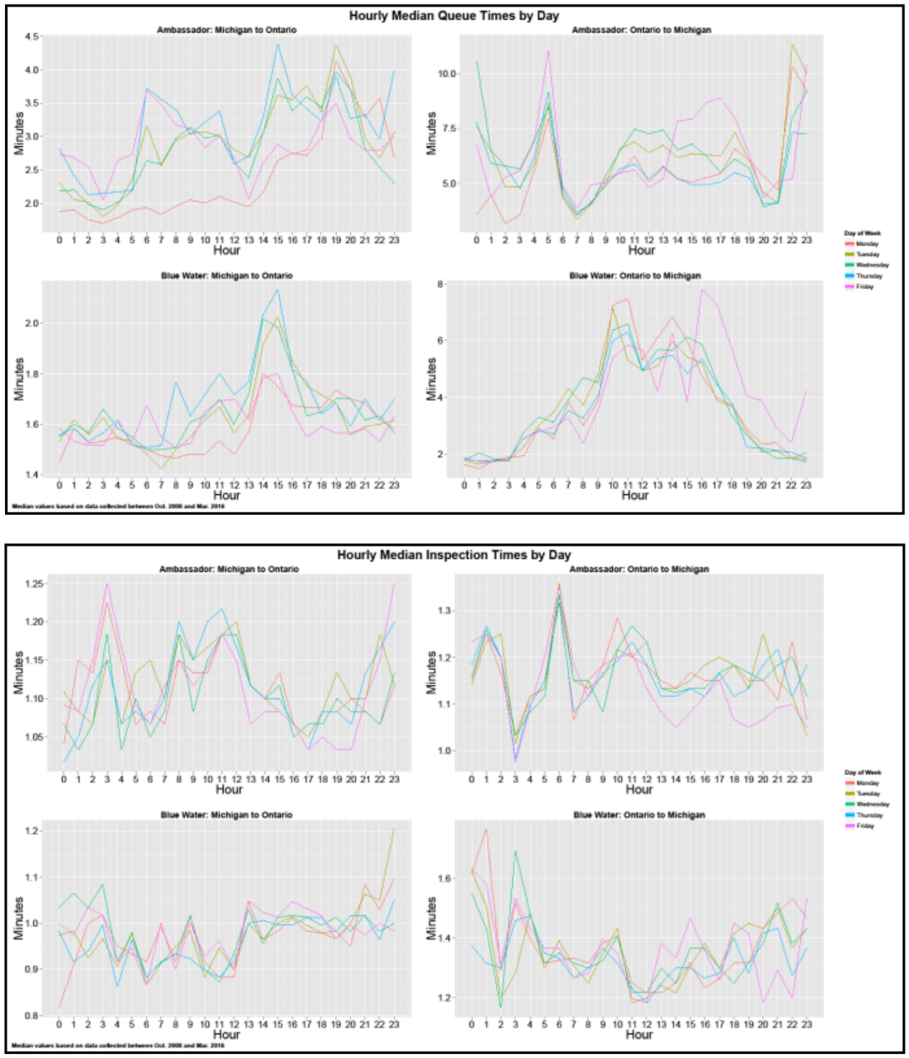


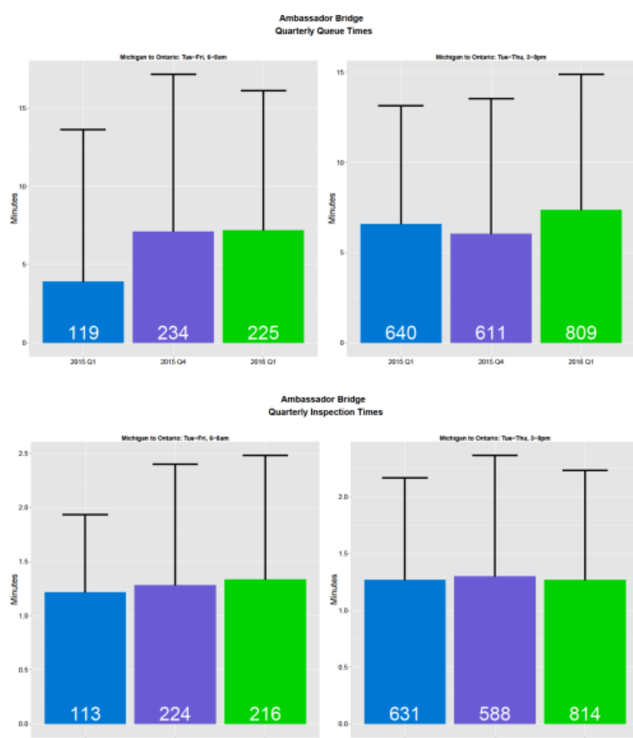
Figure 4.3. Median Inspection and Queue Times by Hour-of-Day/Day-of-Week by Crossing-Direction for Entire Data Set

In Figure 4.3, plots are provided of the median queuing and inspection times by hour-of-day and day-of-week, where the data are aggregated from the beginning of the data collection process (October 2008) to the end of the quarter considered.

