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Developing and Applying an Analysis Methodology to Identify Flow Generation Influences between Vessel and Truck Shipments

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Project Description

Truck activity is logically connected to vessel activity at a port. In turn, vessel activity is also influenced by truck shipments. Although one might expect a direct and straightforward relation between these two types of shipments, that is rarely the case. For instance, many maritime containers carry consolidated cargos that have multiple and different final destinations. Also, different truck capacities, customs clearance and regulations play a critical role in determining the actual relation between these two types of shipments. This project aims at shedding light on the nuances of maritime and roadway flow relations by quantitatively analyzing the linkages between these two types of shipments.

The study performed a statistical analysis to determine the probability distributions of vessel and truck activity, and then explore the correlation of each activity with the other. The analysis yielded coefficients that function as explanatory values for specific truck flows.

The ultimate purpose of this study is to provide a clearer and quantitative understanding of the relationship between maritime and truck shipments, and by doing so, to provide tools to develop a system for managing trucks that maximizes efficiency for industry, while minimizing industry's negative impacts on a region.

For this purpose, the study selected the Port Freeport as a case study.

Texas Port System and Port Freeport Overview

The Texas port system comprises 11 deep draft ports and numerous shallow water ports that process commercial goods. (Deep draft ports are those that have channels that are 25 ft or deeper.) This port system is one of the largest in the United States and plays a major role in the economy and supply chain of the nation. The Texas ports are all connected via the Gulf Intracoastal Waterway (GIWW), a shallow (12 ft) channel, of which approximately 379 miles run along the Texas coast.[1] There are nearly 1,000 docks, piers, or wharves along the Texas coast that handle various cargoes.[2] The port system serves to complement intermodal transportation and aid in a wider distribution of traffic across multiple modes.

Port Freeport is a deep water port located in Brazoria County, Texas, approximately 60 miles south of Houston. Its jurisdiction covers about 85 percent of the county. The inner harbor, which is home to the main operations of the port, is located in Freeport, Texas. Currently, the port encompasses 186 acres of developed land and roughly 7,000 acres of undeveloped land.[3] In addition to the land assets, the port has 18 public and private docks with berthing areas at a depth of up to 46 feet and a 70 ft. deep hole accessible via the Freeport Harbor Channel, which has an authorized depth of 46 ft.[4]

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[1] Texas Department of Transportation. (2014). Master Plan for the Gulf Intracoastal Waterway in Texas. Available at http://ftp.dot.state.tx.us/pub/txdot-info/tpp/giww/master-plan-0614.pdf.

[2] Texas Department of Transportation. (2015). Ports & Waterways. 2015 Educational Series. Available at http://ftp.dot.state.tx.us/pub/txdot-info/sla/education_series/ports-waterways.pdf.

[3] Port Freeport. (n.d.). About the Port. Website. http://www.portfreeport.com/about.htm.

[4] Port Freeport. (n.d.). Impact Statistics/Charts. Website http://www.portfreeport.com/stats.htm

Among U.S. ports, Port Freeport is ranked as the 19th busiest in foreign tonnage[4] and 31st in total tonnage. **Figure 1**, **Figure 2**, and **Figure 3** show Port Freeport´s total exports and imports and total cargo handled from 2014 until 2017.[5]

Figure 1. Port Freeport Total Exports and Imports 2014-2017.[5]

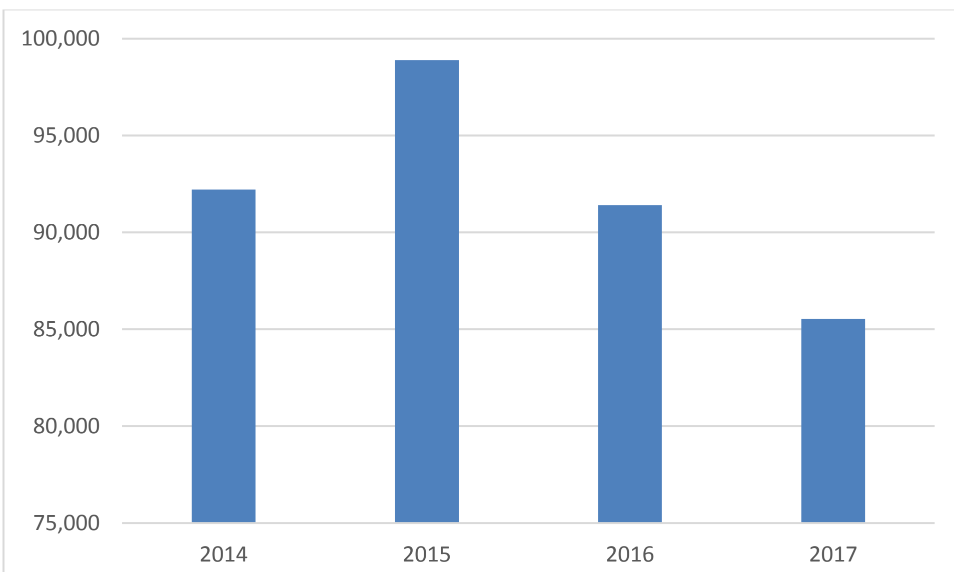


Figure 2. Port Freeport Total Containerized Traffic (TEUs) 2014-2017.[5]

[5] U.S. Army Corps of Engineers. (2017). U.S. Waterway Data: Principal Ports of the United States. Navigation Data Center, Waterborne Commerce Statistics Center – New Orleans, LA. Available at http://www.navigationdatacenter.us/data/datappor.htm.

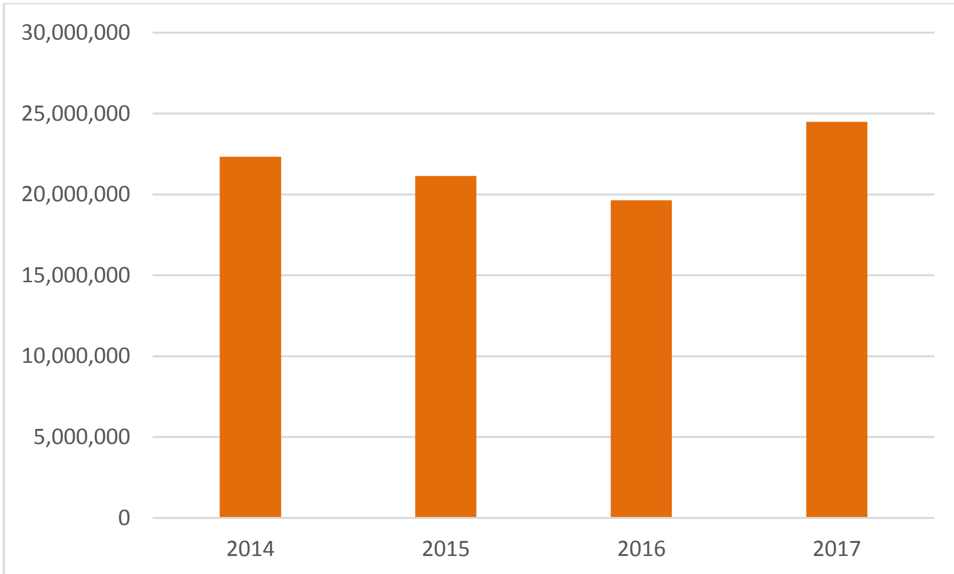


Figure 3. Port Freeport Total Cargo Handled (Tons) 2014-2017.[5]

Main commodities handled by the port include oil and gas, clothing, fresh fruits and vegetables, rice, paper goods, project cargo, plastic resins, aggregate, autos, and windmill components.[6]

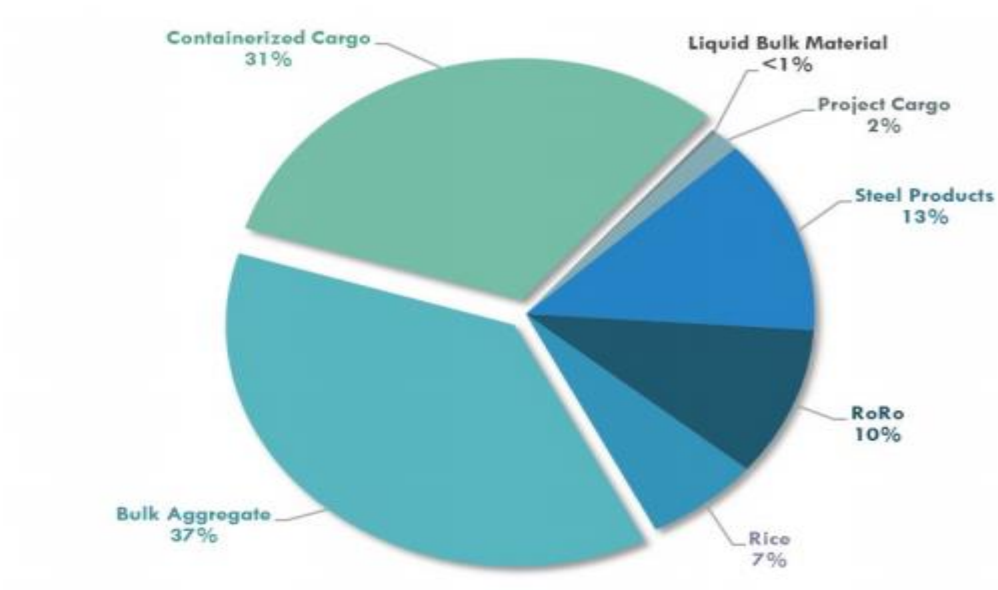


Figure 4. Port Freeport Commodities.[7]

[6] Port Freeport. (July 17, 2015). Welcome to Port Freeport. Presentation. Available at http://www.portfreeport.com/about_files/State%20of%20the%20Port%207.17.15.pdf

[7] B. Huntsman, B. Glover, and J. Rebello Port Freeport Economic Impact Analysis. Texas A&M Transportation Institute. 2019.

Major tenants of the port include Dole Fresh Fruit Company, American Rice, and Chiquita. In addition to these port tenants, there are also private terminal owners present at the port such as Dow Chemical Company and BASF.

The Port of Freeport does trade with nations all around the world, with 11.4 billion dollars of trade generated in 2018. India is by far the largest trade partner of the port this year (2019), but Japan and Mexico also account for over 100 million dollars each so far this year. In 2018, Mexico was the leading trade partner with 15% of the 11.4 billion dollars, followed by Japan with 12% of the revenue. **Figure 5** shows the shares of international trade by country in 2018.

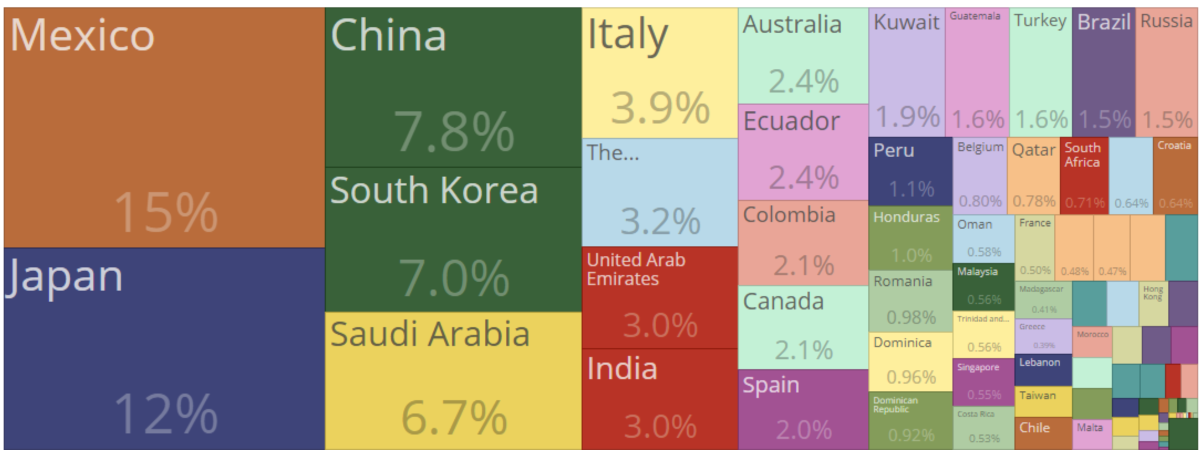


Figure 5. Port Freeport Trade Partners.[8]

Methodological Approach

The methodology comprises three major phases: Data-related activities, statistical analysis, and capacity analysis. Data activities include data collection and data preparation. The statistical analysis includes the models´ specification and results. Capacity analysis includes terminal capacity simulation using specialized software.

Data Collection

The first step of the ground-sea freight flow analysis was to identify needed and available data sources. The requirements of the data are summarized in terms of temporal and geographical perspectives as follows:

- The time resolution of the data should be detailed enough to show the actual fluctuations of the traffic at the port and on the roads nearby. Although finer temporal disaggregation is preferred, daily-level data are acceptable

[8] https://www.ustradenumbers.com/port/Port-of-Freeport,-Texas/

- Temporal coverage of data should be at least one year or more to consider any seasonal trend and to allow adequate sample for weekly analysis.
- The geographic area, especially the roadways, should cover the major traffic arteries to and from Port Freeport. Ideally, it should exclude the road segments whose traffic may be influenced by the outer traffic generators other than Port Freeport.

Considering the key requirements and available data sources, researchers decided to collect data from the following sources:

- Truck volume data: National Performance Management Research Data Set (NPMRDS)
- Vessel call data: PortVision Maritime Business Systems
- Commodity data: Census data and Vessel Visit data from the Port Freeport Administration

PortVision data provide an incoming and outgoing vessel list. However, this dataset does not include any commodity-related information such as type of cargo, tonnage, import and export description, etc. Commodity flow data are essential to analyze the relationship with ground traffic, while vessel "in-and-out" data will only provide an indirect measure of freight traffic.

Therefore, researchers combined the PortVision data with Census data, using the latter to distribute volume on vessels visits; and then researchers performed the initial statistical analysis to obtain the first coefficients of change in truck flows.

After this initial analysis, researchers obtained a dataset (Port Import/Export Reporting Service, or PIERS) from the Port Freeport Administration, which contained commodity information; researchers then updated the initial analysis that was based on PortVision data with an analysis using the Port Freeport Administration data.

Data Preparation

The data collected from the different sources need to be preprocessed before the analysis. Raw data attributes that are not relevant to the purpose of this analysis were removed to facilitate data handling. Some records had incorrect or missing values; however these incorrect records were corrected and kept. There were also additional discrepancies in the data from different sources, such as mismatches of time, location, and units. All these were addressed and corrected. The following paragraphs describe the preparation of the truck volume and commodity data.

Ground Traffic Volume: NPMRDS Data

The National Performance Management Research Data Set (NPMRDS) is a database archive of speed and travel time data procured and sponsored by the FHWA. It covers the National Highway System (NHS), and provides authorized users (state Departments of Transportation and their partnering agencies, such as Metropolitan Planning Organizations) with 5-minute speed data along with the road segment attributes such as Traffic Message Channel (TMC) ID, road name, direction, length, functional system, facility type, and Annual Average Daily Traffic (AADT) counts. AADT could not be used for this analysis because it is too aggregated. However, NPMRDS has added a data density field that researchers used to estimate the truck traffic volume for any given timeframe since 2017.

The main reason for using NPMRDS data for ground volume estimates is that it allows a higher resolution in time-period aggregation than other datasets. Other sources of traffic volume data typically aggregate the data only at monthly or yearly levels. This level of aggregation is not detailed enough for this work.

Researchers used the geographic interface of the NPMRDS analytics feature to obtain traffic condition (i.e., traffic volume), and to determine the roadway segments that are relevant to Port Freeport. **Figure 6** display the geographic coverage of the roadway segments near Port Freeport.

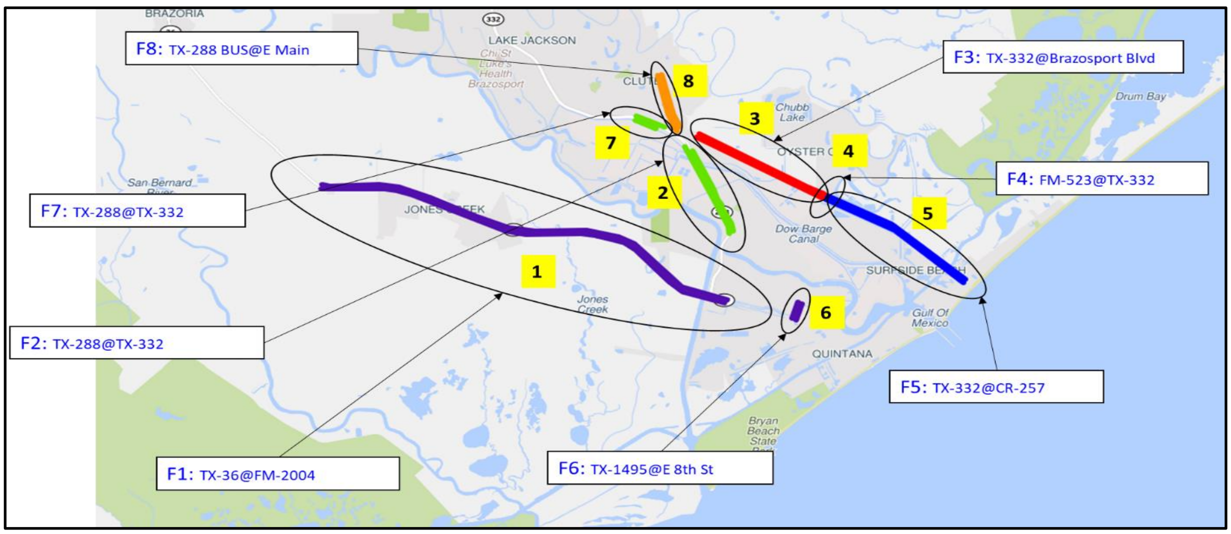


Figure 6. **Main Roadways Connected to Freeport.**[9]

Table 1 shows the ranking by relevance of the road segments. This ranking was developed based on traffic volumes and expert opinion.

Table 1. Ranking of relevance of Freeport neighboring roads segments.

