Advanced Transportation and Congestion Management Technologies Final Report

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Contents

1. Project Summary

Introduction and Background

The Port of Virginia's Truck Reservation System Expansion (TRS 2.0) and Automated Workflow Data Model project was funded by the Federal Highway Administration's 2017 Advanced Transportation and Congestion Management Technologies Deployment Initiative.

Prior to the COVID-19 pandemic and the global supply chain crisis, several ports had undertaken upgrades to increase their efficiency of operations—including instituting a mandatory truck reservation system (TRS). This was a paradigm shift from the historical model where a terminal opened and closed at specific times and trucks arrived whenever was convenient, with no coordination and no regard for the terminal's capacity to service them. Truck reservations were in use at the Port of New York and New Jersey, Port of Baltimore, and the Port of Los Angeles/Long Beach.

Based on the success of the TRS at the Port of New York and New Jersey, The Port of Virginia (POV), also referred to as The Port in this Report, piloted a mandatory TRS at Virginia International Gateway (VIG) and Norfolk International Terminals (NIT). Features were deployed in phases, as represented in Table 1.1 below.

Table 1.1 – Deployment Phases

TRS 1.0	TRS 2.0	TRS 3.0
Deployed 2018	Deployed 2021	Future Deployment
Features: • Mandatory reservations • More efficient housekeeping at night • Decreased truck backup and congestion • Modern truck tracking hardware	Features: • Subscription for stakeholders to track containers • Artificial intelligence (AI)-based yard housekeeping • Enhanced TRS system Mobile Application (Off Terminal information)	Features: • Ability to schedule reservations in advance • Mobile application (On Terminal Information) • Just-in-time truck appointment matching

Prior to 2018, the POV used a voluntary reservation system. However, without a substantial number of truckers using the system, the overall impact to turn-times at The Port was minimal. The POV established dedicated lanes for users with reservations to incentivize usage. These dedicated reservation lanes featured a streamlined gate process in which motor carriers saw a reduction in their gate processing times (six-minute average processing times reduced to three minutes or less) and an overall reduction in their in-gate queue times. However, trucks entering the terminal faster created

yard congestion. Without a mature housekeeping program in place to take advantage of the reservation data, the landside dwell times experienced inside the yard were not optimal. Reservations were interlaced with non-reservations, further contributing to long wait times for all yard transfer operations. The voluntary system did not regulate capacity, resulting in longer wait times for truckers.

The mandatory reservation system implemented in 2018 provided The Port an avenue to efficiently plan for and move cargo by allowing for better housekeeping and organization of containers in the stack yard, resulting in reduced trucker wait times. This ability to plan tomorrow's work has led to a marked improvement of the logistics supply chain through implementation of a policy and expectation that all business transactions should be scheduled in advance. In a mandatory reservation system, the arrival times of trucks are strictly enforced. Entrance into The Port to conduct a transaction is prohibited without a reservation. Initially, the implementation of mandatory reservations was met with skepticism and pushback by the trucking community. Many refused to believe that the trucking process could support this level of pre-planning; therefore, The Port had to deliver superior performance and deliver an on-terminal experience that was highly predictable. This has been a huge success. Today, truckers are making reservations even during non-mandatory hours.

TRS 2.0 Specific Goals

The focus of the Truck Reservation System 2.0 (TRS-2) project involved the analysis, design, and implementation and deployment of the first version of a second-generation truck reservation system. The Port of Virginia sought to improve upon its existing port truck reservation system to a level that exceeded best practices on the U.S. (United States) East Coast. The Port recognized that there were significant enhancements in technology that could improve upon the existing deployment. This was the basis for the need to create a "second generation" system (TRS-2).

The TRS-2 effort included a published data model that provides real-time updates to dispatchers and truckers via their Truck Management Systems. The system includes a Data Subscription Model that pushes information out to the truckers and other logistics chain stakeholders (shippers, brokers, shipping lines, etc.) using a cloud-based system ubiquitous across all of the POV terminals. The proposed Data Model will serve as the basis for a standard industry dataset to scale across other ports for more efficient terminal operations.