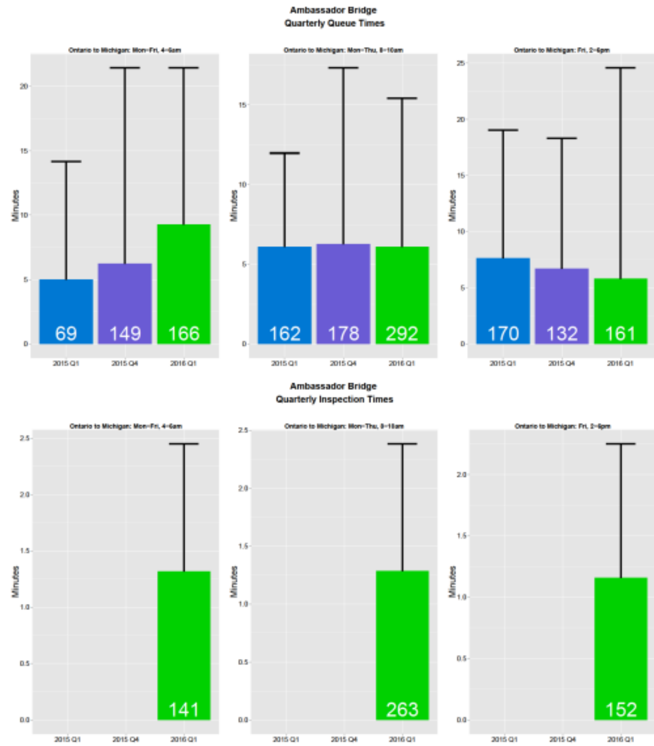
Table 4.2: Days-of-Week/Hours-of-Day selected for further analysis based on peak median queuing times.

Bridge	Direction	Day(s)	Hours
Ambassador	MI - ON	Tue-Fri	6-8am
Ambassador	MI - ON	Tue-Thu	3-8pm
Ambassador	ON - MI	Mon-Fri	4-6am
Ambassador	ON - MI	Mon-Thu	8-10am
Ambassador	ON - MI	Friday	2-6pm
Blue Water	MI - ON	Tue-Fri	11am-2pm
Blue Water	ON - MI	Mon-Fri	9am-3pm

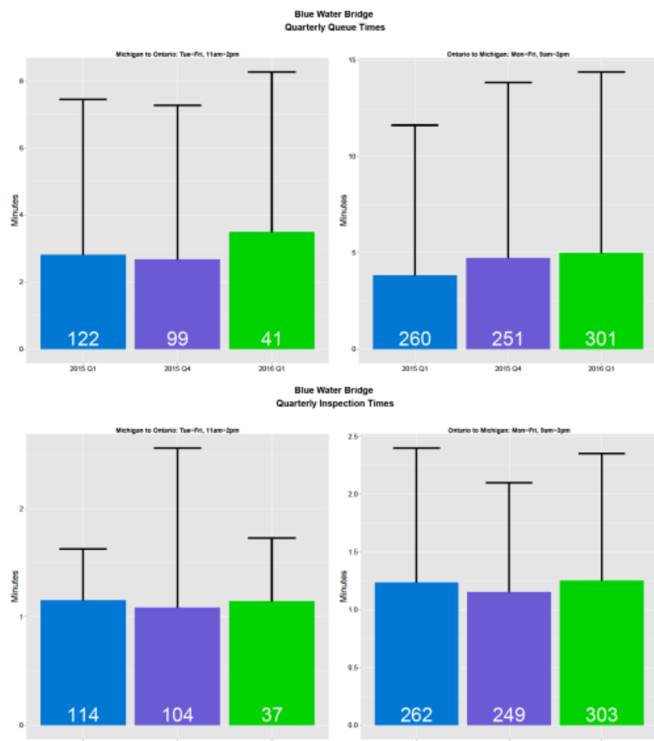
Table 4.2 identifies the Time-of-Day/Day-of-Week periods chosen for further investigation. These selections are based on observation of Figure 4.3, and were chosen as periods where queuing times seemed to be greatest. Note that almost all of these selections are actually a set of consecutive hours over a collection of specific days. The union of select hours and select days provides a number of observations that would be sufficient to provide meaningful summery measures.



(4-4 A)



(4-4 B)



(4-4 C)

Figure 4.4. Quarterly Median Queue and Inspection Times.

Figure 4.4 shows three sets of plots that are similar to those shown in Figure 4.1, but here the bar charts reflect values (median, 90th percentile, and observation size) corresponding to the queue and inspection times estimated for the selection of peak days/hours listed in Table 4.2.

Table 4.3: Index values for the different bridge-directions when considering peak Days-of-week/Hours-of-Day selections presented in Table 4.2

Bridge	Direction	Day(s)	Hours	Inspection Index*	Queue Index*
Ambassador	MI - ON	Tue-Fri	6-8am	1.00	2.42
Ambassador	MI - ON	Tue-Thu	3-8pm	1.03	4.00
Ambassador	ON - MI	Mon-Fri	4-6am	1.08	6.98
Ambassador	ON - MI	Mon-Thu	8-10am	1.08	4.52
Ambassador	ON - MI	Friday	2-6pm	1.03	9.55
Blue Water	MI - ON	Tue-Fri	11am-2pm	0.93	1.62
Blue Water	ON - MI	Mon-Fri	9am-3pm	1.25	6.04

*Index corresponds to time in minutes

Table 4.3 indicates the reference values that are used to normalize the individual series that are plotted in Figures 4.5, 4.6, and 4.7, similar to how Table 4.1 presented the 'normalizing constants' for the time series presented in Figure 4.2. The key difference here is that Table 4.3 reports normalizing constants only for the selection of peak days/hours listed in Table 4.2.