Segment Code	Road Name	Rank by Relevance to Port of Freeport
F1	TX-36	4
F2	TX-288	3
F3	TX-332	1
F4	FM-523	5

[9]*Road coding: F for Freeport, IN for inbound to Port, Out for outbound from port to inland, @ denotes the location of the intersection at the end of the segment.*

Segment Code	Road Name	Rank by Relevance to Port of Freeport
F5	TX-332	8
F6	TX-1495	7
F7	TX-288	2
F8	TX-288	6

Researchers used the NPMRDS data sets with the smallest resolution (5 minutes) in each time period (epoch). Each record contained speed and traffic data density during the five-minute period. Records with no observation were reported as blanks.

The NPMRDS data set does not show actual counts. Instead, it shows counts by range following the following code:

A: Fewer than five reporting vehicles
B: Five to nine reporting values
C: Ten or more reporting vehicles.

To convert these ranges to truck traffic volume nominal counts, researchers estimated average condition of the traffic volume of that time period by replacing “A” with 3 vehicles, “B” with 7 vehicles and “C” with 11 vehicles.

Commodity Data: Vessel Visit Data (from Port Freeport Administration)

The PIERS data provided by the Port Freeport Administration contains comprehensive information about the vessels’ visits, including dock, vessel type, dimension, arrival time, departure time, type of cargo, tonnage, etc. Researchers considered only data pertaining to flows that are typically moved by trucks. Therefore, some types of data, such as liquid cargos, were not considered in the analysis. Count records were matched to tonnage values and aggregated by day, week and month.

Merge of Volume and Commodity Data

At the final step of data preparation, researchers merged truck traffic volume and commodity data using the same time periods. Specifically, for the statistical analysis, researchers produced daily, weekly, and monthly merged data samples.

Statistical Analysis

The objective of this analysis is to find the relationship between truck shipment activities and vessel activities at Port Freeport. Because truck shipment activities cannot be observed directly, truck traffic counts at the port´s vicinity were used as surrogate (proxy) variables.

Based on the roadways identified in the data preparation, the most relevant roads and specific traffic flow directions were identified in Port Freeport´s vicinity. **Figure 7** shows the 2017 truck traffic volumes (into the port- and out of the port volumes) collected from the 5 most relevant roadways (TX-36, TX-288 (South of TX-332), TX-332 (West of FM-523), TX-1495, and TX-288 (West of TX-332)). The traffic volumes for these relevant segments and directions were analyzed together with import and export commodity volumes to assess how import and export commodity volumes affect truck traffic volumes around Port Freeport.

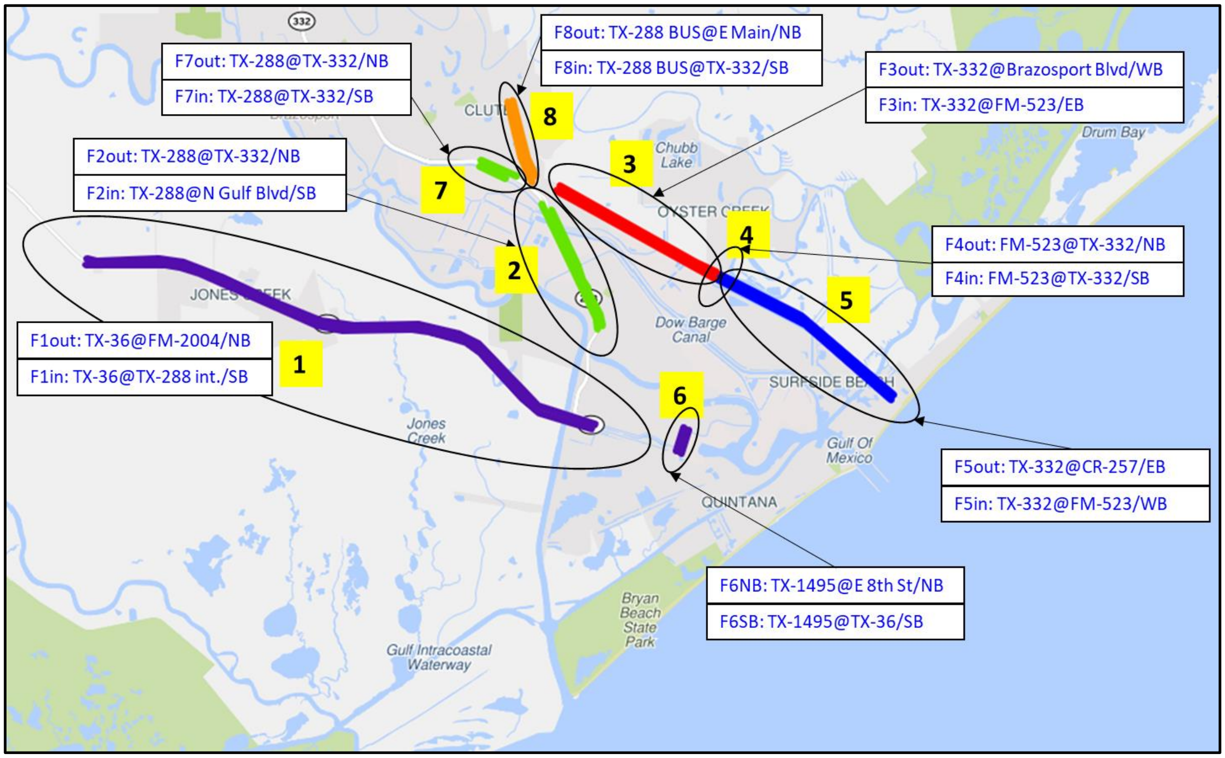


Figure 7. **Relevant Roadways Connected to Freeport, with direction.**[9]

Figure 8 shows weekly truck traffic volumes (truck counts on the Y axis) of the 16 combinations of roadway segments and directions (B1in, B1out, B2in, B2out, B3in, B3out, B4in, B4out, B5in, B5out, B6in, B6out, B7in, B7out, B8in, B8out) deemed as relevant for the Port of Freeport.

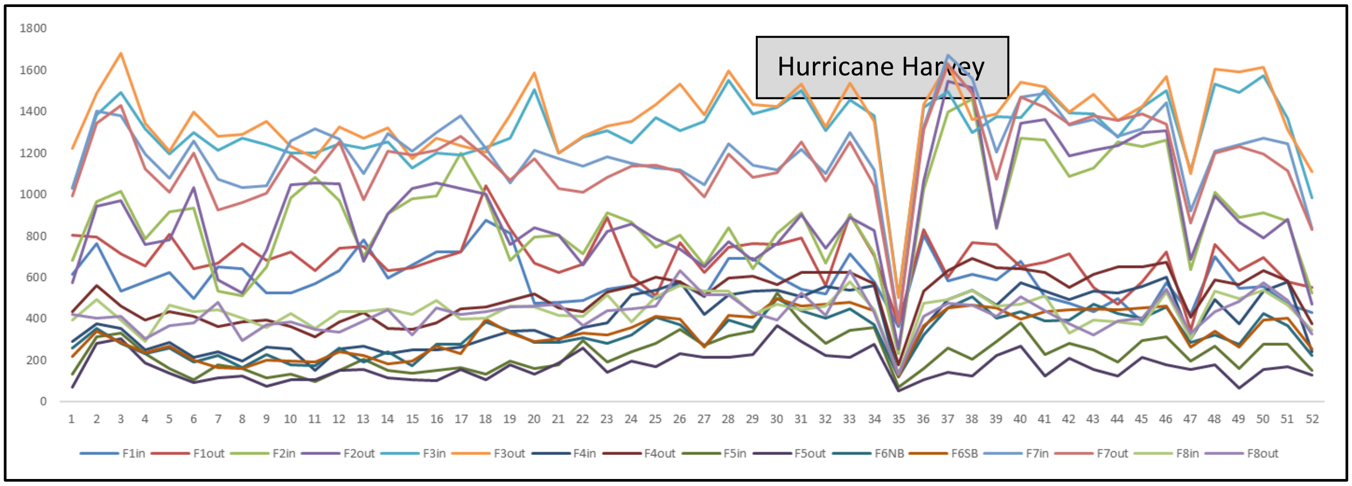


Figure 8. Weekly Truck Shipment Activities at Port Freeport in 2017.

All traffic volumes behave consistently and range between 100 and 1600 trucks per week. Note that in week 35, traffic volumes dropped considerably due to the effects of Hurricane Harvey; however, in week 36 volumes went consistently back to normal. The range presented in this figure will serve to compare and validate the statistical analysis results in terms of truck volumes.

Due to the nature of terminal operations, it is expected that the commodity flows coming from, and going to, the vessels will have some decoupling with truck flows. For instance a container unloaded from the vessel is not necessarily, nor typically, transported immediately out of the terminal or port area. This could be due to several aspects of terminal operations such as, inspections, paper work, warehouse capacities at destination, and even lack of coordination between transportation entities. This decoupling behavior can be captured in terms of lags, which may represent container dwell time at the terminal (e.g., a container sitting at a terminal yard waiting to be loaded onto a ship). For this reason, researchers acknowledge vessel flows as the driver for truck flows, and that vessel activity is far more constrained to arriving, dwelling, and departing times, because of the high costs of the operations and the penalties incurred. Because of this, export vessel departures should happen after loaded truck flows come into the port, and similarly, import vessel arrivals, should occur before loaded truck flows leaving the port. Therefore, the statistical analysis was structured in terms of lags, which allows considering these decoupling events, as well as events where flows are streamlined (e.g., unloaded containers being immediately transported to final destination).

Originally, researchers tried to explore the relationships between daily truck traffic volumes and daily import/export commodity volumes as well as lagged commodity volumes, arriving/leaving by vessel. Due to many missing values in daily commodity volumes, meaningful analyses considering the effects of lagged commodity volumes could not be performed based on the daily data. Therefore, researchers decided to explore the relationships between truck volumes and commodity volumes based on weekly data, which have a significantly smaller proportion of missing data. There were a total of 52 weeks in the weekly data; 51 weeks have non-missing export volumes and 52 weeks have non-missing import volumes.

The relationships between truck traffic volumes for each road segment and direction (i.e., F1in, F1out, F2in, F2out, F3in, F3out, F6in, F6out, F7in, and F7out), and commodity volumes were explored. Because import activity implies that the cargo is first at the vessel, and then is transferred (i.e., loaded on) to trucks, researchers considered commodity volumes from previous weeks as well as volumes from the current week as independent variables that may possibly affect truck traffic volumes. Therefore, lag 0, lag 1 (i.e., a week ago), lag 2 (i.e., two weeks ago), and lag 3 (i.e., 3 weeks ago) import commodity volumes were included in a model exploring the relationship between truck traffic volumes and import commodity volumes. On the other hand, export activities involve transporting cargo by truck to the port, where it is loaded onto vessels. Therefore, truck traffic volumes were expected to be correlated with subsequent export commodity volumes on vessels, and not with preceding export commodity volumes. Then, researchers considered lag 0, lag -1 (i.e., a week after), lag -2 (i.e., two weeks after), and lag -3 (i.e., three weeks after) as independent variables. Also, to aid separation of "through truck traffic volumes" from actual "in and out of the port truck traffic volumes", researchers included truck traffic volumes from the previous week (lag 1 truck volumes) at the same segment as a covariate in the model. Inclusion of lag 1 truck volumes in the model was expected to help identify the relationship between actual truck shipment activities and commodity volumes.

In summary, researchers explored the following three models for truck traffic volumes at each road segment based on weight and TEU[10].

- Model 1 with Import commodity volumes (lags 0, 1, 2, 3) and truck volumes from the previous week (lag 1 truck volumes) as independent variables
- Model 2 with Export commodity volumes (lags 0, -1, -2, -3) and truck volumes from the previous week (lag 1 truck volumes) as independent variables
- Model 3 with Import commodity volumes (lags 0, 1, 2, 3), Export commodity volumes (lags 0, -1, -2, -3), and truck volumes from the previous week (lag 1 truck volumes), as independent variables

Table 2 shows the models explored in the analysis, and the lags they include.

Table 2. Analysis Models.

	Independent Variables (Commodity Volume Lags)		
	Model	Import	Export
Weight	1	0, 1, 2, 3	
	2		0, -1, -2, -3
	3	0, 1, 2, 3	0, -1, -2, -3
TEU	1	0, 1, 2, 3	
	2		0, -1, -2, -3
	3	0, 1, 2, 3	0, -1, -2, -3

[10] TEU = twenty-foot equivalent unit, the standard unit of measure for container traffic. A container that is 20 feet long is one TEU; a 40-foot container is two TEU.

It is important to note that each of these 6 general models was applied to each roadway segment and direction. Researchers assumed missing commodity volumes as zeros, and used R2 and adjusted R2 as fitting (goodness of fit) parameters of the models. (Refer to **Appendix A** – Detailed statistical output for regression outputs).

Terminal Capacity and Operations Analysis

The statistical analysis did not explore specific causes of traffic flows changes. One of the most likely causes of lags is terminal capacity and terminal operations. This phase of the analysis looked into estimating terminal capacity and operations, and its throughputs. The latter could help informing decision-making in terms of infrastructure and operations.

Researchers collected data pertaining to Freeport´s terminal operations. Data were consolidated in tables to serve as input for simulations. **Table 3** and **Table 4** show the input data. Because of data availability issues, the vessels shown in **Table 5** are all container ships.

Table 3. General Operational Information.

Containers mix information per terminal	Reefers make up 45% of container activity
Share of transshipment	0%
Shortsea	0%
Percentage of containers that are 40’	81%

Table 4. Dock-Specific Information.

Data Element	Dock 5	Docks 1-3	Velasco
Dimensions	103 acres (red polygon in **Appendix B** – Docks 1-3, Dock 5, and yard area)		50 acres (red polygon in **Appendix** C – Velasco Terminal and yard area)
Yard Capacities (TEUs)	3385		4818

Data Element	Dock 5	Docks 1-3	Velasco
Throughput distribution	6,586 TEU (year 2017)	20,215 TEU (year 2017)	32,084 TEU (year 2017)
Vessel types	0 jumbo, 1 medium, 0 feeder vessels (year 2017)	0 jumbo, 1 medium, 0 feeder vessels (year 2017)	0 jumbo, 6 medium, 2 feeder vessels (year 2017)
Number of vessel visits	0 jumbo, 9 medium, 0 feeder vessel visits (year 2017)	0 jumbo, 28 medium, 0 feeder vessel visits (year 2017)	0 jumbo, 52 medium, 13 feeder vessel visits (year 2017)
No. Of docks per terminal	berth 5 (see supplement 3)	berth 1, berth 2, berth 3 (see supplement 3)	1 Dock (berth 7)
No. Of cranes per dock/terminal	One mobile crane (Gottwald mobile crane rated at 110 Tons) covers both areas of dock 5 and dock 1-3 (see supplement 4)		2 cranes (two state-of-the-art ZPMC Post-Panamax Gantry Cranes) (maximum safe working load per crane is 110 tons)

Table 5. Input Vessel Information.

Vessel	IMO Number [11]	Capacity (TEU)	Jumbo/ Medium / Feeder	Length (mts.)	Width (mts.)	Max Draft (mts.)	Vessel Visits per Dock			
							5	1-3	Velasco	Grand Total
BOMAR CAEN	9301433	2,556	M	210.06	30.23	11.5			10	10
BOMAR CALAIS	9301445	2,556	M	210.1	30.23	11.5			11	11
DOLE CALIFORNIA	8513467	982	F	178.85	27.01	8.666	9	28	11	48
DOLE COSTA RICA	8900335	982	F	178.99	27.05	8.666			2	2
MSC CORINNA	9307267	2,526	M	210	30.17	11.5			10	10
MSC WESER	9236690	2,524	M	208.16	29.8	11.4			9	9
MSC ZEBRA	9231157	2,602	M	210	30.17	11.5			11	11
TIGER	9307841	2,524	M	207.46	29.8	11.4			1	1
Grand Total							**9**	**28**	**65**	**102**

Researchers opted for Chesscon simulation software for the capacity analysis. Chesscon is an event-based (discrete) simulation package that allows simulation of stochastic events. The main advantage of Chesscon is that it offers a specialized module named "Chesscon Capacity," which specifically assesses terminal capacity. This capacity module simulates flows to determine operational capacity. Main

[11] IMO=International Maritime Organization. The IMO number for a vessel stays with the vessel its entire life.

performance features include a limitless number of system elements and interrelations, easy representation of dynamic behavior, differentiation by vessel types and various type of containers. Chesscon works by first defining the terminal area and its components such as stack buffers and quays. The terminal area and components design is considered the first step in the Chesscon capacity analysis. The second step in the analysis is the input of all data in the simulation package. These data included vessel information (**Figure 9**), crane data (**Figure 10**), and container flow information (**Figure 11**).