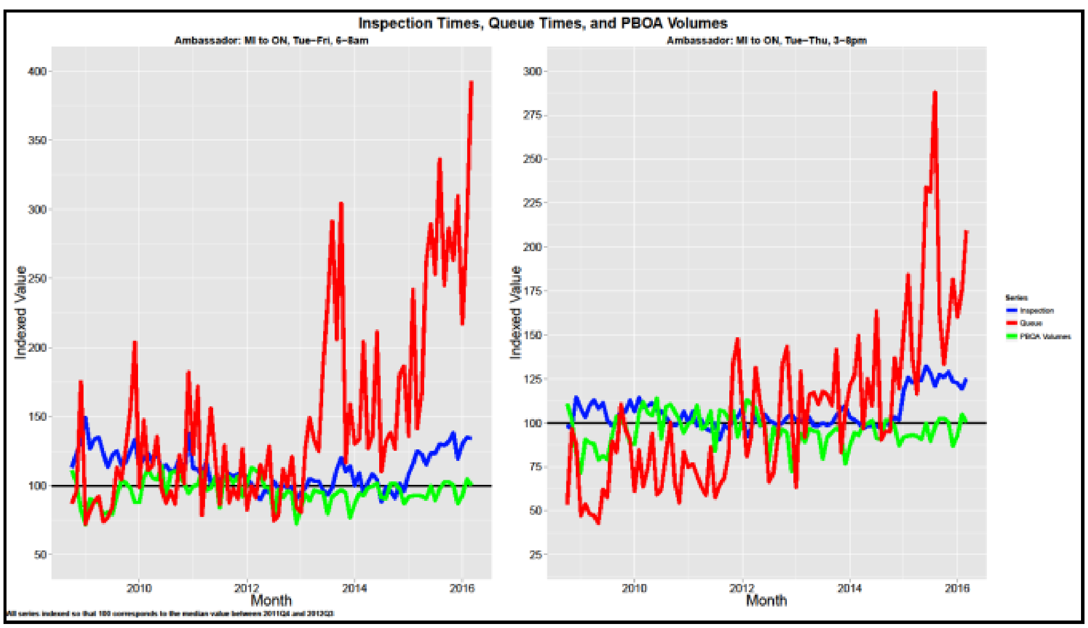


Figure 4.5. Monthly Indexed Inspection and Queue Times with PBOA Volumes for Selected Peak Day(s)/Hour(s).

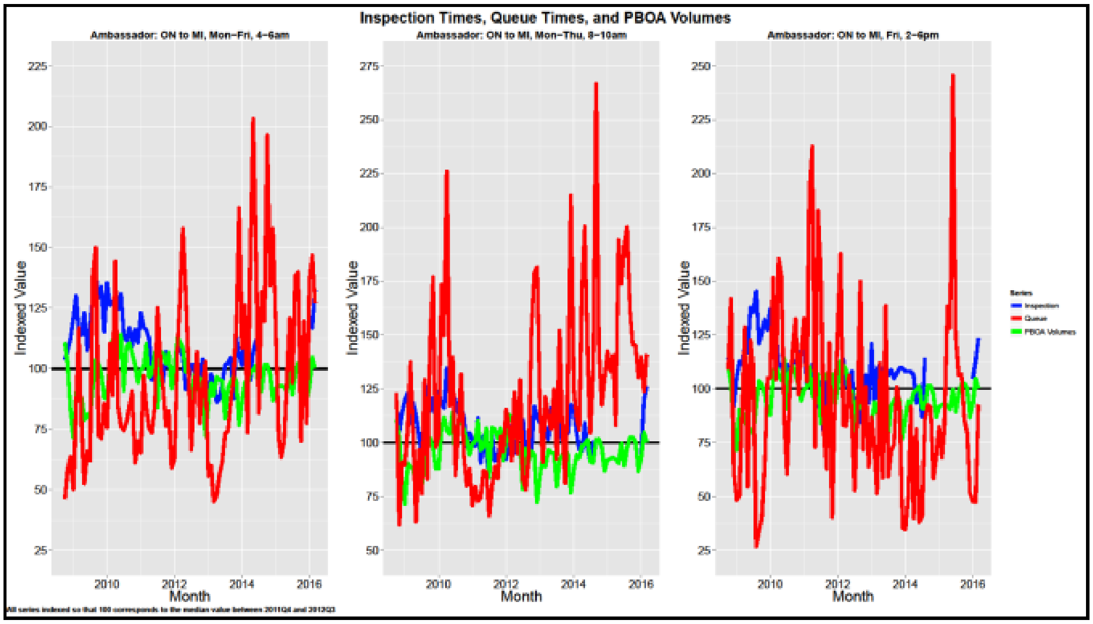
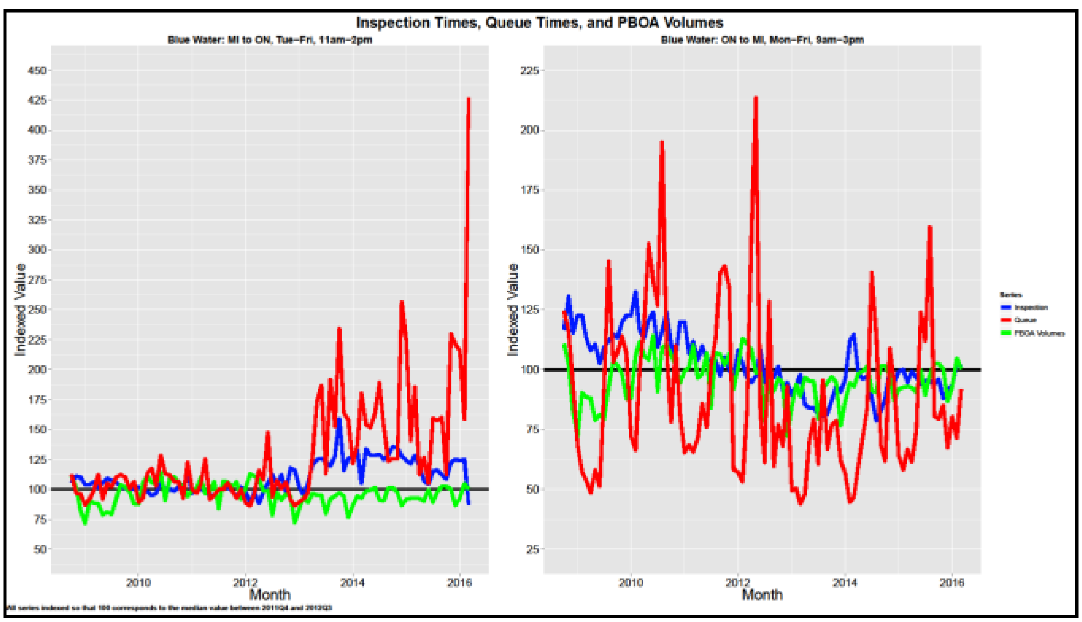


Figure 4.6. Monthly Indexed Inspection and Queue Times with PBOA Volumes for Selected Peak Day(s)/Hour(s).



Figures 4.7. Monthly Indexed Inspection and Queue Times with PBOA Volumes for Selected Peak Day(s)/Hour(s).

Figures 4.5, 4.6, and 4.7 are indexed time series plots that are similar to those presented in Figure 4.2, but for values corresponding to the peak days/hours listed in Table 4.2.

5. Conclusions

A wealth of data has been collected over the years on times trucks incur in inspection and when queuing before inspection in both directions at the Ambassador Bridge and Blue Water Bridge border crossing facilities, two of the busiest and most highly valued land border crossings in North America. The geofence approach can be relatively simple to implement in that it takes advantage of hardware and communication systems already in use on many truck fleets and requires no additional roadside infrastructure. As a result, it was equally easy to collect data at the privately owned and operated Ambassador Bridge facilities as it was to collect data at the publicly owned and operated Blue Water Bridge facilities. The data appear to be unprecedented in the detail and length of time during which the data were collected. As such, the data can be used to indicate trends and to investigate behavioral relations, such as those presented in (*2*). The tables and figures presented in Section 4 illustrate the types of quantitative, systematic reporting that could be produced. The data collection efforts were made possible because of relations with well situated individuals in a large trucking company. Because of likely retirements and changes in the company, it is unlikely that systematic data collection can continue as in the past. The increased public efforts to use roadside systems to collect similar, but different data, make it less likely that efforts will be made to collect geofence data at these border crossing facilities in the future. Nevertheless, the data that have been collected can be used in future studies.

6. References

(1) McCord, M.R., P.K. Goel, C. Brooks, P. Kapat, R. Wallace, H. Dong, D.E. Keefauver, Documenting Truck Activity Times at International Border Crossings Using Redesigned Geo-fences and Existing On0board Systems. *Transportation Research Record 2162*, 2010, pp. 81-89.

(2) McCord, M.R., C.N. Brooks and D. Banach (2015). Truck Activity and Wait Times at International Border Crossings. USDOT Region V Regional University Transportation Center Final Report, NEXTRANS Project No. 120OSU2.1, 52 pgs.

Appendix A: Report Production Documentation

This Appendix outlines the steps necessary to produce the information and figures presented in Sections 2 and 4. The trip-chaining algorithms discussed above are implemented in a series of SAS Programs. Additional steps necessary to estimate inspection/queuing times for the four bridge directions are also implemented in these SAS scripts. The outputs of these SAS scripts are *CSV* tables containing the summary estimates necessary to produce the figures. Actual figure production is achieved through a set of R programs. The R programs read-in the *CSV* outputs from the SAS programs, and then draw the appropriate bar/line charts. NOTE that the output figures, from R, are saved in *PDF* format and are 'inserted' into a Microsoft Word document (with a **.doc** extension, not a **.docx**).

A.1 Data and Script

A.1.1 Data Acquisition and Storage Structure

The first step is to download the new set of CEVA data from the MTRI ftp[1] site (see section A.3.2 for Python automated download instructions). The most pertinent set of data is two *CSV* files of the following form:

- **ceva_data_export_MM_DD_YYYY_AMB.csv**
- **ceva_data_export_MM_DD_YYYY_BWB.csv**

Here, MM_DD_YYYY corresponds to the two-digit month, two-digit day, and four-digit year of the most recent data posted. In practice we save the new data files to a folder location similar to:

- **C:\MTRI\DATA\YYYYMM**

Where YYYY is the four-digit year and MM is the two-digit month of the most recent data.

A.1.2 Data Processing, Calculations, and Figures

All of the trip-chaining and time estimation calculations are done in a series of SAS programs. These programs are located at **C:\MTRI\SAS\Production**. The necessary set of SAS programs, their outputs, and what lines need to be edited are indicated in Table A.1 (see appendix A.3.1 below for important notes).

The general order of operations is to open the necessary SAS program, edit the lines indicated in Table A.1 to reflect the most recent set of data, then running the entire SAS program, which will produce the indicated output file(s) for subsequent use in R.

[1] ftp://ftp.mtri.org/pub/OSU/

Table A.1 SAS program list

SAS File	Edit Lines	Output File(s)	Figure(s)
Inspection Time QTR Report.sas Queue Time QTR Report.sas	20, 28, 41, 546, 1585 20, 28, 41, 541, 1568	QTRInspectionReport.csv QTRQueueReport.csv	Figure 1
Inspection Time Estimation.sas Queue Time Estimation.sas	26, 39, 577, 594 28, 41, 495, 512	MonthInsp.csv & DailyInsp.csv MonthQue.csv & DailyQue.csv	Figure 2 (Monthly) and Figure 3 (Daily)
HD Inspection Time QTR Report.sas HD Queue Time QTR Report.sas	10, 18, 31, 1368 10, 18, 31, 1294	HDQTRInspectionReport.csv HDQTRQueueReport.csv	Figures 4, 5, and 6
HD Inspection Time Series.sas HD Queue Time Series.sas	15, 28, 438 15, 28, 431	HDMonthInsp.csv HDMonthQue.csv	Figures 7, 8, and 9

A series of R scripts are used to produce the report plots and summaries. These programs are located at **C:\MTRI\R\PRODUCTION**. The necessary set of R programs, their inputs, and what lines need to be edited are indicated in Table A.2 (below).