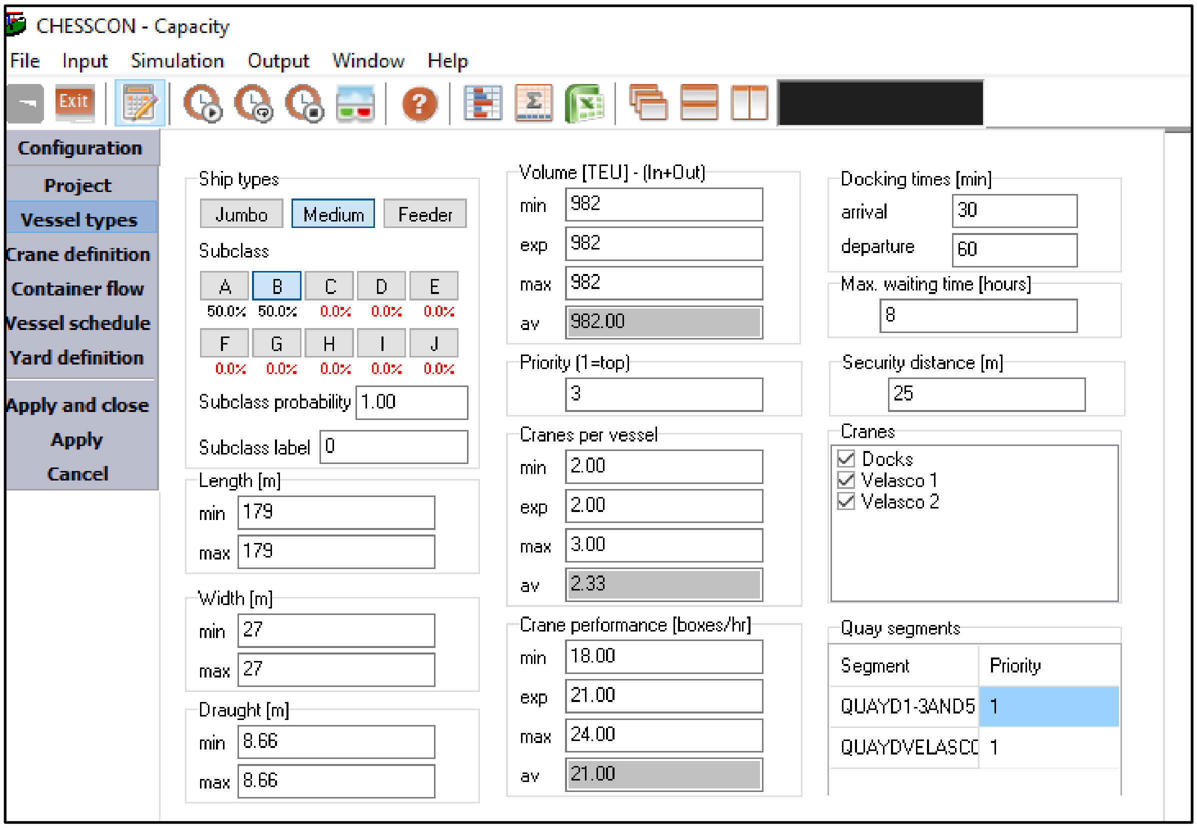


Figure 9. Chesscon vessel information input screen.

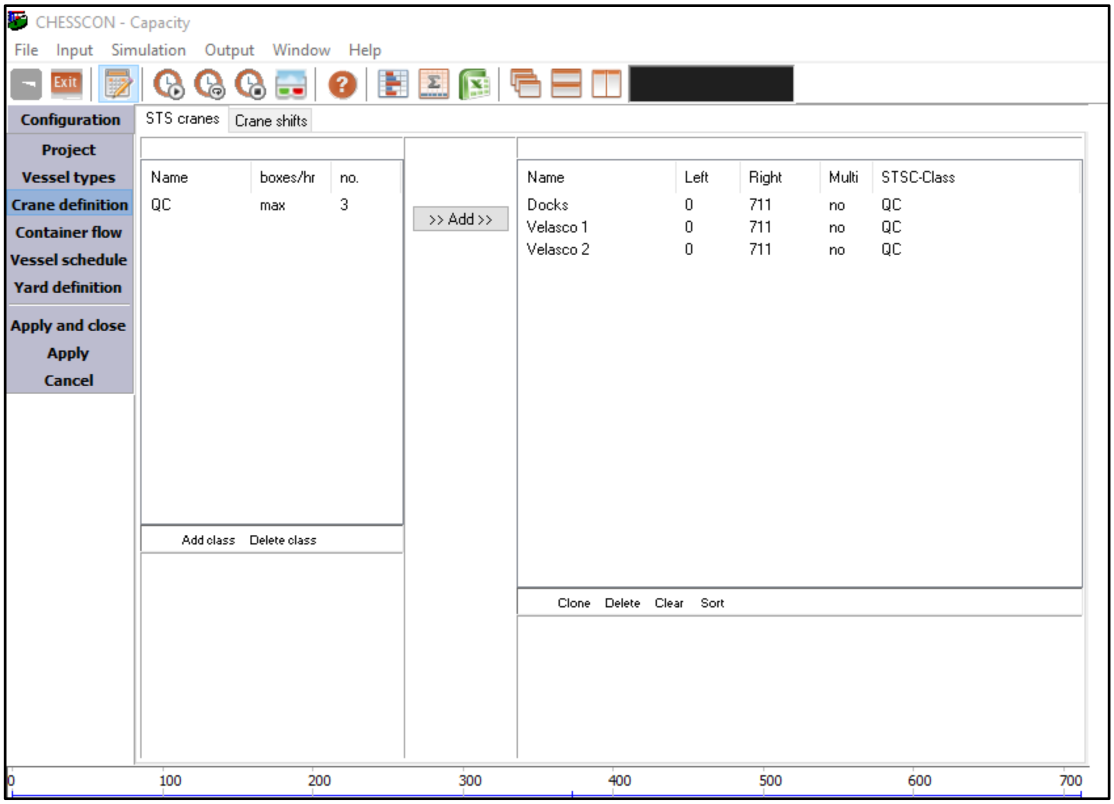


Figure 10. Chesscon crane definition input screen.

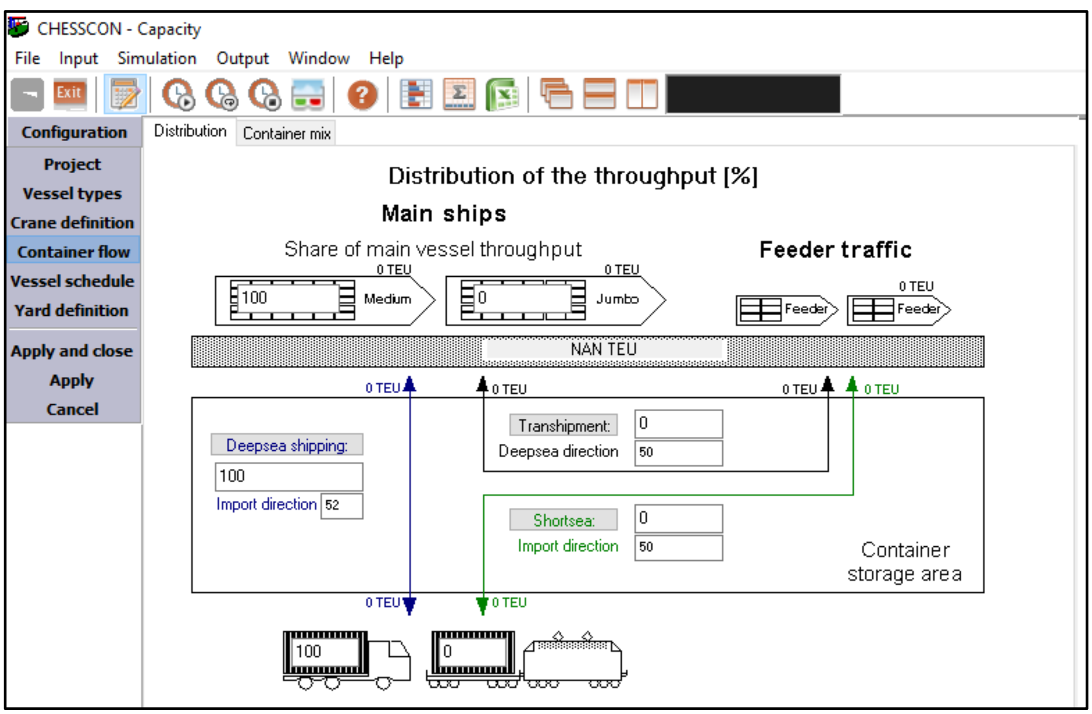


Figure 11. Chesscon container flow input screen.

Next, as the third step, the vessel schedule is generated. This vessel schedule visit is the basis for the simulation runs. The vessel schedule is generated by determining a projected yearly throughput (**Figure 12**), which in the case of Freeport is roughly 60,000 TEUs.

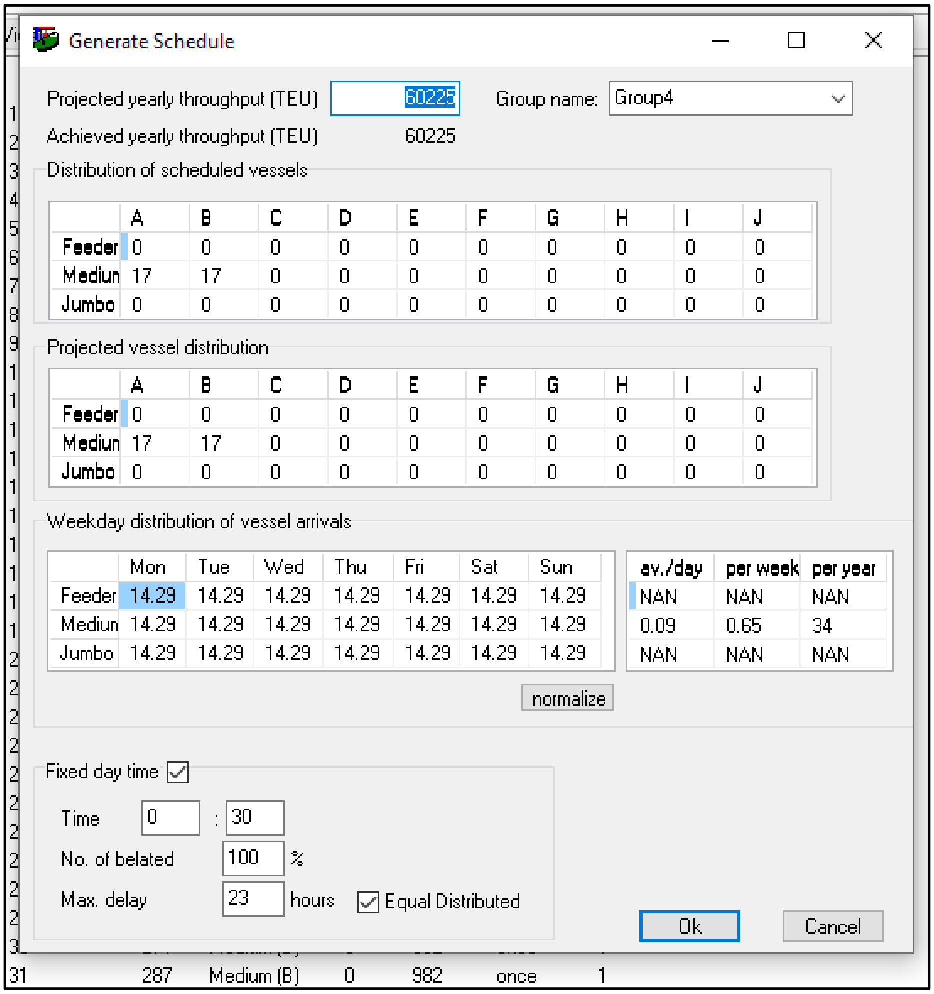
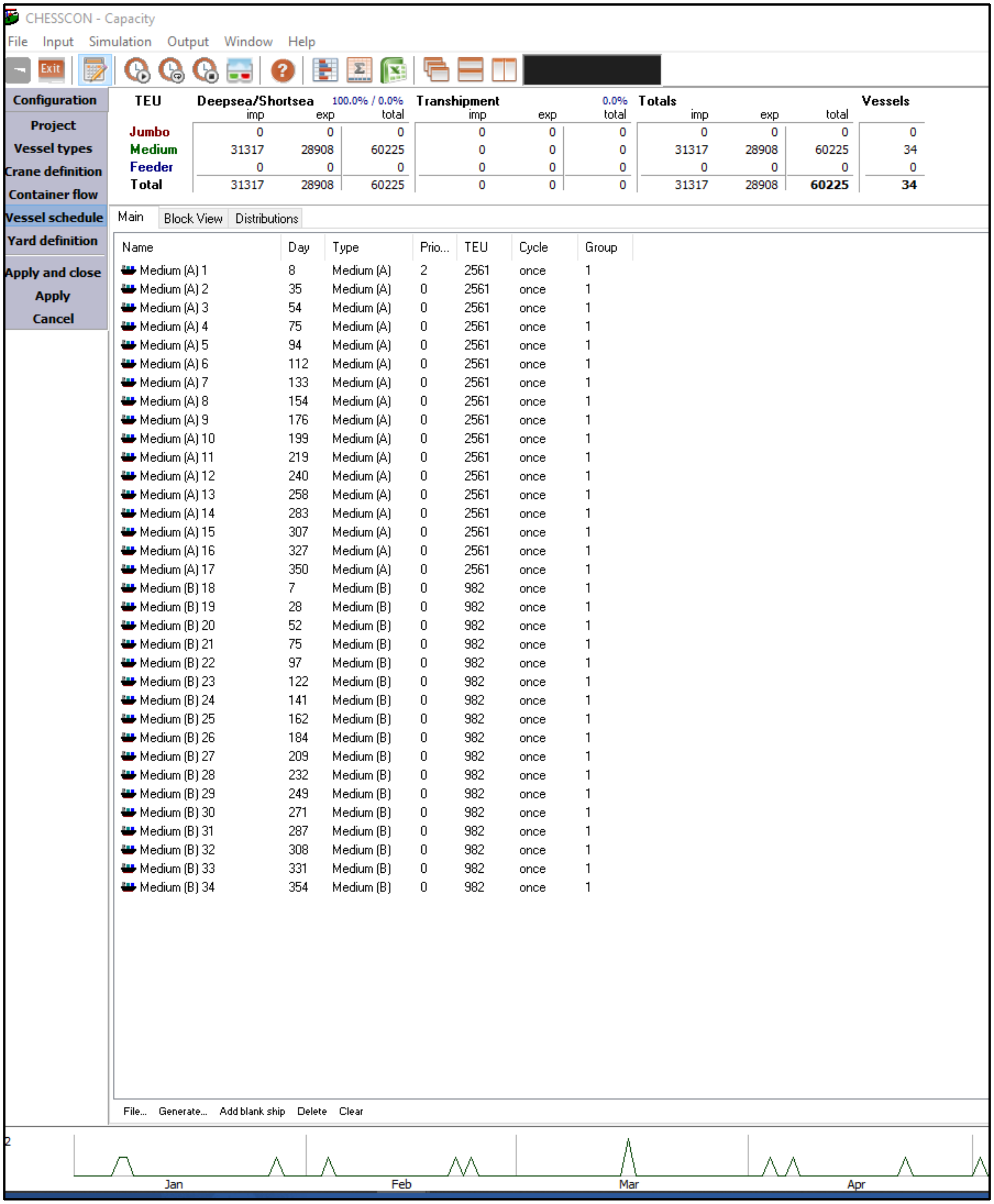


Figure 12. Vessel schedule generation screen.

The actual vessel schedule generated for the simulation is shown in **Figure 13**.



TEU	Deepsea/Shortsea imp	exp	total	Transhipment imp	exp	total	Totals imp	exp	total	Vessels
	100.0% / 0.0%					0.0%				
Jumbo	0	0	0	0	0	0	0	0	0	0
Medium	31317	28908	60225	0	0	0	31317	28908	60225	34
Feeder	0	0	0	0	0	0	0	0	0	0
Total	31317	28908	60225	0	0	0	31317	28908	60225	34

Name	Day	Type	Prio...	TEU	Cycle	Group
Medium (A) 1	8	Medium (A)	2	2561	once	1
Medium (A) 2	35	Medium (A)	0	2561	once	1
Medium (A) 3	54	Medium (A)	0	2561	once	1
Medium (A) 4	75	Medium (A)	0	2561	once	1
Medium (A) 5	94	Medium (A)	0	2561	once	1
Medium (A) 6	112	Medium (A)	0	2561	once	1
Medium (A) 7	133	Medium (A)	0	2561	once	1
Medium (A) 8	154	Medium (A)	0	2561	once	1
Medium (A) 9	176	Medium (A)	0	2561	once	1
Medium (A) 10	199	Medium (A)	0	2561	once	1
Medium (A) 11	219	Medium (A)	0	2561	once	1
Medium (A) 12	240	Medium (A)	0	2561	once	1
Medium (A) 13	258	Medium (A)	0	2561	once	1
Medium (A) 14	283	Medium (A)	0	2561	once	1
Medium (A) 15	307	Medium (A)	0	2561	once	1
Medium (A) 16	327	Medium (A)	0	2561	once	1
Medium (A) 17	350	Medium (A)	0	2561	once	1
Medium (B) 18	7	Medium (B)	0	982	once	1
Medium (B) 19	28	Medium (B)	0	982	once	1
Medium (B) 20	52	Medium (B)	0	982	once	1
Medium (B) 21	75	Medium (B)	0	982	once	1
Medium (B) 22	97	Medium (B)	0	982	once	1
Medium (B) 23	122	Medium (B)	0	982	once	1
Medium (B) 24	141	Medium (B)	0	982	once	1
Medium (B) 25	162	Medium (B)	0	982	once	1
Medium (B) 26	184	Medium (B)	0	982	once	1
Medium (B) 27	209	Medium (B)	0	982	once	1
Medium (B) 28	232	Medium (B)	0	982	once	1
Medium (B) 29	249	Medium (B)	0	982	once	1
Medium (B) 30	271	Medium (B)	0	982	once	1
Medium (B) 31	287	Medium (B)	0	982	once	1
Medium (B) 32	308	Medium (B)	0	982	once	1
Medium (B) 33	331	Medium (B)	0	982	once	1
Medium (B) 34	354	Medium (B)	0	982	once	1

Figure 13. Vessel schedule screen.

Yard capacities and allocations to containers are designated before running the simulation (**Figure 14**). For the case of Port Freeport 5 yards are assigned the standard operational utilization of 80%.