The general order of operations is to open the necessary R script, edit the lines indicated in Table 2 to reflect the most recent set of data, then running the entire R script, which will produce the necessary plots. These plots are then saved and/or exported to PDF format and it is the *PDF* figures that are then inserted to the report Word document.

Table A.2 R script list

R Script	Edit Lines	Inputs File(s)	Figure(s)
Inspection Bar Charts Quarterly.R Queue Bar Charts Quarterly.R	11, 14, 15, 16 11, 14, 15, 16	QTRInspectionReport.csv QTRQueueReport.csv	Figure 1
Inspection & Queue Indexed Plots.R	12	MonthInsp.csv, MonthQue.csv, & PBOA.csv	Figure 2
Inspection Plots.R Queue Plots.R	11, 211 11, 211	DailyInsp.csv DailyQue.csv	Figures 3
HD Inspection Bar Charts Quarterly.R HD Queue Bar Charts Quartely.R	12, 15, 16, 17 12, 15, 16, 17	HDQTRInspectionReport.csv HDQTRQueueReport.csv	Figures 4, 5, & 6
HD Inspection & Queue Indexed Plots.R	12	HDMonthInsp.csv, HDMonthQue.csv, & PBOA.csv	Figures 7, 8, & 9

A.1.3 PBOA Data

The time series plots (Figures 4.2, 4.5, 4.6, and 4.7) include average two-way daily volume of truck traffic, for both bridges, which comes from the Public Border Operators Association[2] (PBOA). PBOA publishes monthly estimates of all truck traffic for the seven bridges along the US-Canadian border.

The report takes their data as is, as it is simply added it to the collection of processed geofence data before the requisite charts and tables are produced. To acquire the most recent PBOA data go to the website listed in the footnote below. Once there, click on the Traffic Data link (Figure A.1 (top)). On the resulting page click the 'click here' link (Figure A.1 (bottom)).

[2] http://publicborderoperators.org/

When prompted to save the necessary *XLSX* file, save it to the **PBOA** directory – which should be located on a path that looks like: **C:\MTRI\PBOA**. Note that the file will have a name similar to **PBOA Traffic YYYY.xlsx**, where YYYY corresponds to the current (most up-to-date) year. Save over the current copy in **C:\MTRI\PBOA**, if a file with the same name already exists in the folder.

There is a *CSV* file in the PBOA directory called **C:\MTRI\PBOA\PBOA.csv**. Manually update this file by typing in the data for the new set of months and years since the last update.[3] This includes typing in the new data values for volumes on both the Ambassador Bridge (column C in **PBOA.csv**) and the Blue Water Bridge (column D), both of which can be found in rows 10 and 15, respectively, in **PBOA Traffic YYYY.xlsx**. The requisite data will typically be in the left-most worksheet (tab) of **PBOA Traffic YYYY.xlsx**.

Once the new data has been entered into **PBOA.csv**, save it, and close out of both **PBOA Traffic YYYY.xlsx** and **PBOA.csv**. Copy and paste the new version of **PBOA.csv** into the current **DATA** directory. Once done there will be a *CSV* file located at **C:\MTRI\DATA\YYYYMM\PBOA.csv**.

[3] For example, if the data in **PBOA.csv** only goes to 3/2016 (March 2016) and we now have data up to 6/2016 (June 2016) manually add months 4, 5, and 6 to column A and add 2016, 2016, and 2016 to column B.