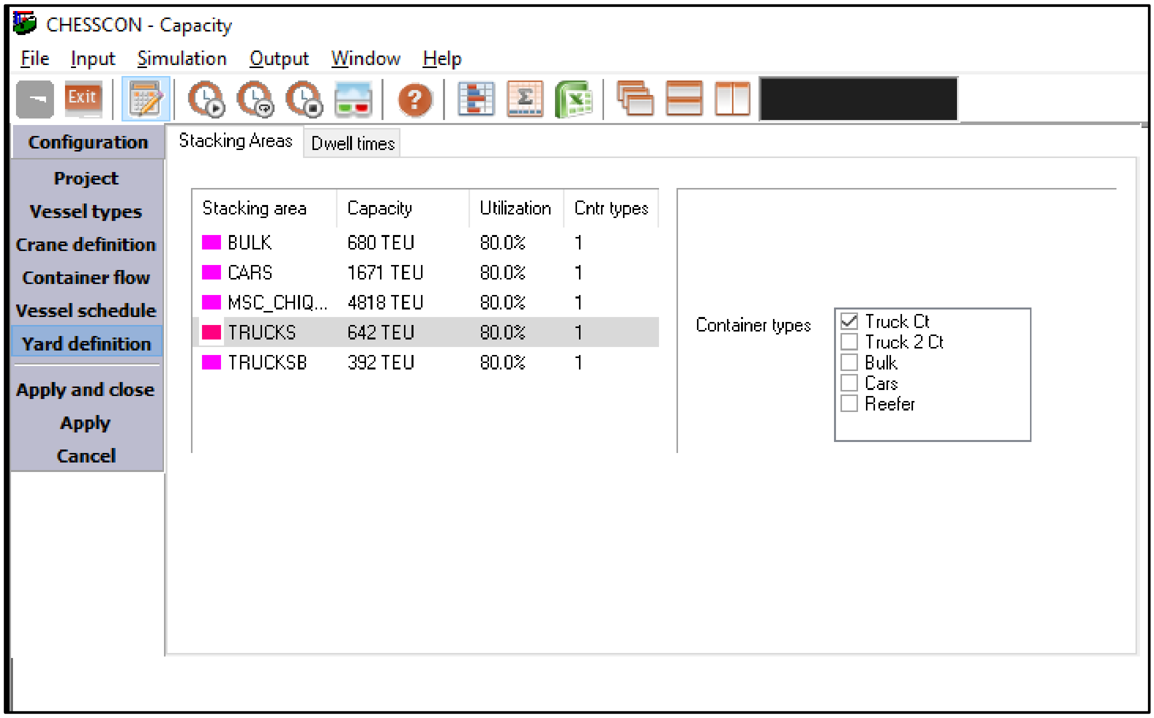


Figure 14. Yard definition screen.

After all data are fed in the software and all allocations are complete, the simulation parameters are set. For this study, the simulation period is 1 year, simulated randomly; 20 simulations are run to obtain results (**Figure 15**).

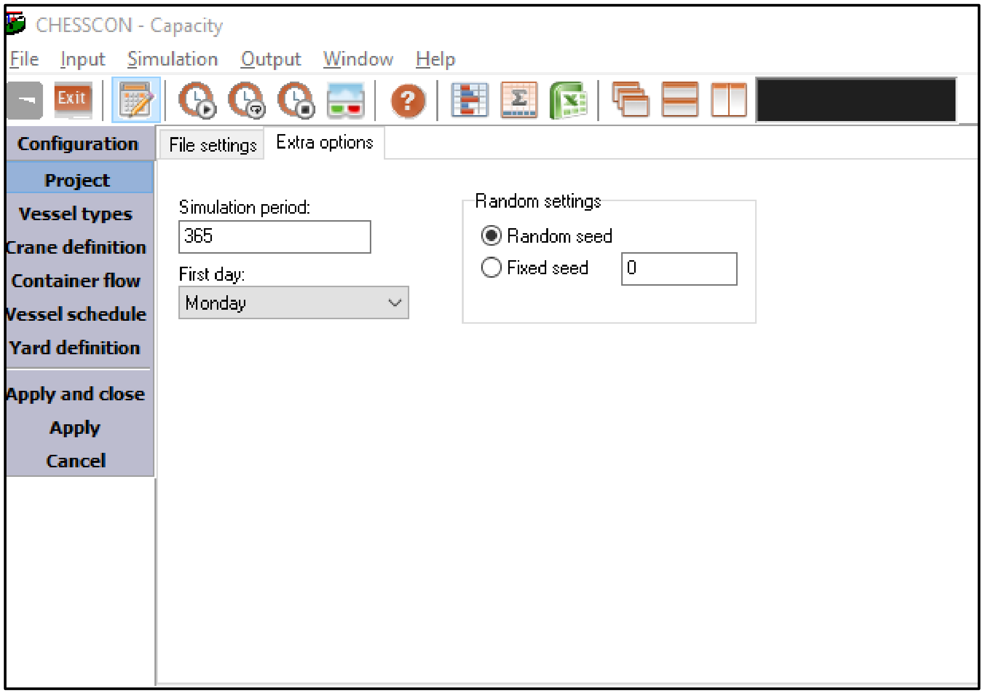


Figure 15. Simulation settings.

Results/Findings

The statistical analysis results are in the form of coefficients representing the increments of traffic for the corresponding roadway and direction by a unit of change in import or export weights. **Table 6** consolidates all models´ regression results showing these traffic increment coefficients.

Green cells highlight better model fit. Yellow and orange cells shows the significant coefficients (at 95% and 90% respectively), from better fitted models. We can see that results suggest that Tx-36 Northbound (F1out) is the only road and direction significantly correlated to export flows.

Table 6. Summary of Regression Results.

Truck Volumes	Goodness of fit	Model 1 (with Import weights)	Model 2 (with Export weights)	Model 3 (with Import weights, Export weights)
F1in TX-36	R^2	0.12	0.09	0.13
	R^2 adj	0.02	-0.02	-0.1
	Sig at α=0.05	None	None	None
	Sig at α=0.1	None	None	None
F1out TX-36	R^2	0.13	0.26	0.37
	R^2 adj	0.03	0.17	0.21
	Sig at α=0.05	None	Export_lag0(3.2681e-5), Export_lag-2(-2.918e-5)	Export_lag0(3.8369e-5), Export_lag-2(-2.918e-5)
	Sig at α=0.1	Import_lag0(1.5403e-6)	Export_lag0(3.2681e-5), Export_lag-2(-2.918e-5)	Export_lag0(3.2681e-5), Export_lag-2(-0.000027)
F2in TX-288	R^2	0.21	0.24	0.27
	R^2 adj	0.12	0.15	0.07
	Sig at α=0.05	None	None	None
	Sig at α=0.1	None	None	None
F2out TX-288	R^2	0.25	0.26	0.31
	R^2 adj	0.16	0.17	0.13
	Sig at α=0.05	None	None	None
	Sig at α=0.1	None	None	None

Truck Volumes	Goodness of fit	Model 1 (with Import weights)	Model 2 (with Export weights)	Model 3 (with Import weights, Export weights)
F3in TX-332	R^2	0.11	0.1	0.13
	R^2 adj	0	-0.02	-0.09
	Sig at α=0.05	Import_lag2(2.523e-6)	None	None
	Sig at α=0.1	Import_lag2(2.523e-6)	None	None
F3out TX-332	R^2	0.11	0.09	0.11
	R^2 adj	0.01	-0.02	-0.13
	Sig at α=0.05	Import_lag2(2.6464e-6)	None	None
	Sig at α=0.1	Import_lag2(2.6464e-6)	None	None
F6NB TX-1495	R^2	0.39	0.48	0.49
	R^2 adj	0.31	0.42	0.36
	Sig at α=0.05	None	None	None
	Sig at α=0.1	None	None	None
F6SB TX-1495	R^2	0.46	0.52	0.55
	R^2 adj	0.4	0.46	0.43
	Sig at α=0.05	None	None	None
	Sig at α=0.1	None	None	None
F7in TX-288	R^2	0.12	0.08	0.15
	R^2 adj	0.01	-0.04	-0.08
	Sig at α=0.05	None	None	None
	Sig at α=0.1	Import_lag2(2.3139e-6)	None	None
F7out TX-288	R^2	0.11	0.11	0.15
	R^2 adj	0.01	0	-0.08

Truck Volumes	Goodness of fit	Model 1 (with Import weights)	Model 2 (with Export weights)	Model 3 (with Import weights, Export weights)
	Sig at α=0.05	None	None	None
	Sig at α=0.1	None	None	None

Table 7 and **Table 8** show the parameter estimates for each F1out regression (model 2 and 3). Highlighted numbers show the intercept (i.e., baseline flow) and statistically significant parameter estimates.

Table 7. Model 2 F1out parameter estimates.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	674.40571	115.05	5.86	<.0001*
Export_lag0	3.2681e-5	1.054e-5	3.10	0.0035*
Export_lag-1	-3.885e-6	1.123e-5	-0.35	0.7312
Export_lag-2	-2.918e-5	0.000012	-2.45	0.0189*
Export_lag-3	9.5094e-6	1.141e-5	0.83	0.4094
F1out_lag1	-0.034655	0.152463	-0.23	0.8213

Table 8. Model 3 F1out parameter estimates.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	609.82445	134.3542	4.54	<.0001*
Import_lag0	3.1161e-7	9.021e-7	0.35	0.7319
Import_lag1	-1.117e-6	9.014e-7	-1.24	0.2237
Import_lag2	2.7682e-7	8.378e-7	0.33	0.7431
Import_lag3	8.8758e-7	7.791e-7	1.14	0.2626
Export_lag0	3.8369e-5	1.288e-5	2.98	0.0053*
Export_lag-1	-1.134e-5	1.273e-5	-0.89	0.3793
Export_lag-2	-0.000027	1.242e-5	-2.18	0.0364*
Export_lag-3	8.5311e-6	1.141e-5	0.75	0.4596
F1out_lag1	0.048307	0.165775	0.29	0.7725

Table 7 and **Table 8** show the baseline (i.e., intercept) to be between 674 and 609 trucks traveling out of the port on Tx-36 in any given week, which is consistent with the range shown in **Figure 8**. These parameters also show that outgoing traffic on Tx-36 (F1out) increases, with respect to the baseline of 674-609 trucks, between 0.000032681 and 0.000038369 trucks per each kg of export cargo by vessel in the same week; and decreases by 0.00002918 trucks per kg of export cargo by vessel two weeks later.

In other words, a vessel visit with 1,000 TEUs of cargo (roughly 15,240 tons of cargo[12]), would represent between 499 and 585 additional trucks traveling on Tx-36 inland in the same week, and 444 trucks less than the baseline of 674-609 trucks, on Tx-36 inland two weeks later. **Figure 16** shows this traffic changes in Tx-36 inland direction.

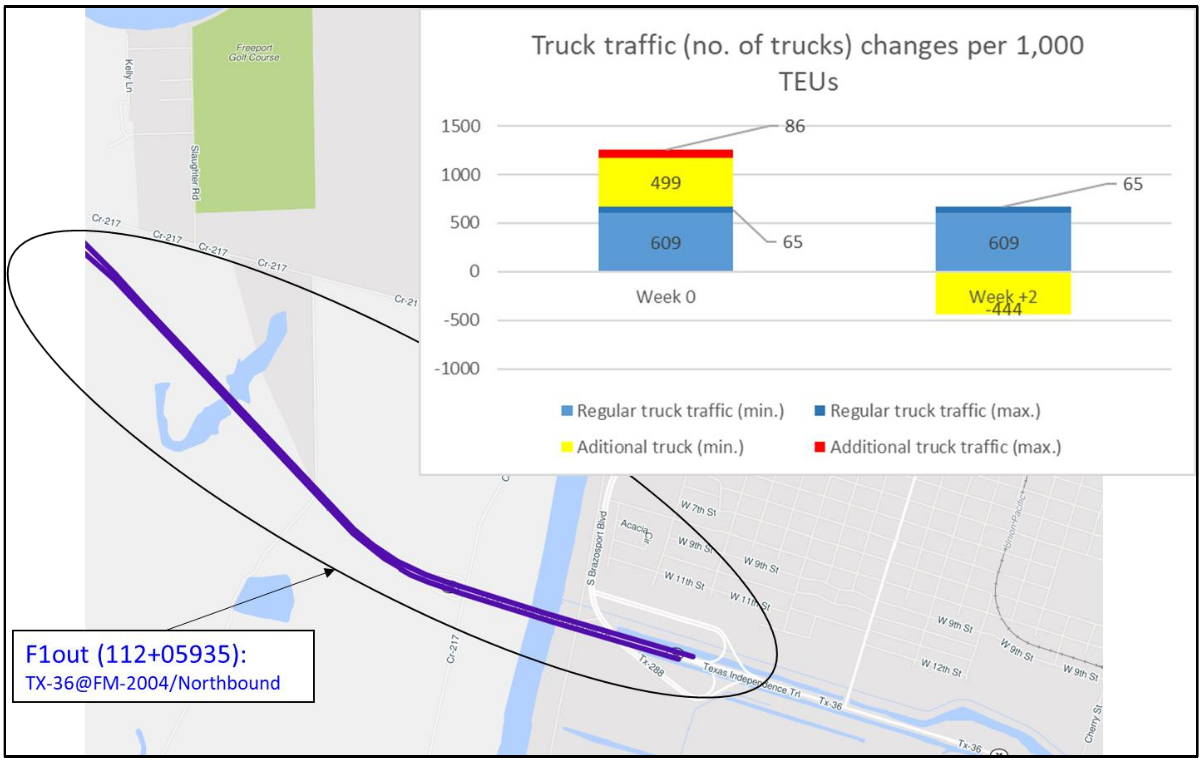


Figure 16. Truck traffic (no. of trucks) changes per 1,000 TEUs in Tx-36 Inland direction

These results seem counterintuitive given that the direction of F1out is inland, but the relation is with export flows, not with import. This is because traffic counts are not exclusive to loaded trucks (i.e., they include empty trucks). Therefore, the traffic impact may be significant because of returning trucks. But, why not to loaded trucks? Since trucks coming back empty had to go into the port loaded just hours before, why wouldn't these loaded trucks have equal impact? The reason may be container inventory at the yard. Trucks are not unloaded directly to the vessel (i.e., the container may be unloaded to the yard, dwell for some time, and then loaded to the vessel), so trucks may be feeding the terminal yards long before vessel arrival (i.e., with long periods or dwell time at the yard). The latter scenario concurs with results from the terminal capacity analysis.

[12] See "How To Calculate Capacity On Shipping Containers" on ITI Manufacturing's website: https://www.itimanufacturing.com/news/calculate-capacity-shipping-containers/

The terminal capacity and operations simulation shows a high utilization (I.e., the use of space or containers slots), of most yards. These can be noted in **Figure 17**, **Figure 18**, and **Figure 19**, which show percentage of utilization on the left Y axis and TEUs on the right Y axis.

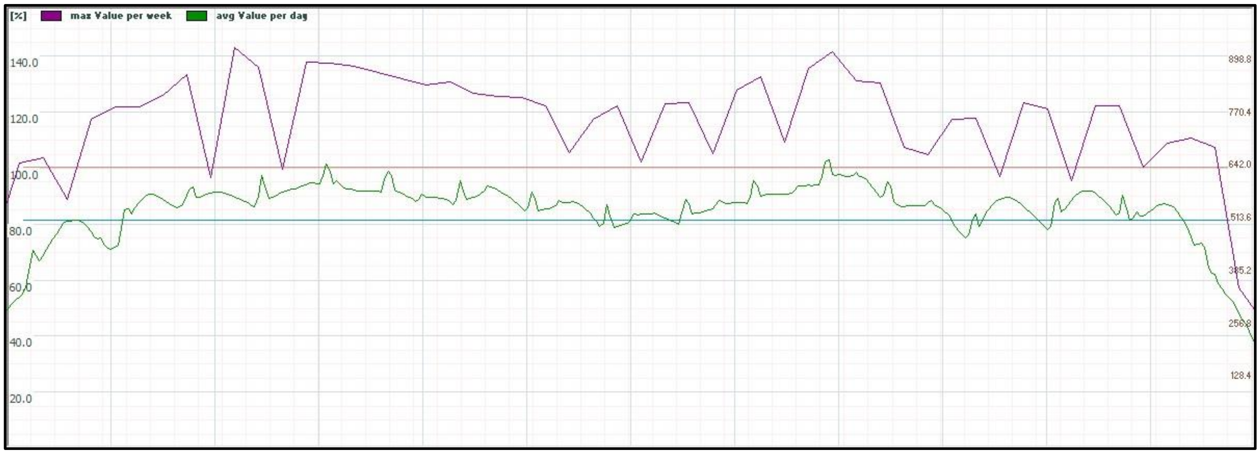


Figure 17. Container Yard A Utilization.

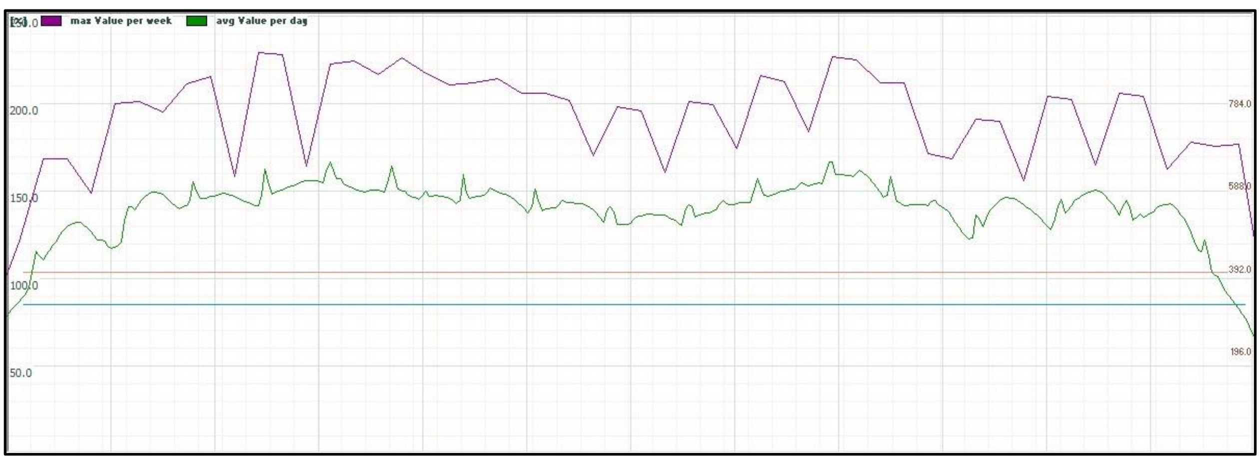


Figure 18. Container Yard B Utilization.