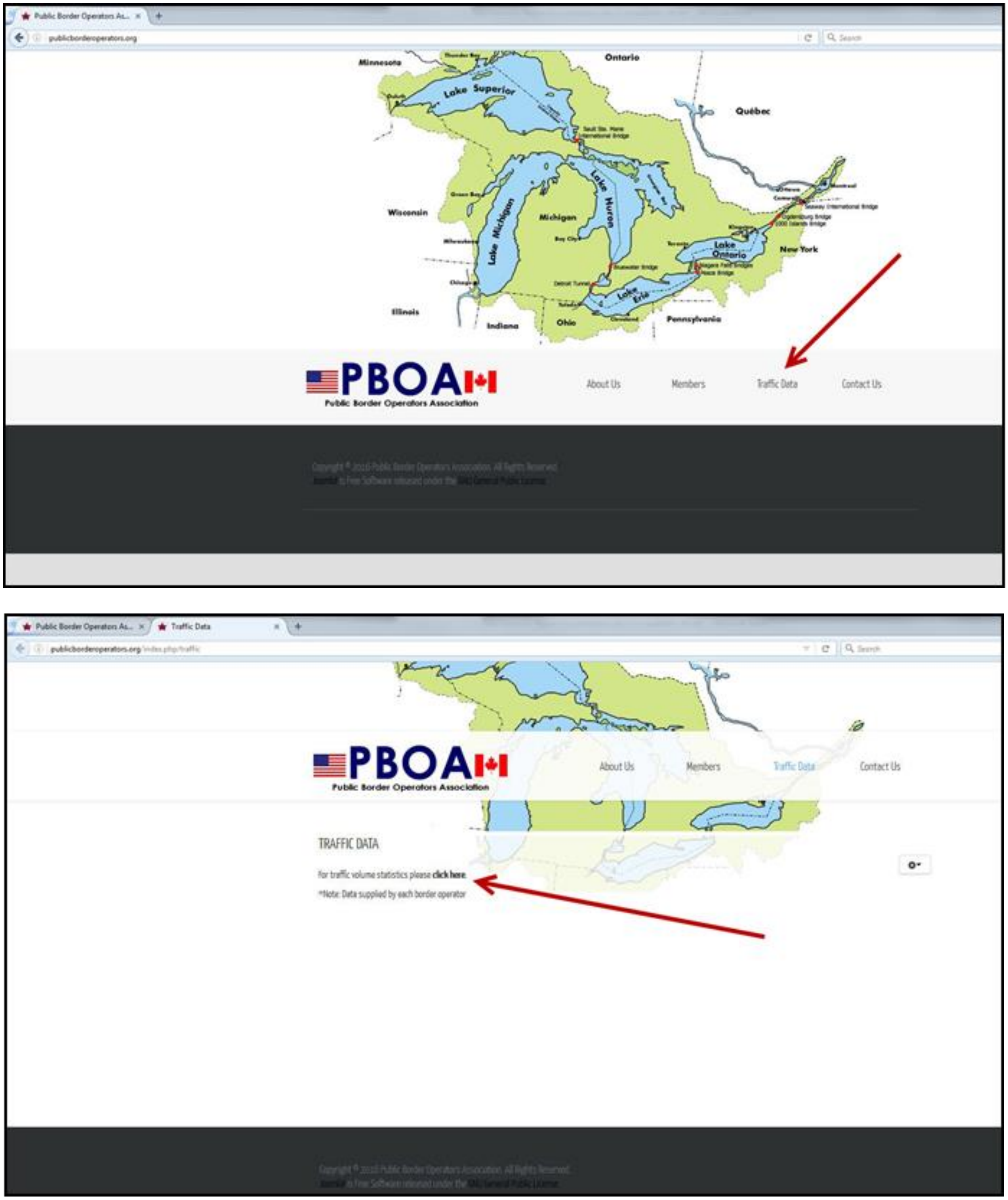


Figure A.1. Public Border Operators Association (PBOA) website (top), PBOA data download (bottom).

A.2 Figure Production

A.2.1 Quarterly Box Plots for Inspection and Queue Times

Run the following steps (1-13) to produce: Quarterly Queue and Inspection Time Statistics. Steps 1-7 produce a *PDF* figure of quarterly inspection bar charts, whereas steps 8-13 produce the same figure for queue times.

Inspection Times

1. Ensure that the most recent data download is saved to the correct folder location:
   - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_AMB.csv**
   - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv**

2. Open **C:\MTRI\SAS\Production\Inspection Time QTR Report.sas** and edit lines 20, 28, 41, 546, and 1585 to reflect the current dates. For example, line 20 says:

   ```
   %let DATE = 'DDMMMYY:00:00:00'dt;
   ```

   Here, change DDMMMYY to 30JUN16 if the most current data corresponds to June 2016. Note that there are 30 days in June, hence the 30.

3. After updating the script, save it, and then run the whole thing.

4. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\QTRInspectionReport.csv**, which is read into the following R script.

5. Open **C:\MTRI\R\PRODUCTION\Inspection Bar Charts Quarterly.R** and edit lines 11, 14, 15, and 16 to reflect the current dates. For example, line 14 says:

   ```
   Current <- "YYYY QQ"
   ```

   Change YYYY to 2016 and QQ to Q2 if the most current data corresponds to June 2016. Similarly, set the previous quarter (Previous <- "YYYY QQ") to the quarter immediately preceding the current quarter (2016 Q1 from the running example) and set the 'Year_Ago' quarter (Year_Ago <- "YYYY QQ") to the same quarter as the current, but from the previous year (2015 Q2).

6. After updating the script, save it, and then run the entire thing – all 96lines. The result is an R figure plot (from ggplot2).

7. Save the figure in *PDF* format to **C:\MTRI\DATA\YYYYMM\Report \Bar Charts Inspection.pdf**.

Queue Times

8. Open **C:\MTRI\SAS\Production\Queue Time QTR Report.sas** and edit lines 20, 28, 41, 541, and 1568 to reflect the current dates in the same way as in **Inspection Time QTR Report.sas**.

9. After updating the script, save it, and then run the whole thing.

10. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\QTRQueueReport.csv**, which is read into the following R script.

11. Open **C:\MTRI\R\PRODUCTION\Queue Bar Charts Quarterly.R** and edit lines 11, 14, 15, and 16 to reflect the current dates in the same way as in **Inspection Bar Charts Quarterly.R**.

12. After updating the script, save it, and then run the entire thing – all 96 lines. The result is an R figure plot (from ggplot2).

13. Save the figure in *PDF* format to **C:\MTRI\DATA\YYYYMM\Report \Bar Charts Queue.pdf**.

Now the requisite *PDF* figures (**Bar Charts Inspection.pdf**, **Bar Charts Queue.pdf**) are available to add to the Data Summary Report.

A.2.2 Monthly Indexed Time Series Plot, Inspection and Queue Times

Run the following steps (1-9) to produce Monthly Indexed Inspection and Queue Times with PBOA Volumes. The R script, **Inspection & Queue Indexed Plots.R**, reads in monthly inspection, queue, and PBOA data to produce a *PDF* figure of the indexed time series.

Inspection Times

1. Ensure that the most recent data download is saved to the correct folder location:

    - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_AMB.csv**
    - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv**

2. Open **C:\MTRI\SAS\Production\Inspection Time Estimation.sas** and edit lines 26, 39, 577, and 594 to reflect the current dates. For example, line 26 says:

```
infile 'C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv'
```

   Here, change MM_DD_YYYY to 06_30_2016 if the most current data corresponds to June 2016. Note that there are 30 days in June, hence the 30. Similarly, change YYYYMM to 201606.

3. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\MonthInsp.csv**, which is read into the R script indicated in Step 7 below.

Queue Times

4. Open **C:\MTRI\SAS\Production\Queue Time Estimation.sas** and edit lines 28, 41, 495, and 512 to reflect the current dates in the same way as in **Inspection Time Estimation.sas**.