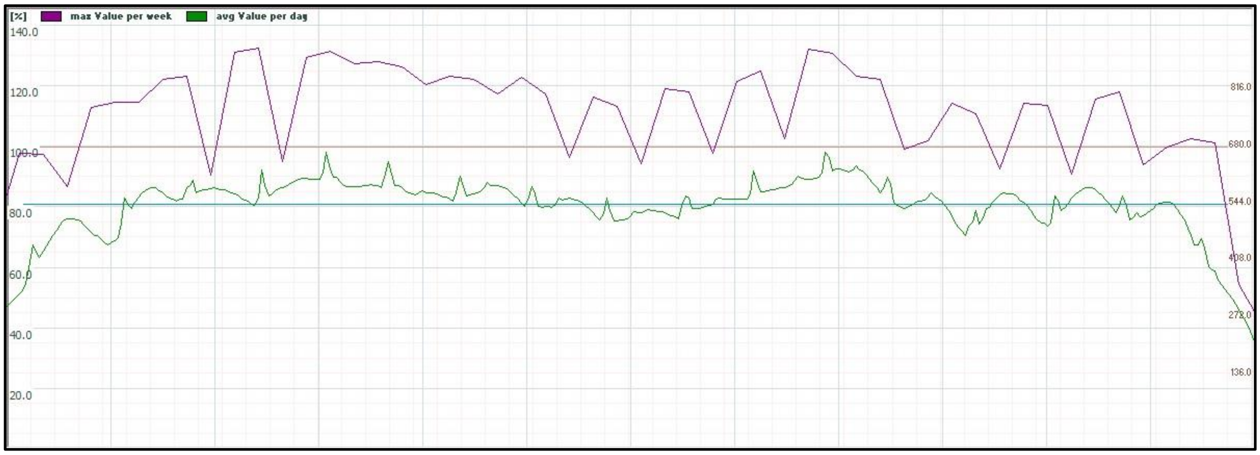


Figure 19. Yard C Utilization.

The ideal utilization is generally below 80% capacity, because container operations typically need empty slots for rotation and general container handling. A utilization higher than 100% means yard slots are completely occupied; hence, surplus containers are probably accommodated in locations not designated for that purpose.

Figure 20, **Figure 21** and **Figure 22** show the number of days (Y axis) these yards were used at the corresponding percentage (X axis).

Yard occupancy [TEU]		
Min.	Av.	Max.
230.00	547.46	942.00
Given operational capacity: 80.00%		

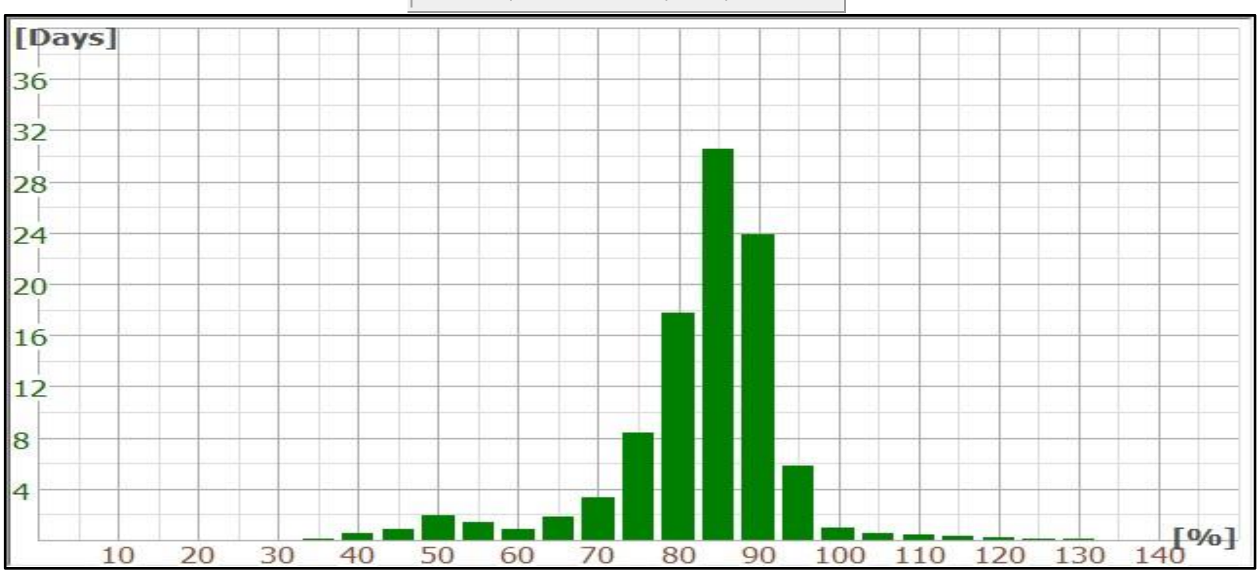


Figure 20. Container A Yard Utilization (Days of percentage utilization).

Yard occupation [TEU]		
Min.	Av.	Max.
226.00	547.72	920.00
Given operational capacity: 80.00%		

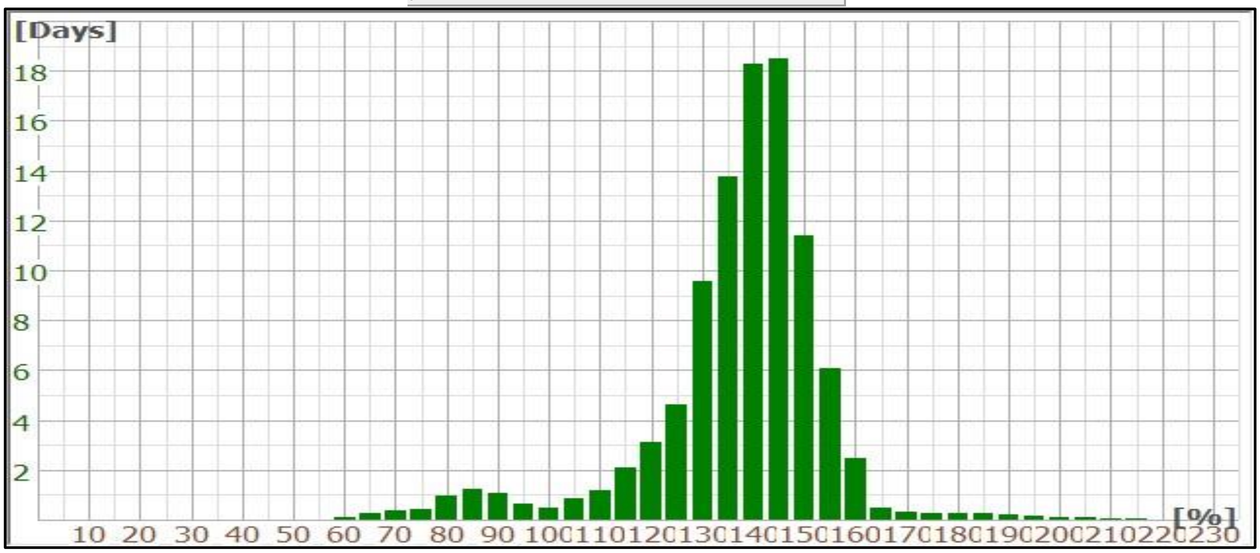


Figure 21. Container B Yard Utilization (Days of percentage utilization).

Yard occupation [TEU]		
Min.	Av.	Max.
226.00	546.77	910.00
Given operational capacity: 80.00%		

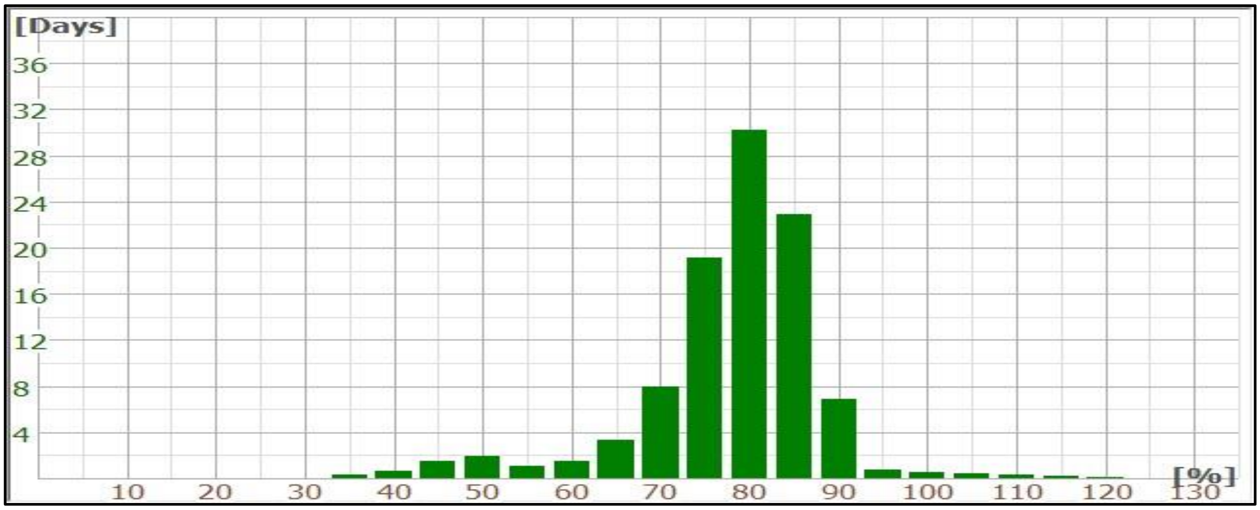


Figure 22. Yard C Utilization (Days of percentage utilization).

The simulation also yielded how the overall incoming and outgoing flows behave daily and weekly (**Figure 23**). The right Y axis denotes TEU, while the left Y axis shows truck counts with weekly curves at the top and daily curves at the bottom.

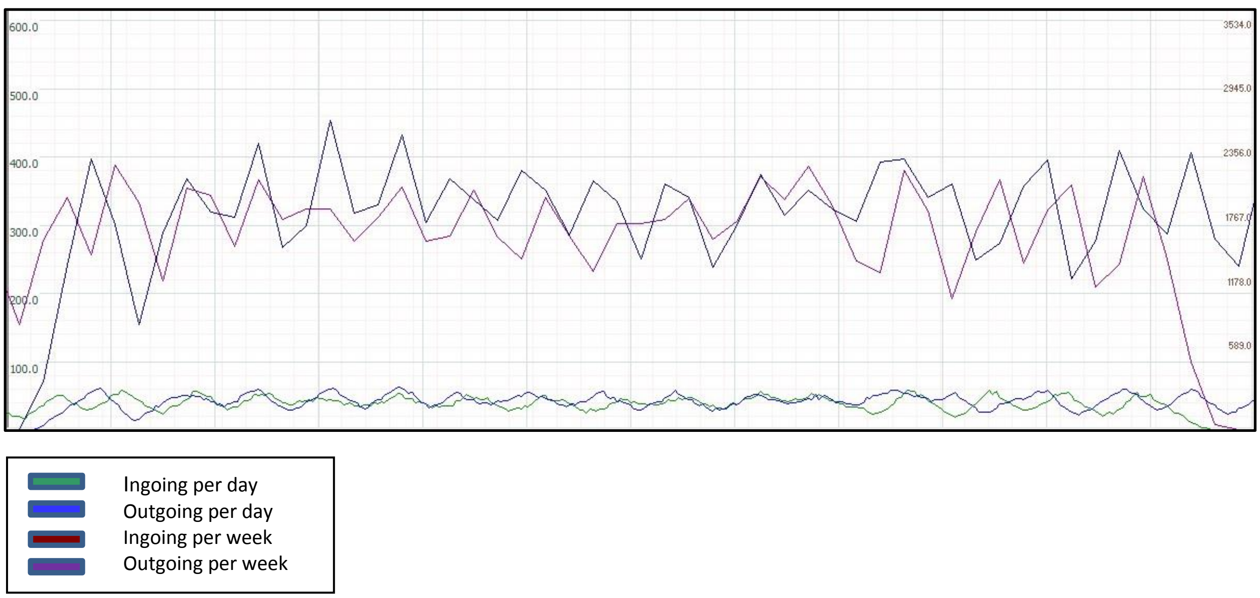


Figure 23. Gate (Truck Flows) Fluctuation.

Ingoing and outgoing flows look consistent. For instance, Ingoing per week and Outgoing per week (the two top curves), behave similarly. However, all curves show valleys and peaks that represent lumping behavior, which could result in the lags already suggested by the statistical analysis.

In addition, high yard utilization means high container inventory, which is congruent with the truck flows lags also shown by the statistical analysis; thus, yards appear to be supporting export inventory prior to vessel arrival.

Impacts/Benefits of Implementation (actual, not anticipated)

This study shed light on the relationship between multimodal flows (trucks and vessels), which will enable agencies and organizations to increase efficiency – and thus competitiveness – for industry, while minimizing negative impacts on a region.

Specifically, this analysis provides estimates of specific traffic changes in specific roads, with specific directions of traffic flows and the time when those changes could be expected (**Table 6**, **Table 7** and **Table 8**). These coefficients represent the main contribution of this study because, even though general results are intuitively straightforward, the magnitude of the impact and delays may not be obtained by simple observation. These coefficients help in planning, by estimating specific changes in the traffic of specific road segments and directions, and the time when those changes will occur (**Figure 16**). This is a powerful tool for planning any activity or change in road infrastructure that is relevant or linked to port operations.

In addition, the analysis explored terminal capacity and operations, which concurred with the statistical findings, by showing high utilization of yards in terms of container inventory (**Figure *17***, **Figure *18***, **Figure *19***, **Figure *20***, **Figure *21***, and **Figure *22***), and by depicting the ingoing and outgoing flows behavior (**Figure 23**). In this way, the terminal capacity analysis and operations provided possible causes for the traffic behavior that was observed. This is also an important part of the research contribution and helpful to determine planning and operational measures to better manage traffic flows from and to seaports.

Altogether, results from the statistical analysis and terminal capacity analysis from the Port Freeport case study will benefit public sector and private sector decision makers in activities such as investment planning, resource allocation, and operations management in general.

Recommendations and Conclusions

Terminal capacity is a determinant and a coupling link for vessel and truck flows. Although the current study provided a basic measure of the role that terminal operations play in vessel-truck behavior, a deeper analysis is recommended to identify more precisely the impacts of terminal operations on these multimodal flows. This study found data availability as an important constraint for a more detailed analysis. Therefore, the main recommendation is to explore new data sources, and evaluate data generation techniques to produce a more complete data set for a more thorough analysis.

Appendix A – Detailed statistical output

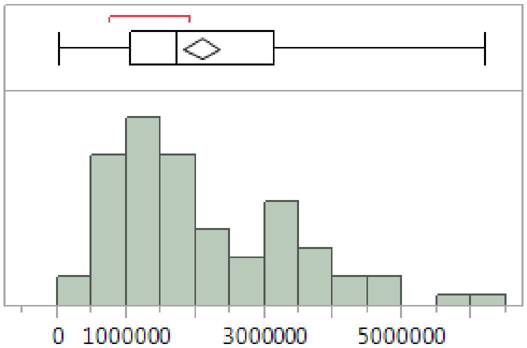
Originally, researchers tried to explore the relationships between daily truck traffic volumes and daily import/export commodity volumes as well as lagged commodity volumes. Due to many missing values in daily commodity volumes (which are presumed to be zeroes representing no vessel activity), physically meaningful analyses considering the effects of lagged commodity volumes could not be performed based on the daily data. **Figure 24** and **Figure 25** show the distribution of daily export and import commodity volumes. It can be seen that there are only 93 days (25% of 365 days) with non-missing (non-zero) export volumes (see **Figure 24**) and 212 days (58% of 365 days) with non-missing import volumes (see **Figure 25**).

Researchers decided to explore the relationships between truck volumes and commodity volumes based on weekly data, which have a significantly lower proportion of missing data. There was a total of 52 weeks in the weekly data; 51 weeks have non-missing export volumes and 52 weeks have non-missing import volumes. **Figure 26** and **Figure 27** show the distribution of weekly export and import commodity volumes.

Figure 28 and **Figure 29** contain overlay plots of weekly import and export commodity volumes as well as weekly truck traffic volumes at each of 10 segments (F1in, F1out, F2in, F2out, F3in, 3out, F6in, F6out, F7in, and F7out) originally selected from roadways around Port Freeport.

Distribution of Daily commodity volumes

PIER_Export Weight



Quantiles

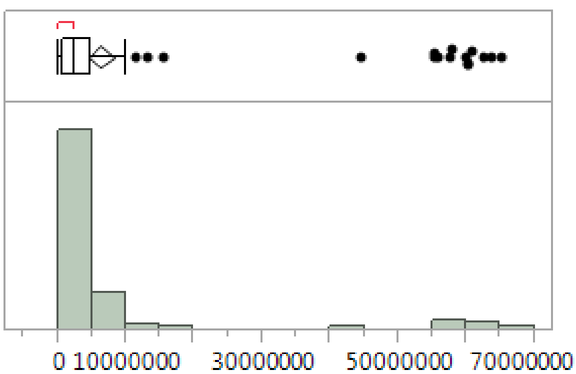
100.0%	maximum	6210093
99.5%		6210093
97.5%		5468754
90.0%		3880470
75.0%	quartile	3148472
50.0%	median	1746533
25.0%	quartile	1054797
10.0%		762642
2.5%		182894
0.5%		20943
0.0%	minimum	20943

Summary Statistics

Mean	2080522.6
Std Dev	1302145.4
Std Err Mean	135026.18
Upper 95% Mea	2348696.3
Lower 95% Mean	1812348.9
N	93

Figure 24. Daily export commodity volumes.

PIER_Import Weight



Quantiles

100.0%	maximum	6.53e+7
99.5%		6.52e+7
97.5%		6.02e+7
90.0%		8916516
75.0%	quartile	4828292
50.0%	median	2473936
25.0%	quartile	715914
10.0%		2767.2
2.5%		81.375
0.5%		1
0.0%	minimum	1

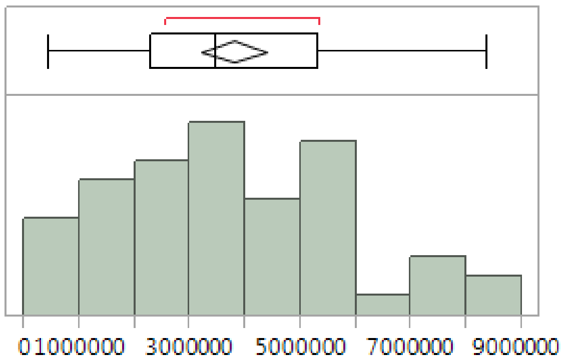
Summary Statistics

Mean	6293295.6
Std Dev	13663505
Std Err Mean	938413.35
Upper 95% Mea	8143162.3
Lower 95% Mean	4443428.9
N	212

Figure 25. Daily import commodity volumes.

Distribution of Weekly Commodity Volumes

PIER_Export Weight



Quantiles

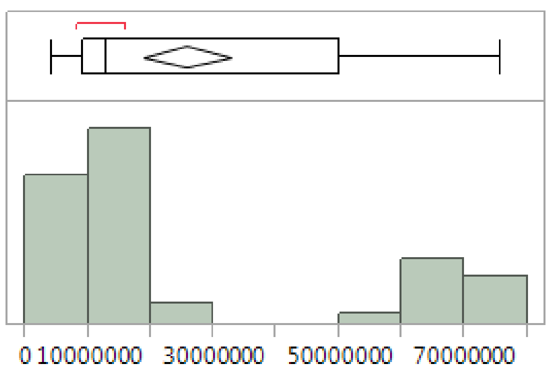
100.0%	maximum	8386789
99.5%		8386789
97.5%		8339700
90.0%		7228038
75.0%	quartile	5330563
50.0%	median	3478597
25.0%	quartile	2271793
10.0%		875681
2.5%		485305
0.5%		450437
0.0%	minimum	450437

Summary Statistics

Mean	3793894.1
Std Dev	2086149.9
Std Err Mean	292119.41
Upper 95% Mea	4380633.2
Lower 95% Mean	3207155
N	51

Figure 26. Weekly export commodity volumes.

PIER_Import Weight



Quantiles

100.0%	maximum	7.57e+7
99.5%		7.57e+7
97.5%		7.54e+7
90.0%		7.06e+7
75.0%	quartile	5e+7
50.0%	median	1.28e+7
25.0%	quartile	9230207
10.0%		6176184
2.5%		4451013
0.5%		4210224
0.0%	minimum	4210224

Summary Statistics

Mean	25625036
Std Dev	24976028
Std Err Mean	3463551.9
Upper 95% Mea	32578407
Lower 95% Mean	18671666
N	52

Figure 27. Weekly import commodity volumes.

Overlay Plots of Weekly Vessel Activities and Truck Shipment Activities

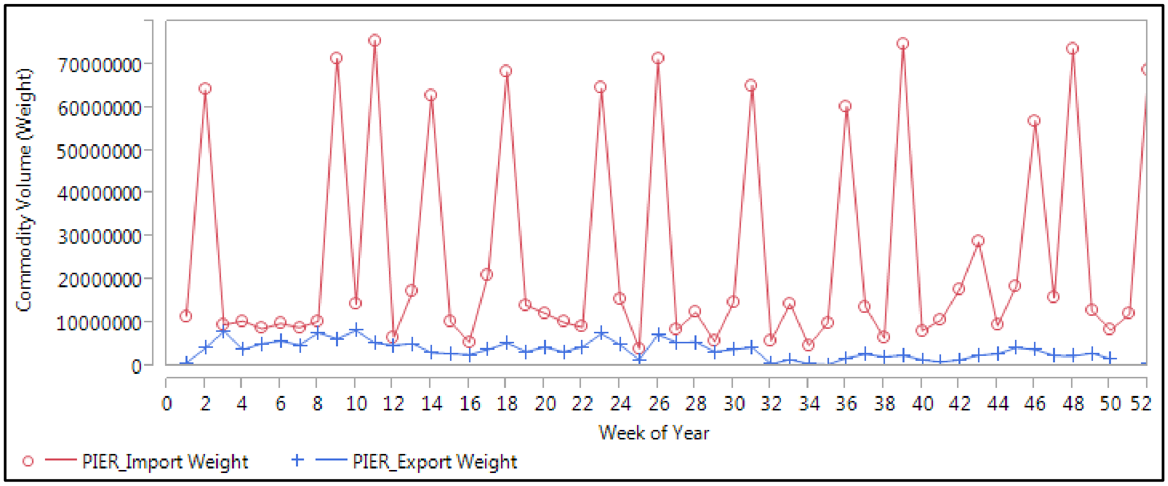


Figure 28. Weekly commodity volumes.

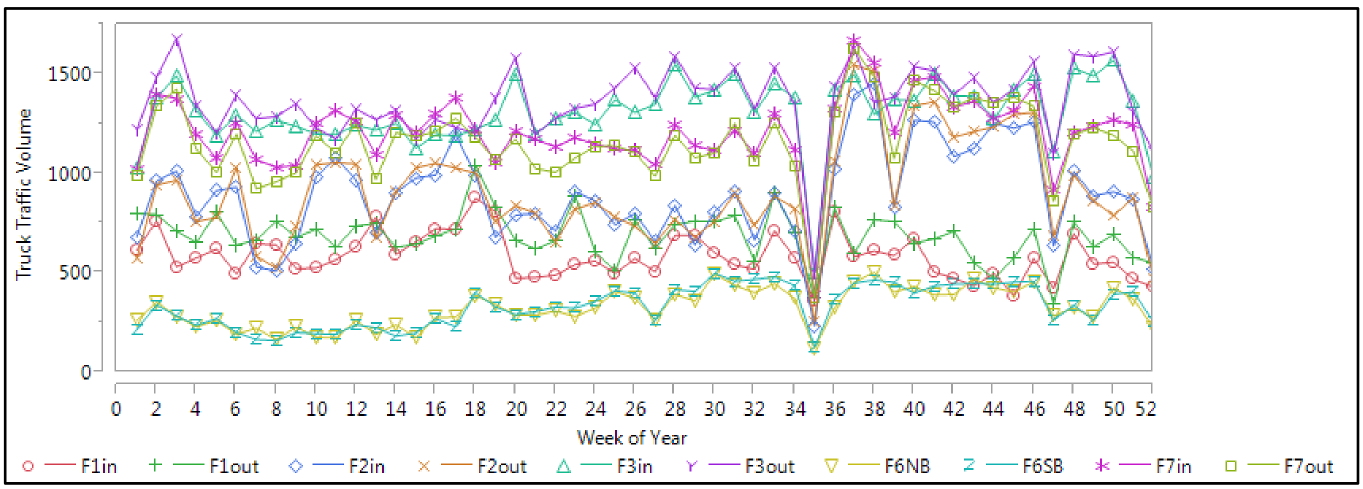


Figure 29. Weekly truck traffic volumes at each road segment.

Regression Analysis with Models M1-M3 Based on the Original Weekly Data

Model M1:
Response F1in
Summary of Fit

RSquare	0.119754
RSquare Adj	0.0174
Root Mean Square Error	111.715
Mean of Response	580.7143
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	73009.45	14601.9	1.1700
Error	43	536650.55	12480.2	**Prob > F**
C. Total	48	609660.00		0.3395

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	358.51705	98.31809	3.65	0.0007*
Import_lag0	1.0145e-6	7.02e-7	1.45	0.1557
Import_lag1	4.6134e-7	7.67e-7	0.60	0.5506
Import_lag2	8.5158e-7	7.482e-7	1.14	0.2613
Import_lag3	8.3959e-8	7.098e-7	0.12	0.9064
F1in_lag1	0.2771501	0.151666	1.83	0.0746

Response F1out
Summary of Fit

RSquare	0.127195
RSquare Adj	0.025707
Root Mean Square Error	122.418
Mean of Response	682.1429
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	93910.47	18782.1	1.2533
Error	43	644405.53	14986.2	**Prob > F**
C. Total	48	738316.00		0.3015

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	580.57338	124.2456	4.67	<.0001*
Import_lag0	1.5403e-6	7.78e-7	1.98	0.0542
Import_lag1	-4.898e-7	8.554e-7	-0.57	0.5699
Import_lag2	4.9145e-7	8.265e-7	0.59	0.5552
Import_lag3	5.8989e-7	7.685e-7	0.77	0.4469
F1out_lag1	0.0683504	0.158711	0.43	0.6689

Response F2in
Summary of Fit

RSquare	0.207485
RSquare Adj	0.115332
Root Mean Square Error	230.8256
Mean of Response	894.6939
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	599812.7	119963	2.2515
Error	43	2291059.7	53280	**Prob > F**
C. Total	48	2890872.4		0.0662

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	403.12967	154.9408	2.60	0.0127*
Import_lag0	1.5907e-6	1.439e-6	1.11	0.2750
Import_lag1	1.5086e-6	1.582e-6	0.95	0.3455
Import_lag2	1.7194e-6	1.565e-6	1.10	0.2779
Import_lag3	3.0048e-7	1.473e-6	0.20	0.8394
F2in_lag1	0.4016557	0.143509	2.80	0.0076*

Response F2out
Summary of Fit

RSquare	0.246897
RSquare Adj	0.159327
Root Mean Square Error	241.7855
Mean of Response	909.8163
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	824119.8	164824	2.8194
Error	43	2513789.6	58460	**Prob > F**
C. Total	48	3337909.3		0.0274*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	379.55671	158.889	2.39	0.0214*
Import_lag0	1.2919e-6	1.508e-6	0.86	0.3963
Import_lag1	2.174e-6	1.648e-6	1.32	0.1942
Import_lag2	1.0101e-6	1.65e-6	0.61	0.5437
Import_lag3	-1.373e-7	1.535e-6	-0.09	0.9292
F2out_lag1	0.4593828	0.140891	3.26	0.0022*

Response F3in
Summary of Fit

RSquare	0.105395
RSquare Adj	0.001371
Root Mean Square Error	173.321
Mean of Response	1310.51
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	152180.8	30436.2	1.0132
Error	43	1291727.5	30040.2	**Prob > F**
C. Total	48	1443908.2		0.4217

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1114.8114	228.5013	4.88	<.0001*
Import_lag0	8.5739e-7	1.134e-6	0.76	0.4538
Import_lag1	9.8388e-7	1.174e-6	0.84	0.4068
Import_lag2	2.523e-6	1.158e-6	2.18	0.0350*
Import_lag3	1.1949e-6	1.123e-6	1.06	0.2932
F3in_lag1	0.0423065	0.16226	0.26	0.7955

Response F3out
Summary of Fit

RSquare	0.113397
RSquare Adj	0.010304
Root Mean Square Error	185.8067
Mean of Response	1360.571
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	189873.6	37974.7	1.0999
Error	43	1484538.4	34524.1	**Prob > F**
C. Total	48	1674412.0		0.3745

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1093.6744	234.4681	4.66	<.0001*
Import_lag0	1.4223e-6	1.242e-6	1.15	0.2585
Import_lag1	1.7162e-6	1.259e-6	1.36	0.1801
Import_lag2	2.6464e-6	1.252e-6	2.11	0.0403*
Import_lag3	1.062e-6	1.205e-6	0.88	0.3830
F3out_lag1	0.0693774	0.160177	0.43	0.6671

Response F6NB
Summary of Fit

RSquare	0.386003
RSquare Adj	0.314608
Root Mean Square Error	81.7135
Mean of Response	325.102
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	180501.39	36100.3	5.4066
Error	43	287115.10	6677.1	**Prob > F**
C. Total	48	467616.49		0.0006*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	108.18168	56.64364	1.91	0.0628
Import_lag0	1.4457e-7	5.112e-7	0.28	0.7787
Import_lag1	-9.814e-8	5.534e-7	-0.18	0.8601
Import_lag2	4.3518e-7	5.476e-7	0.79	0.4312
Import_lag3	2.8887e-9	5.131e-7	0.01	0.9955
F6NB_lag1	0.6269024	0.121566	5.16	<.0001*

Response F6SB
Summary of Fit

RSquare	0.464814
RSquare Adj	0.402583
Root Mean Square Error	82.52479
Mean of Response	334.9388
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	254338.15	50867.6	7.4692
Error	43	292844.66	6810.3	**Prob > F**
C. Total	48	547182.82		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	84.342375	56.6351	1.49	0.1437
Import_lag0	3.3886e-7	5.18e-7	0.65	0.5165
Import_lag1	-2.405e-7	5.59e-7	-0.43	0.6692
Import_lag2	6.0456e-7	5.554e-7	1.09	0.2824
Import_lag3	8.6525e-8	5.181e-7	0.17	0.8682
F6SB_lag1	0.6863699	0.11364	6.04	<.0001*

Response F7in
Summary of Fit

RSquare	0.11568
RSquare Adj	0.012852
Root Mean Square Error	192.2849
Mean of Response	1204.02
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	207973.9	41594.8	1.1250
Error	43	1589859.1	36973.5	**Prob > F**
C. Total	48	1797833.0		0.3616

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	850.34174	201.7371	4.22	0.0001*
Import_lag0	9.5445e-7	1.216e-6	0.79	0.4367
Import_lag1	0.0000017	1.305e-6	1.30	0.1998
Import_lag2	2.3139e-6	1.297e-6	1.78	0.0815
Import_lag3	1.2202e-6	1.234e-6	0.99	0.3283
F7in_lag1	0.1635222	0.15548	1.05	0.2988

Response F7out
Summary of Fit

RSquare	0.11363
RSquare Adj	0.010564
Root Mean Square Error	197.7012
Mean of Response	1153.469
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	215459.8	43092.0	1.1025
Error	43	1680688.4	39085.8	**Prob > F**
C. Total	48	1896148.2		0.3732

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	779.84525	193.4555	4.03	0.0002*
Import_lag0	9.5372e-7	1.252e-6	0.76	0.4503
Import_lag1	2.1179e-6	1.34e-6	1.58	0.1213
Import_lag2	1.6743e-6	1.349e-6	1.24	0.2212
Import_lag3	6.4891e-7	1.26e-6	0.52	0.6091
F7out_lag1	0.2051955	0.153134	1.34	0.1873

Model M2:
Response F1in
Summary of Fit

RSquare	0.090357
RSquare Adj	-0.02335
Root Mean Square Error	115.9241
Mean of Response	588.0652
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	53394.94	10679.0	0.7947
Error	40	537535.87	13438.4	**Prob > F**
C. Total	45	590930.80		0.5600

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	430.98677	103.2106	4.18	0.0002*
Export_lag0	6.1843e-6	1.064e-5	0.58	0.5643
Export_lag-1	6.0029e-6	1.114e-5	0.54	0.5929
Export_lag-2	-1.069e-5	0.000012	-0.89	0.3791
Export_lag-3	-6.693e-7	1.144e-5	-0.06	0.9536
F1in_lag1	0.257057	0.156019	1.65	0.1073

Response F1out
Summary of Fit

RSquare	0.258843
RSquare Adj	0.166198
Root Mean Square Error	114.9727
Mean of Response	689.4565
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	184660.68	36932.1	2.7939
Error	40	528748.73	13218.7	**Prob > F**
C. Total	45	713409.41		0.0295*

Parameter Estimates[13]

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	674.40571	115.05	5.86	<.0001*
Export_lag0	3.2681e-5	1.054e-5	3.10	0.0035*
Export_lag-1	-3.885e-6	1.123e-5	-0.35	0.7312
Export_lag-2	-2.918e-5	0.000012	-2.45	0.0189*
Export_lag-3	9.5094e-6	1.141e-5	0.83	0.4094
F1out_lag1	-0.034655	0.152463	-0.23	0.8213

[13] Numbers highlighted show the intercept (i.e., baseline flow) and statistically significant parameter estimates.