5. After updating the script, save it, and then run the whole thing.

6. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\MonthQue.csv**, which is read into the following R script.

7. Open **C:\MTRI\R\PRODUCTION\Inspection & Queue Indexed Plots.R** and edit line 12 to reflect the current dates.

   Note that **Inspection & Queue Indexed Plots.R** calculates indexed time series values based on individual series median values from October 1, 2011 to September 30, 2012. These median values are calculated in **Inspection Time Indexes.sas** and **Queue Time Indexes.sas**, both found in **C:\MTRI\SAS\Misc**.

   Also note that **Inspection & Queue Indexed Plots.R** reads in monthly PBOA volumes. See **Section C. PBOA Truck Volume Data** for details on preparing the necessary data.

8. After updating the script, save it, and then run the entire thing – all 173 lines. Lines 171 to 173 produce an R figure plot (from ggplot2).

9. Save the figure in *PDF* format to **C:\MTRI\DATA\YYYYMM\Report\Index Plot Inspection & Queue.pdf**.

Now the requisite *PDF* figure (**Index Plot Inspection & Queue.pdf**) is available to add to the Data Summary Report.

A.2.3 Aggregate Hour-of-Day/Day-of-Week Plots for Inspection and Queue Times

Inspection Times – Note that Steps 1-4 do not need to be run if Section 4.2.1 has been completed. Inspection Time Estimation.sas produces both MonthInsp.csv and DailyInsp.csv.

Run the following steps (1-13) to produce Median Inspection and Queue Times by Hour-of-Day/Day-of-Week by Crossing-Direction. Steps 1-7 produce a *PDF* figure of quarterly inspection line charts, whereas steps 8-13 produce the same figures for queue times.

1. Ensure that the most recent data download is saved to the correct folder location:
   - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_AMB.csv**
   - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv**

2. Open **C:\MTRI\SAS\Production\Inspection Time Estimation.sas** and edit lines 26, 39, 577, and 594 to reflect the current dates. For example, line 26 says:

```
infile 'C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv'
```

Here, change MM_DD_YYYY to 06_30_2016 if the most current data corresponds to June 2016. Note that there are 30 days in June, hence the 30. Similarly, change YYYYMM to 201606.

3. After updating the script, save it, and then run the whole thing.

4. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\DailyInsp.csv**, which is read into the R script indicated in the next step.

5. Open **C:\MTRI\R\PRODUCTION\Inspection Plots.R** and edit lines 11 and 211 to reflect the current date.

6. After updating the script, save it, and then run lines 1 through 11. Then run lines 116 through 211. The result is an R figure plot (from ggplot2).

7. Save the figure in *PDF* format to **C:\MTRI\DATA\YYYYMM\Report \HD Inspection ALL.pdf**.

Queue Times – Note that Steps 8-10 do not need to be run if Section 4.2.1 has been completed. Queue Time Estimation.sas produces both MonthQue.csv and DailyQue.csv.

8. Open **C:\MTRI\SAS\Production\Queue Time Estimation.sas** and edit lines 28, 41, 495, and 512 to reflect the current dates in the same way as in **Inspection Time Estimation.sas**.

9. After updating the script, save it, and then run the whole thing.

10. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\DailyQue.csv**, which is read into the following R script.

11. Open **C:\MTRI\R\PRODUCTION\Queue Plots.R** and edit lines 11 and 211 to reflect the current date.

12. After updating the script, save it, and then run lines 1 through 11. Then run lines 116 through 211. The result is an R figure plot (from ggplot2).

13. Save the figure in *PDF* format to **C:\MTRI\DATA\YYYYMM\Report\HD Queue ALL.pdf**.

Now the requisite *PDF* figures (**HD Inspection ALL.pdf, HD Queue ALL.pdf**) are available to add to the Data Summary Report.

A.2.4 Quarterly Box Plots for Select Hour-of-Day/Day-of-Week

Run the following steps (1-11) to produce Figure 4.4-A, 4.4-B, and 4.4-C : Quarterly Median Queue and Inspection Times bar charts. Steps 1-6 produce *PDF* figures of quarterly inspection bar charts, whereas steps 7-11 produce the same *PDF* figures for queue times.

Inspection Times

1. Ensure that the most recent data download is saved to the correct folder location:
   - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_AMB.csv**
   - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv**

2. Open **C:\MTRI\SAS\Production\HD Inspection Time QTR Report.sas** and edit lines 10, 18, 31, and 1368 to reflect the current dates. For example, line 20 says:

   ```
   %let DATE = 'DDMMMYY:00:00:00'dt;
   ```

   Here, change DDMMMYY to 30JUN16 if the most current data corresponds to June 2016. Note that there are 30 days in June, hence the 30.

3. After updating the script, save it, and then run the whole thing.

4. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\HDQTRInspectionReport.csv**, which is read into the following R script.

5. Open **C:\MTRI\R\PRODUCTION\HD Inspection Bar Charts Quarterly.R** and edit lines 12, 15, 16, and 17 to reflect the current dates. For example, line 15 says:

   ```
   Current <- "YYYY QQ"
   ```

   Here, change YYYY to 2016 and QQ to Q2 if the most current data corresponds to June 2016. Similarly, set the previous quarter (Previous <- "YYYY QQ") to the quarter immediately preceding the current quarter (2016 Q1 from the running example) and set the 'Year_Ago' quarter (Year_Ago <- "YYYY QQ") to the same quarter as the current, but from the previous year (2015 Q2).

6. After updating the script, save it, and then run all lines up to 45.
   - Run lines 49-72 to produce Figure 4.4-A, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Inspection AMO.pdf**.
   - Run lines 75-109 to produce Figure 4.4-B, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Inspection AOM.pdf**.
   - Run lines 112-135 to produce Figure 4.4-C, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Inspection BWB.pdf**.