Response F2in
Summary of Fit

RSquare	0.240855
RSquare Adj	0.145962
Root Mean Square Error	228.5314
Mean of Response	904.7174
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	662799.1	132560	2.5382
Error	40	2089064.2	52227	**Prob > F**
C. Total	45	2751863.3		0.0437*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	586.7467	183.3524	3.20	0.0027*
Export_lag0	1.9249e-5	0.000021	0.91	0.3671
Export_lag-1	-1.447e-5	0.000022	-0.65	0.5163
Export_lag-2	-0.000031	2.373e-5	-1.30	0.1999
Export_lag-3	0.0000109	2.26e-5	0.48	0.6319
F2in_lag1	0.4151271	0.147372	2.82	0.0075*

Response F2out
Summary of Fit

RSquare	0.260749
RSquare Adj	0.168343
Root Mean Square Error	239.9813
Mean of Response	923.7609
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	812542.5	162509	2.8218
Error	40	2303641.8	57591	**Prob > F**
C. Total	45	3116184.4		0.0283*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	625.47931	190.5355	3.28	0.0021*
Export_lag0	1.0287e-5	2.231e-5	0.46	0.6472
Export_lag-1	-2.07e-5	2.314e-5	-0.89	0.3764
Export_lag-2	-2.076e-5	2.489e-5	-0.83	0.4091
Export_lag-3	8.4226e-6	2.371e-5	0.36	0.7242
F2out_lag1	0.4203243	0.145275	2.89	0.0061*

Response F3in
Summary of Fit

RSquare	0.095203
RSquare Adj	-0.0179
Root Mean Square Error	166.1525
Mean of Response	1307.63
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	116191.2	23238.2	0.8418
Error	40	1104265.5	27606.6	**Prob > F**
C. Total	45	1220456.7		0.5282

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1331.1274	226.3448	5.88	<.0001*
Export_lag0	2.1888e-5	1.523e-5	1.44	0.1584
Export_lag-1	-0.000011	1.629e-5	-0.68	0.5014
Export_lag-2	-2.443e-5	1.735e-5	-1.41	0.1670
Export_lag-3	4.4202e-6	1.643e-5	0.27	0.7893
F3in_lag1	0.0076671	0.155779	0.05	0.9610

Response F3out
Summary of Fit

RSquare	0.093221
RSquare Adj	-0.02013
Root Mean Square Error	187.5858
Mean of Response	1361.13
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	144701.7	28940.3	0.8224
Error	40	1407537.5	35188.4	**Prob > F**
C. Total	45	1552239.2		0.5411

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1255.1582	233.8833	5.37	<.0001*
Export_lag0	2.8445e-5	1.72e-5	1.65	0.1060
Export_lag-1	-1.215e-5	0.000018	-0.67	0.5059
Export_lag-2	-2.361e-5	1.953e-5	-1.21	0.2340
Export_lag-3	6.6577e-6	1.847e-5	0.36	0.7204
F3out_lag1	0.0776249	0.156316	0.50	0.6222

Response F6NB
Summary of Fit

RSquare	0.484286
RSquare Adj	0.419822
Root Mean Square Error	75.81037
Mean of Response	324.913
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	215879.18	43175.8	7.5125
Error	40	229888.48	5747.2	**Prob > F**
C. Total	45	445767.65		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	235.19462	73.12981	3.22	0.0026*
Export_lag0	-4.8e-6	6.954e-6	-0.69	0.4940
Export_lag-1	5.5504e-6	7.537e-6	0.74	0.4658
Export_lag-2	-0.000012	7.958e-6	-1.51	0.1399
Export_lag-3	-5.811e-6	7.607e-6	-0.76	0.4494
F6NB_lag1	0.4789044	0.143665	3.33	0.0019*

Response F6SB
Summary of Fit

RSquare	0.523239
RSquare Adj	0.463644
Root Mean Square Error	79.47698
Mean of Response	334.3478
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	277294.82	55459.0	8.7799
Error	40	252663.62	6316.6	**Prob > F**
C. Total	45	529958.43		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	235.54381	78.55105	3.00	0.0046*
Export_lag0	-3.731e-7	7.35e-6	-0.05	0.9598
Export_lag-1	4.2285e-7	7.902e-6	0.05	0.9576
Export_lag-2	-1.035e-5	8.368e-6	-1.24	0.2234
Export_lag-3	-7.744e-6	7.958e-6	-0.97	0.3363
F6SB_lag1	0.5042388	0.143743	3.51	0.0011*

Response F7in
Summary of Fit

RSquare	0.079742
RSquare Adj	-0.03529
Root Mean Square Error	198.6153
Mean of Response	1216.935
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	136729.4	27345.9	0.6932
Error	40	1577921.4	39448.0	**Prob > F**
C. Total	45	1714650.8		0.6316

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1018.858	223.8991	4.55	<.0001*
Export_lag0	1.3529e-5	1.824e-5	0.74	0.4627
Export_lag-1	-1.021e-5	1.912e-5	-0.53	0.5965
Export_lag-2	-1.824e-5	2.06e-5	-0.89	0.3813
Export_lag-3	4.6421e-6	1.957e-5	0.24	0.8137
F7in_lag1	0.194418	0.159181	1.22	0.2291

Response F7out
Summary of Fit

RSquare	0.107171
RSquare Adj	-0.00443
Root Mean Square Error	204.8123
Mean of Response	1167.913
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	201409.7	40281.9	0.9603
Error	40	1677923.9	41948.1	**Prob > F**
C. Total	45	1879333.7		0.4535

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	969.7962	221.3083	4.38	<.0001*
Export_lag0	0.0000151	1.887e-5	0.80	0.4282
Export_lag-1	-1.41e-5	1.973e-5	-0.71	0.4790
Export_lag-2	-0.000021	2.125e-5	-0.99	0.3302
Export_lag-3	5.3432e-6	2.02e-5	0.26	0.7927
F7out_lag1	0.2169504	0.159056	1.36	0.1802

Model 3:

Response F1in
Summary of Fit

RSquare	0.131523
RSquare Adj	-0.09837
Root Mean Square Error	119.2918
Mean of Response	585.4091
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	73272.71	8141.4	0.5721
Error	34	483837.92	14230.5	**Prob > F**
C. Total	43	557110.64		0.8102

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	369.00224	122.9753	3.00	0.0050*
Import_lag0	5.942e-7	9.486e-7	0.63	0.5352
Import_lag1	3.3689e-7	9.166e-7	0.37	0.7155
Import_lag2	6.9775e-7	8.823e-7	0.79	0.4345
Import_lag3	2.9604e-7	8.261e-7	0.36	0.7223
Export_lag0	9.8324e-6	1.353e-5	0.73	0.4722
Export_lag-1	-1.237e-6	0.000013	-0.09	0.9249
Export_lag-2	-5.808e-6	0.000013	-0.45	0.6570
Export_lag-3	-7.506e-7	1.188e-5	-0.06	0.9500
F1in_lag1	0.2739041	0.168222	1.63	0.1127

Response F1out
Summary of Fit

RSquare	0.373587
RSquare Adj	0.207771
Root Mean Square Error	113.6805
Mean of Response	686.5682
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	262048.20	29116.5	2.2530
Error	34	439390.59	12923.3	**Prob > F**
C. Total	43	701438.80		0.0423*

Parameter Estimates[14]

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	609.82445	134.3542	4.54	<.0001*

[14] Numbers highlighted show the intercept (i.e., baseline flow) and statistically significant parameters estimates.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Import_lag0	3.1161e-7	9.021e-7	0.35	0.7319
Import_lag1	-1.117e-6	9.014e-7	-1.24	0.2237
Import_lag2	2.7682e-7	8.378e-7	0.33	0.7431
Import_lag3	8.8758e-7	7.791e-7	1.14	0.2626
Export_lag0	3.8369e-5	1.288e-5	2.98	0.0053*
Export_lag-1	-1.134e-5	1.273e-5	-0.89	0.3793
Export_lag-2	-0.000027	1.242e-5	-2.18	0.0364*
Export_lag-3	8.5311e-6	1.141e-5	0.75	0.4596
F1out_lag1	0.048307	0.165775	0.29	0.7725

Response F2in
Summary of Fit

RSquare	0.266482
RSquare Adj	0.072316
Root Mean Square Error	242.9489
Mean of Response	900.9091
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	729064.6	81007.2	1.3724
Error	34	2006821.1	59024.1	**Prob > F**
C. Total	43	2735885.6		0.2388

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	522.38847	219.3765	2.38	0.0230*
Import_lag0	1.1666e-6	1.93e-6	0.60	0.5495
Import_lag1	8.9371e-7	1.877e-6	0.48	0.6370
Import_lag2	1.0773e-6	1.827e-6	0.59	0.5592
Import_lag3	1.6919e-8	1.692e-6	0.01	0.9921
Export_lag0	1.454e-5	2.78e-5	0.52	0.6044
Export_lag-1	-1.824e-5	2.653e-5	-0.69	0.4963
Export_lag-2	-2.333e-5	2.642e-5	-0.88	0.3835
Export_lag-3	9.7504e-6	2.438e-5	0.40	0.6917
F2in_lag1	0.4052503	0.162766	2.49	0.0178*

Response F2out
Summary of Fit

RSquare	0.310329
RSquare Adj	0.127769
Root Mean Square Error	251.3202
Mean of Response	922.3409
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	966303.9	107367	1.6999

Source	DF	Sum of Squares	Mean Square	F Ratio
Error	34	2147502.0	63162	**Prob > F**
C. Total	43	3113805.9		0.1274

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	522.16373	227.5772	2.29	0.0281*
Import_lag0	1.4183e-6	0.000002	0.71	0.4819
Import_lag1	1.8577e-6	1.93e-6	0.96	0.3427
Import_lag2	5.664e-7	1.906e-6	0.30	0.7682
Import_lag3	-5.187e-7	1.747e-6	-0.30	0.7683
Export_lag0	3.502e-6	0.000029	0.12	0.9043
Export_lag-1	-2.418e-5	2.74e-5	-0.88	0.3836
Export_lag-2	-1.069e-5	2.729e-5	-0.39	0.6976
Export_lag-3	8.6168e-6	2.519e-5	0.34	0.7344
F2out_lag1	0.4395827	0.160192	2.74	0.0096*

Response F3in

Summary of Fit

RSquare	0.134857
RSquare Adj	-0.09415
Root Mean Square Error	173.1996
Mean of Response	1301.682
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	158985.6	17665.1	0.5889
Error	34	1019936.0	29998.1	**Prob > F**
C. Total	43	1178921.5		0.7969

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1305.0701	277.9623	4.70	<.0001*
Import_lag0	-8.942e-8	1.451e-6	-0.06	0.9512
Import_lag1	-1.997e-7	1.322e-6	-0.15	0.8808
Import_lag2	1.4255e-6	1.274e-6	1.12	0.2709
Import_lag3	6.2005e-7	1.209e-6	0.51	0.6115
Export_lag0	0.000024	1.976e-5	1.21	0.2330
Export_lag-1	-1.357e-5	1.921e-5	-0.71	0.4847
Export_lag-2	-2.338e-5	1.881e-5	-1.24	0.2223
Export_lag-3	9.3367e-7	1.745e-5	0.05	0.9576
F3in_lag1	-0.001049	0.177677	-0.01	0.9953

Response F3out

Summary of Fit

RSquare	0.109437
RSquare Adj	-0.1263

Root Mean Square Error	193.4428
Mean of Response	1350.955
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	156345.5	17371.7	0.4642
Error	34	1272284.4	37420.1	**Prob > F**
C. Total	43	1428629.9		0.8882

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1238.0912	285.3172	4.34	0.0001*
Import_lag0	3.6491e-7	1.63e-6	0.22	0.8242
Import_lag1	5.4675e-7	1.475e-6	0.37	0.7132
Import_lag2	1.6311e-6	1.431e-6	1.14	0.2624
Import_lag3	6.733e-7	1.352e-6	0.50	0.6218
Export_lag0	2.4357e-5	0.000022	1.10	0.2779
Export_lag-1	-1.258e-5	2.128e-5	-0.59	0.5581
Export_lag-2	-1.95e-5	0.000021	-0.93	0.3597
Export_lag-3	2.1441e-6	1.94e-5	0.11	0.9126
F3out_lag1	0.0402269	0.177597	0.23	0.8222

Response F6NB
Summary of Fit

RSquare	0.494758
RSquare Adj	0.361018
Root Mean Square Error	81.14265
Mean of Response	325.2273
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	219215.32	24357.3	3.6994
Error	34	223860.41	6584.1	**Prob > F**
C. Total	43	443075.73		0.0026*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	236.27488	100.2478	2.36	0.0243*
Import_lag0	2.5511e-7	6.589e-7	0.39	0.7010
Import_lag1	-2.169e-7	6.273e-7	-0.35	0.7317
Import_lag2	1.962e-8	6.035e-7	0.03	0.9743
Import_lag3	-1.197e-7	5.566e-7	-0.22	0.8310
Export_lag0	-5.293e-6	9.196e-6	-0.58	0.5687
Export_lag-1	0.0000034	9.227e-6	0.37	0.7148
Export_lag-2	-1.016e-5	0.000009	-1.13	0.2667
Export_lag-3	-5.691e-6	8.307e-6	-0.69	0.4979
F6NB_lag1	0.4859432	0.160316	3.03	0.0046*

Response F6SB
Summary of Fit

RSquare	0.551042
RSquare Adj	0.4322
Root Mean Square Error	83.4558
Mean of Response	335.3636
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	290650.59	32294.5	4.6368
Error	34	236805.59	6964.9	**Prob > F**
C. Total	43	527456.18		0.0005*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	226.62777	106.5863	2.13	0.0408*
Import_lag0	2.2726e-7	6.811e-7	0.33	0.7407
Import_lag1	-4.276e-7	6.462e-7	-0.66	0.5126
Import_lag2	1.885e-7	6.261e-7	0.30	0.7652
Import_lag3	-5.819e-8	5.723e-7	-0.10	0.9196
Export_lag0	1.1204e-6	9.477e-6	0.12	0.9066
Export_lag-1	-3.455e-6	9.425e-6	-0.37	0.7162
Export_lag-2	-7.97e-6	9.336e-6	-0.85	0.3993
Export_lag-3	-7.7e-6	8.511e-6	-0.90	0.3720
F6SB_lag1	0.5317323	0.158987	3.34	0.0020*

Response F7in
Summary of Fit

RSquare	0.148482
RSquare Adj	-0.07692
Root Mean Square Error	203.4129
Mean of Response	1209.091
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	245310.1	27256.7	0.6587
Error	34	1406811.6	41376.8	**Prob > F**
C. Total	43	1652121.6		0.7393

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	928.62299	253.1567	3.67	0.0008*
Import_lag0	1.1787e-6	1.622e-6	0.73	0.4723
Import_lag1	1.3656e-6	1.56e-6	0.88	0.3875
Import_lag2	2.0606e-6	1.529e-6	1.35	0.1867
Import_lag3	9.2535e-7	1.436e-6	0.64	0.5237

Term	Estimate	Std Error	t Ratio	Prob>|t|
Export_lag0	9.7237e-6	0.000023	0.42	0.6761
Export_lag-1	-1.416e-5	2.218e-5	-0.64	0.5274
Export_lag-2	-9.797e-6	0.000022	-0.44	0.6601
Export_lag-3	1.2336e-6	2.039e-5	0.06	0.9521
F7in_lag1	0.1606504	0.175443	0.92	0.3663

Response F7out
Summary of Fit

RSquare	0.148724
RSquare Adj	-0.07661
Root Mean Square Error	210.99
Mean of Response	1158.091
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	264432.7	29381.4	0.6600
Error	34	1513571.0	44516.8	**Prob > F**
C. Total	43	1778003.6		0.7382

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	926.72126	254.3229	3.64	0.0009*
Import_lag0	7.9464e-7	1.68e-6	0.47	0.6392
Import_lag1	1.5484e-6	1.612e-6	0.96	0.3435
Import_lag2	1.2529e-6	1.602e-6	0.78	0.4397
Import_lag3	4.0948e-7	1.47e-6	0.28	0.7823
Export_lag0	8.0124e-6	0.000024	0.33	0.7404
Export_lag-1	-1.627e-5	0.000023	-0.71	0.4847
Export_lag-2	-0.000013	0.000023	-0.57	0.5737
Export_lag-3	1.3372e-6	2.117e-5	0.06	0.9500
F7out_lag1	0.1798931	0.175722	1.02	0.3132

Regression Analysis with Models M1-M3 Based on the Imputed Data Replacing the Missing Week 51 Export Commodity Volume with a Zero

Model 1: Same as previous output

Model 2:

Response F1in

Summary of Fit

RSquare	0.066656
RSquare Adj	-0.04446
Root Mean Square Error	115.942
Mean of Response	589.5
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	40320.76	8064.2	0.5999
Error	42	564587.24	13442.6	**Prob > F**
C. Total	47	604908.00		0.7002

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	464.42732	99.53735	4.67	<.0001*
Export_lag0	5.3691e-6	1.059e-5	0.51	0.6147
Export_lag-1	6.8713e-6	1.111e-5	0.62	0.5397
Export_lag-2	-9.22e-6	1.18e-5	-0.78	0.4388
Export_lag-3	-2.72e-6	1.113e-5	-0.24	0.8082
F1in_lag1	0.2054269	0.151739	1.35	0.1830

Response F1out

Summary of Fit

RSquare	0.242328
RSquare Adj	0.152129
Root Mean Square Error	114.0809
Mean of Response	689.7292
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	174822.46	34964.5	2.6866
Error	42	546607.01	13014.5	**Prob > F**
C. Total	47	721429.48		0.0340*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	705.06354	103.6784	6.80	<.0001*
Export_lag0	3.1617e-5	1.04e-5	3.04	0.0041*

Term	Estimate	Std Error	t Ratio	Prob>|t|
Export_lag-1	-3.961e-6	1.114e-5	-0.36	0.7239
Export_lag-2	-2.679e-5	1.159e-5	-2.31	0.0258*
Export_lag-3	9.3528e-6	1.112e-5	0.84	0.4049
F1out_lag1	-0.085541	0.139692	-0.61	0.5436

Response F2in
Summary of Fit

RSquare	0.219839
RSquare Adj	0.126963
Root Mean Square Error	226.5579
Mean of Response	906.5833
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	607475.3	121495	2.3670
Error	42	2155796.4	51328	**Prob > F**
C. Total	47	2763271.7		0.0558

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	621.97338	173.2371	3.59	0.0009*
Export_lag0	1.6969e-5	2.078e-5	0.82	0.4187
Export_lag-1	-1.325e-5	2.186e-5	-0.61	0.5478
Export_lag-2	-2.761e-5	0.000023	-1.20	0.2379
Export_lag-3	6.9864e-6	2.162e-5	0.32	0.7482
F2in_lag1	0.3842123	0.142603	2.69	0.0101*

Response F2out
Summary of Fit

RSquare	0.245418
RSquare Adj	0.155586
Root Mean Square Error	236.932
Mean of Response	924
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	766823.9	153365	2.7320
Error	42	2357744.1	56137	**Prob > F**
C. Total	47	3124568.0		0.0317*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	641.39943	179.8418	3.57	0.0009*
Export_lag0	7.967e-6	2.188e-5	0.36	0.7176
Export_lag-1	-1.956e-5	2.28e-5	-0.86	0.3959

Term	Estimate	Std Error	t Ratio	Prob>|t|
Export_lag-2	-1.722e-5	0.000024	-0.71	0.4786
Export_lag-3	5.9832e-6	2.26e-5	0.26	0.7925
F2out_lag1	0.4029419	0.140748	2.86	0.0065*

Response F3in
Summary of Fit

RSquare	0.114997
RSquare Adj	0.00964
Root Mean Square Error	165.5692
Mean of Response	1316.125
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	149606.9	29921.4	1.0915
Error	42	1151352.3	27413.2	**Prob > F**
C. Total	47	1300959.3		0.3792

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1389.1868	216.9644	6.40	<.0001*
Export_lag0	2.2568e-5	0.000015	1.50	0.1422
Export_lag-1	-0.00001	1.621e-5	-0.62	0.5405
Export_lag-2	-2.613e-5	1.689e-5	-1.55	0.1293
Export_lag-3	-1.037e-6	1.581e-5	-0.07	0.9480
F3in_lag1	-0.016772	0.149606	-0.11	0.9113

Response F3out
Summary of Fit

RSquare	0.104395
RSquare Adj	-0.00223
Root Mean Square Error	188.0319
Mean of Response	1370.917
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	173090.5	34618.1	0.9791
Error	42	1484951.2	35356.0	**Prob > F**
C. Total	47	1658041.7		0.4417

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1326.7837	224.0565	5.92	<.0001*
Export_lag0	**0.0000294**	**1.713e-5**	**1.72**	**0.0935**
Export_lag-1	-1.062e-5	1.811e-5	-0.59	0.5609
Export_lag-2	-2.616e-5	1.914e-5	-1.37	0.1789

Term	Estimate	Std Error	t Ratio	Prob>|t|
Export_lag-3	-1.283e-7	0.000018	-0.01	0.9943
F3out_lag1	0.0494542	0.150122	0.33	0.7435

Response F6NB
Summary of Fit

RSquare	0.465155
RSquare Adj	0.401482
Root Mean Square Error	75.54078
Mean of Response	323.875
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	208440.03	41688.0	7.3055
Error	42	239669.22	5706.4	**Prob > F**
C. Total	47	448109.25		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	206.31583	68.06803	3.03	0.0042*
Export_lag0	-5.635e-6	6.893e-6	-0.82	0.4183
Export_lag-1	6.0486e-6	7.492e-6	0.81	0.4240
Export_lag-2	-9.68e-6	7.731e-6	-1.25	0.2175
Export_lag-3	-4.181e-6	7.272e-6	-0.57	0.5684
F6NB_lag1	0.5184523	0.138368	3.75	0.0005*

Response F6SB
Summary of Fit

RSquare	0.497865
RSquare Adj	0.438087
Root Mean Square Error	79.96447
Mean of Response	332.9792
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	266277.66	53255.5	8.3286
Error	42	268561.32	6394.3	**Prob > F**
C. Total	47	534838.98		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	204.47804	72.76471	2.81	0.0075*
Export_lag0	-1.338e-6	7.361e-6	-0.18	0.8567
Export_lag-1	1.1716e-6	7.935e-6	0.15	0.8833
Export_lag-2	-7.406e-6	8.2e-6	-0.90	0.3716
Export_lag-3	-6.403e-6	7.671e-6	-0.83	0.4086
F6SB_lag1	0.5432931	0.138033	3.94	0.0003*

Response F7in
Summary of Fit

RSquare	0.078214
RSquare Adj	-0.03152
Root Mean Square Error	194.0236
Mean of Response	1217.167
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	134157.6	26831.5	0.7127
Error	42	1581097.1	37645.2	**Prob > F**
C. Total	47	1715254.7		0.6173

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1027.0395	206.5843	4.97	<.0001*
Export_lag0	1.3033e-5	1.772e-5	0.74	0.4660
Export_lag-1	-0.00001	1.865e-5	-0.53	0.5971
Export_lag-2	-1.739e-5	1.974e-5	-0.88	0.3833
Export_lag-3	4.0252e-6	1.848e-5	0.22	0.8286
F7in_lag1	0.1876309	0.15026	1.25	0.2187

Response F7out
Summary of Fit

RSquare	0.105668
RSquare Adj	-0.0008
Root Mean Square Error	200.2948
Mean of Response	1169.854
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	199082.1	39816.4	0.9925
Error	42	1684955.9	40118.0	**Prob > F**
C. Total	47	1884038.0		0.4339

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	994.42802	204.2234	4.87	<.0001*
Export_lag0	1.4575e-5	1.834e-5	0.79	0.4312
Export_lag-1	-1.366e-5	1.927e-5	-0.71	0.4822
Export_lag-2	-2.038e-5	2.037e-5	-1.00	0.3230
Export_lag-3	3.5971e-6	0.000019	0.19	0.8514
F7out_lag1	0.2008931	0.150071	1.34	0.1879

Model 3:

Response F1in

Summary of Fit

RSquare	0.122793
RSquare Adj	-0.09651
Root Mean Square Error	118.0016
Mean of Response	587.0217
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	70169.77	7796.6	0.5599
Error	36	501277.21	13924.4	**Prob > F**
C. Total	45	571446.98		0.8202

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	382.48187	121.0449	3.16	0.0032*
Import_lag0	8.9804e-7	8.821e-7	1.02	0.3154
Import_lag1	2.83e-7	8.648e-7	0.33	0.7454
Import_lag2	8.1609e-7	8.346e-7	0.98	0.3347
Import_lag3	1.652e-7	7.885e-7	0.21	0.8352
Export_lag0	6.8417e-6	1.311e-5	0.52	0.6049
Export_lag-1	6.3697e-8	1.275e-5	0.00	0.9960
Export_lag-2	-3.494e-6	1.259e-5	-0.28	0.7829
Export_lag-3	-1.596e-6	1.151e-5	-0.14	0.8905
F1in_lag1	0.2427634	0.163479	1.48	0.1463

Response F1out

Summary of Fit

RSquare	0.363274
RSquare Adj	0.204093
Root Mean Square Error	112.0251
Mean of Response	686.9783
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	257760.27	28640.0	2.2821
Error	36	451786.71	12549.6	**Prob > F**
C. Total	45	709546.98		0.0384*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	632.14965	129.0492	4.90	<.0001*
Import_lag0	5.4367e-7	8.386e-7	0.65	0.5209
Import_lag1	-1.158e-6	8.377e-7	-1.38	0.1753
Import_lag2	3.1855e-7	7.997e-7	0.40	0.6927
Import_lag3	7.4005e-7	7.393e-7	1.00	0.3235

Term	Estimate	Std Error	t Ratio	Prob>|t|
Export_lag0	3.5882e-5	1.244e-5	2.89	0.0066*
Export_lag-1	-0.000011	1.251e-5	-0.88	0.3861
Export_lag-2	-2.457e-5	0.000012	-2.05	0.0473*
Export_lag-3	8.363e-6	0.000011	0.75	0.4556
F1out_lag1	0.0118352	0.153868	0.08	0.9391

Response F2in
Summary of Fit

RSquare	0.257123
RSquare Adj	0.071404
Root Mean Square Error	238.1293
Mean of Response	903.0217
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	706566.0	78507.3	1.3845
Error	36	2041401.0	56705.6	**Prob > F**
C. Total	45	2747967.0		0.2313

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	532.86751	214.0596	2.49	0.0176*
Import_lag0	1.5777e-6	1.762e-6	0.90	0.3767
Import_lag1	7.5707e-7	1.745e-6	0.43	0.6670
Import_lag2	1.2017e-6	1.697e-6	0.71	0.4834
Import_lag3	-2.082e-7	1.592e-6	-0.13	0.8967
Export_lag0	9.9162e-6	2.652e-5	0.37	0.7107
Export_lag-1	-1.67e-5	2.575e-5	-0.65	0.5206
Export_lag-2	-1.947e-5	2.537e-5	-0.77	0.4479
Export_lag-3	8.6273e-6	2.322e-5	0.37	0.7124
F2in_lag1	0.3899256	0.154203	2.53	0.0160*

Response F2out
Summary of Fit

RSquare	0.29925
RSquare Adj	0.124063
Root Mean Square Error	246.5257
Mean of Response	922.6522
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	934326.8	103814	1.7082
Error	36	2187897.7	60775	**Prob > F**
C. Total	45	3122224.4		0.1230

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	528.12435	222.3967	2.37	0.0230*
Import_lag0	1.7749e-6	1.826e-6	0.97	0.3375
Import_lag1	1.6093e-6	1.799e-6	0.89	0.3771
Import_lag2	6.0112e-7	1.769e-6	0.34	0.7359
Import_lag3	-8.252e-7	1.645e-6	-0.50	0.6190
Export_lag0	-1.029e-6	2.759e-5	-0.04	0.9705
Export_lag-1	-0.000023	2.657e-5	-0.87	0.3924
Export_lag-2	-6.404e-6	2.623e-5	-0.24	0.8085
Export_lag-3	8.4276e-6	0.000024	0.35	0.7277
F2out_lag1	0.4326439	0.15226	2.84	0.0073*

Response F3in
Summary of Fit

RSquare	0.171356
RSquare Adj	-0.0358
Root Mean Square Error	170.5701
Mean of Response	1310.804
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	216591.3	24065.7	0.8272
Error	36	1047389.9	29094.2	**Prob > F**
C. Total	45	1263981.2		0.5956

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1303.6144	272.0969	4.79	<.0001*
Import_lag0	2.4789e-7	1.362e-6	0.18	0.8566
Import_lag1	1.1702e-7	1.243e-6	0.09	0.9255
Import_lag2	1.7672e-6	1.204e-6	1.47	0.1508
Import_lag3	7.9989e-7	1.153e-6	0.69	0.4924
Export_lag0	2.2618e-5	1.911e-5	1.18	0.2443
Export_lag-1	-0.000011	1.872e-5	-0.59	0.5586
Export_lag-2	-2.417e-5	1.815e-5	-1.33	0.1913
Export_lag-3	-2.676e-6	1.677e-5	-0.16	0.8741
F3in_lag1	-0.009145	0.173406	-0.05	0.9582

Response F3out
Summary of Fit

RSquare	0.151261
RSquare Adj	-0.06092
Root Mean Square Error	190.7654
Mean of Response	1361.609
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	233483.2	25942.6	0.7129
Error	36	1310091.7	36391.4	**Prob > F**
C. Total	45	1543575.0		0.6935

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1240.7551	279.1584	4.44	<.0001*
Import_lag0	7.2024e-7	1.541e-6	0.47	0.6431
Import_lag1	9.3449e-7	1.389e-6	0.67	0.5054
Import_lag2	2.039e-6	1.351e-6	1.51	0.1400
Import_lag3	9.1072e-7	1.291e-6	0.71	0.4851
Export_lag0	0.0000231	2.141e-5	1.08	0.2876
Export_lag-1	-9.748e-6	2.077e-5	-0.47	0.6417
Export_lag-2	-2.071e-5	2.03e-5	-1.02	0.3143
Export_lag-3	-2.082e-6	1.865e-5	-0.11	0.9118
F3out_lag1	0.027865	0.172758	0.16	0.8728

Response F6NB
Summary of Fit

RSquare	0.483157
RSquare Adj	0.353947
Root Mean Square Error	79.96963
Mean of Response	324.1304
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	215220.14	23913.3	3.7393
Error	36	230225.08	6395.1	**Prob > F**
C. Total	45	445445.22		0.0021*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	225.54456	98.1882	2.30	0.0275*
Import_lag0	2.236e-7	6.108e-7	0.37	0.7165
Import_lag1	-3.755e-7	5.974e-7	-0.63	0.5336
Import_lag2	-8.96e-8	5.756e-7	-0.16	0.8772
Import_lag3	-2.499e-7	5.298e-7	-0.47	0.6399
Export_lag0	-5.715e-6	8.861e-6	-0.65	0.5230
Export_lag-1	3.1389e-6	9.021e-6	0.35	0.7299
Export_lag-2	-8.581e-6	8.65e-6	-0.99	0.3278
Export_lag-3	-4.029e-6	7.943e-6	-0.51	0.6150
F6NB_lag1	0.5152318	0.155205	3.32	0.0021*

Response F6SB
Summary of Fit

RSquare	0.539346
RSquare Adj	0.424182
Root Mean Square Error	82.54308
Mean of Response	333.8913
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	287181.49	31909.1	4.6833
Error	36	245280.97	6813.4	**Prob > F**
C. Total	45	532462.46		0.0004*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	211.82713	104.4707	2.03	0.0501
Import_lag0	2.6515e-7	6.367e-7	0.42	0.6796
Import_lag1	-5.989e-7	6.189e-7	-0.97	0.3397
Import_lag2	1.0685e-7	6.024e-7	0.18	0.8602
Import_lag3	-2.203e-7	5.466e-7	-0.40	0.6893
Export_lag0	2.4344e-7	9.163e-6	0.03	0.9790
Export_lag-1	-3.404e-6	9.257e-6	-0.37	0.7152
Export_lag-2	-5.762e-6	0.000009	-0.64	0.5261
Export_lag-3	-6.187e-6	8.156e-6	-0.76	0.4530
F6SB_lag1	0.5645251	0.153466	3.68	0.0008*

Response F7in
Summary of Fit

RSquare	0.14314
RSquare Adj	-0.07107
Root Mean Square Error	198.3542
Mean of Response	1209.674
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	236612.7	26290.3	0.6682
Error	36	1416397.4	39344.4	**Prob > F**
C. Total	45	1653010.1		0.7316

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	908.84928	242.8246	3.74	0.0006*
Import_lag0	1.0829e-6	1.494e-6	0.73	0.4731
Import_lag1	1.1327e-6	1.445e-6	0.78	0.4383
Import_lag2	1.8499e-6	1.411e-6	1.31	0.1982
Import_lag3	7.3545e-7	1.337e-6	0.55	0.5856
Export_lag0	9.8017e-6	0.000022	0.45	0.6583

Term	Estimate	Std Error	t Ratio	Prob>|t|
Export_lag-1	-1.52e-5	2.14e-5	-0.71	0.4819
Export_lag-2	-8.585e-6	2.111e-5	-0.41	0.6866
Export_lag-3	3.3151e-6	1.932e-5	0.17	0.8647
F7in_lag1	0.1821483	0.164017	1.11	0.2741

Response F7out
Summary of Fit

RSquare	0.149349
RSquare Adj	-0.06331
Root Mean Square Error	205.3522
Mean of Response	1160.543
Observations (or Sum Wgts)	46

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	266532.7	29614.7	0.7023
Error	36	1518102.7	42169.5	**Prob > F**
C. Total	45	1784635.4		0.7026

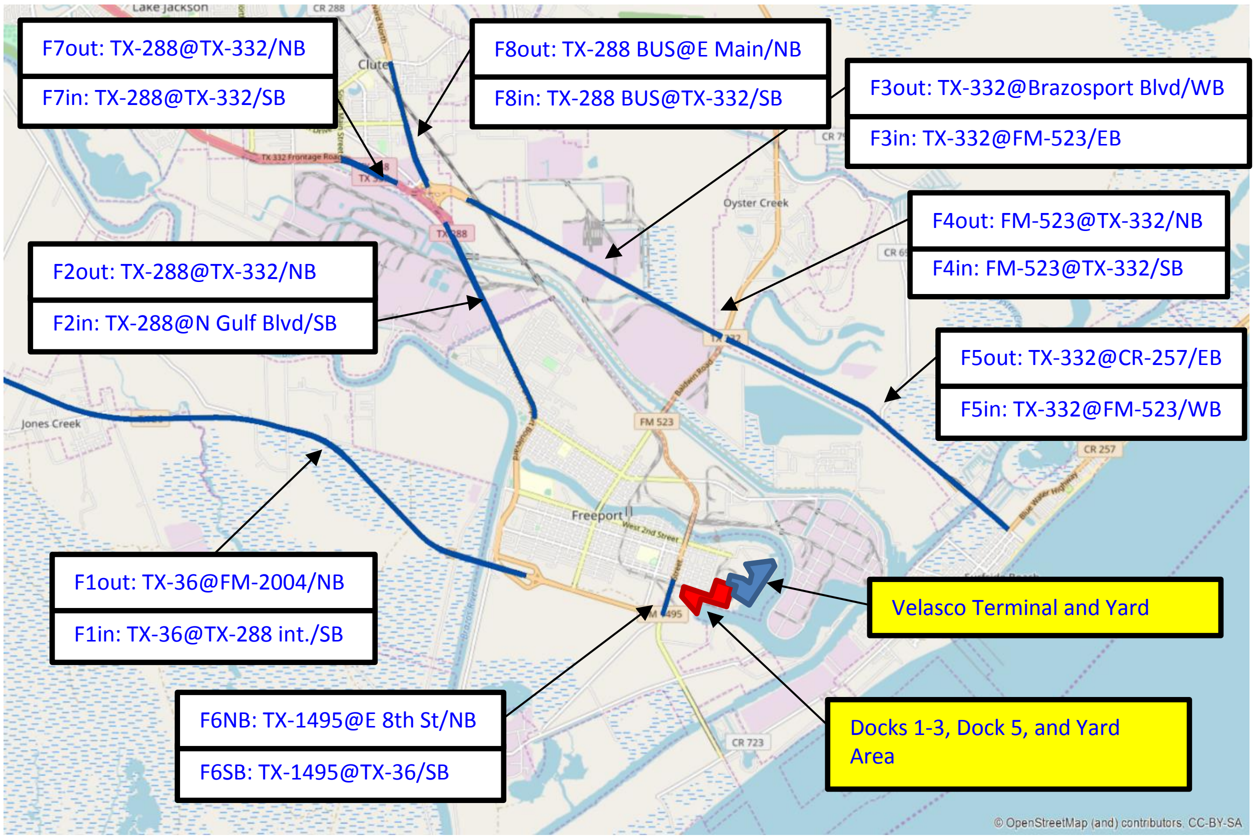
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	926.14817	243.4338	3.80	0.0005*
Import_lag0	8.6199e-7	1.546e-6	0.56	0.5805
Import_lag1	1.4265e-6	1.495e-6	0.95	0.3464
Import_lag2	1.2109e-6	1.471e-6	0.82	0.4157
Import_lag3	2.8571e-7	1.372e-6	0.21	0.8362
Export_lag0	6.8636e-6	2.277e-5	0.30	0.7648
Export_lag-1	-1.621e-5	2.219e-5	-0.73	0.4698
Export_lag-2	-1.158e-5	2.185e-5	-0.53	0.5995
Export_lag-3	1.7826e-6	0.00002	0.09	0.9295
F7out_lag1	0.1815143	0.163667	1.11	0.2748

Appendix B – Docks 1-3, Dock 5, and yard area

Appendix C – Velasco Terminal and yard area

Appendix D – Port Freeport marine terminal locations relative to the identified highway corridors.[15]



[15] *Road coding: F for Freeport, IN for inbound to Port, Out for outbound from port to inland, @ denotes the location of the intersection at the end of the segment.*