Queue Times

7. Open **C:\MTRI\SAS\Production\HD Queue Time QTR Report.sas** and edit lines 10, 18, 31, and 1294 to reflect the current dates in the same way as in **HD Inspection Time QTR Report.sas**.

8. After updating the script, save it, and then run the whole thing.

9. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\HDQTRQueueReport.csv**, which is read into the following R script.

10. Open **C:\MTRI\R\PRODUCTION\HD Queue Bar Charts Quarterly.R** and edit lines 12, 15, 16, and 17 to reflect the current dates in the same way as in **HD Inspection Bar Charts Quarterly.R**.

11. After updating the script, save it, and then run all lines up to 45.
    - Run lines 49-72 for Ambassador Michigan-to-Ontario, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Queue AMO.pdf**.
    - Run lines 75-109 for Ambassador Ontario-to-Michigan, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Queue AOM.pdf**.
    - Run lines 112-135 for BWB, save figure plot to **C:\MTRI\REPORTS\YYYYQQ\Report\HD Queue BWB.pdf**.

Now the requisite *PDF* figures (**HD Inspection AMO.pdf**, **HD Inspection AOM.pdf**, **HD Inspection BWB.pdf**, **HD Queue AMO.pdf**, **HD Queue AOM.pdf**, and **HD Queue BWB.pdf**) are available to add to the Data Summary Report.

A.2.5 Monthly Indexed Times Series Plots for Select Hour-of-Day/Day-of-Week

Run the following steps (1-8) to produce Figures 4.5, 4.6, and 4.7: Monthly Indexed Inspection and Queue Times with PBOA Volumes for Selected Peak Day(s)/Hour(s) line charts. The R script, **HDInspection & Queue Indexed Plots.R**, reads in monthly inspection, queue, and PBOA data to produce *PDF* figures of the indexed time series for the select hours/days.

Inspection Times

1. Ensure that the most recent data download is saved to the correct folder location:
    - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_AMB.csv**
    - **C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv**

2. Open **C:\MTRI\SAS\Production\HD Inspection Time Estimation.sas** and edit lines 15, 28, and 438 to reflect the current dates. For example, line 15 says:

```
infile 'C:\MTRI\DATA\YYYYMM\ceva_data_export_MM_DD_YYYY_BWB.csv'
```

Here, change MM_DD_YYYY to 06_30_2016 if the most current data corresponds to June 2016. Note that there are 30 days in June, hence the 30. Similarly, change YYYYMM to 201606.

3. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\HDMONTHINSP.csv**, which is read into the R script indicated in Step 7 below.

Queue Times

4. Open **C:\MTRI\SAS\Production\HD Queue Time Estimation.sas** and edit lines 15, 28, and 431 to reflect the current dates in the same way as in **HD Inspection Time Estimation.sas.**

5. After updating the script, save it, and then run the whole thing.

6. The output is a *CSV* file saved to **C:\MTRI\DATA\YYYYMM\HDMONTHQUE.csv**, which is read into the following R script.

7. Open **C:\MTRI\R\PRODUCTION\HDInspection & Queue Indexed Plots.R** and edit line 12 to reflect the current dates.

   <u>Note</u> that **HD Inspection & Queue Indexed Plots.R** calculates indexed time series values based on individual series median values from October 1, 2011 to September 30, 2012. These median values are calculated in HD Inspection Time Indexes.sas and **HD Queue Time Indexes.sas**, both found in **C:\MTRI\SAS\Misc**.

   <u>Also note</u> that **HD Inspection & Queue Indexed Plots.R** reads in monthly PBOA volumes.

8. After updating the script, save it, and then run all lines up to 140.

   - Run lines 143-167 for Ambassador Michigan-to-Ontario, , save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Index Plots AMO.pdf.**
   - Run lines 170-205 for Ambassador Ontario-to-Michigan, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Index Plots AOM.pdf.**
   - Run lines 207-231 for Blue Water, save figure plot to **C:\MTRI\DATA\YYYYMM\Report\HD Index Plots BWB.pdf.**

Now the requisite *PDF* figures (HD Index Plots AMO.pdf, HD Index Plots AOM.pdf, and HD Index Plots BWB.pdf) are available to add to the Data Summary Report.

A.3 Programming Appendix

A.3.1 SAS Notes

Important

1. Ensure that the SAS data file **original.sas7bdat** is located at
   - **C:\MTRI\DATA\original.sas7bdat**

This file is vital for all of the above mentioned SAS programs to run correctly.

To Show Line Numbers in SAS

2. Go to the main toolbar and click **Tools** -> **Options** -> **Enhanced Editor** (or just **Editor**). Check the box next to the Show line numbers in the ***General options*** section.

A.3.2 PYTHON Notes

The Python script **C:\MTRI\PY\mtriDownload.py** automates the download of the necessary CEVA data files from the MTRI ftp site. An IMPORTANT NOTE: DO NOT double click **mtriDownload.py** to open it. Python files should be opened either:

- in an appropriate editor, or by
- left-clicking and choosing Edit with IDLE

To automate the download:

1. Edit line 10 of **mtriDownload.py** to reflect the most recent month of data:

   ```
   folder = r"C:\MTRI\DATA\YYYYMM"
   ```

   Where YYYY is the four-digit year and MM is the two-digit month of the most recent data.

2. After updating the script, save it and run the entire thing by hitting the F5 button at the top of the keyboard.

3. The script will take some time to complete the task of downloading all of the data from the ftp site – between 10 and 20 minutes.

4. Once completed, exit all Python windows and go to **C:\MTRI\DATA\YYYYMM**. The necessary CEVA files should now be there.