A core update provided by the TRS-2 included a revamp of the truck reservation system user experience. The revamp, referred to as port manager, was a complete redesign of the graphical user interface. Port Manager allowed for more efficient reservation creation through facilitating dynamic edits, reflecting real-world usage by motor carriers. The improved experience of port manager allowed The Port of Virginia to maximize reservation capacity and usage. Another aspect of the TRS-2 project is the use of artificial intelligence (AI) to optimize the container stack in the yard by grooming or housekeeping during off hours. These AI optimization activities allow The Port to position the containers for next day activities resulting in fewer moves and greater efficiency. The Port also

created a Mobile application with both Apple and Android operating systems to access Truck Reservation Information.

2. Performance Metrics, Evaluation Methods, and Data Sources

This section will address the project goals and how they align with Section 6004 of the Fixing America's Surface Transportation (FAST) Act (PL 114-94).

Improved Safety

One of the most direct ways to improve safety is to limit the amount of time truck drivers are on the terminal. If a driver is constantly being serviced at The Port at the different stop points in-gate, stack, and out-gate, the less likely they are to engage in other activities, such and talking with other truck drivers outside their truck cabs, which could put them in a dangerous situation. Two separate measures were used to evaluate this goal:

- Turn times Pre and Post TRS-2; and
- The number of instances a truck driver falls into the "unsatisfactory" category by exiting his truck cab and putting himself in harm's way. The number of instances must be captured for both Pre and Post TRS-2 implementations.

The technology responsible for improved safety at The Port of Virginia is the reservation system and the improvements made with the deployment of Port Manager. The Port anticipated that the integration of port manager into the second iteration of the reservation system, would maximize the use of the daily reservation capacity allocated to the motor carrier community with enough precision to minimize stack wait times. By over-allocating capacity, congestion is created inside the terminal, especially for trucks waiting for their assigned stacks which in turn results in an increase in turn times. By under-allocating capacity, congestion inside the terminal is reduced and turn times are improved, but target productivity is not achieved, which is necessary to meet terminal cargo demands. The POV would anticipate that by delivering precise daily reservation capacity. This resulted in a reduction in terminal congestion while minimizing key safety risks

Data was collected from the POV Health and Safety and Operations teams using quarterly surveillance audits of activities on terminal. The data is continuously collected using a series of safety and operationally focused cameras with digital video recording capabilities at Virginia International Gateway. The cameras are focused on specific areas of operational and safety concern.

Improved Mobility

Faster turn times and higher efficiency across all port operations is a goal for all stakeholders entering and exiting port facilities. Two types of turn times are measured at The Port of Virginia. The standard turn time, which is used at most terminals across the country, begins when the truck driver starts the in-gate process through the completion of the out-gate process. The extended turn time begins when the driver enters The Port through the optical character recognition (OCR) Portal. The extended turn time captures the time in which the driver waits to begin the in-gate process.

Reduced Transportation-Related Emissions

Reduction in port turn times and congestion experienced within The port has an additional direct positive environmental impact. We will use the afore-mentioned extended turn time method for calculating turn times along with the Environmental Protection Agency's Idling Vehicle Emissions for Heavy duty Truck (https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT) guidelines to determine emission reductions and cost benefit of project related activity.

The Port anticipated that by deploying reservation system enhancements and the AI housekeeping technology, the hourly appointment capacity and gate throughput would increase while maintaining or even reducing overall truck turn times. The clearest benefit derived from optimized housekeeping that The Port expected to see was a reduction in stack wait times. By reducing the rehandles needed to deliver containers, the expected gross time trucks would spend idling at a yard transfer point would be reduced. Additionally, each reduction of rehandle moves has a compounding effect for other drivers waiting in the same queue.

Optimized Multimodal System Performance

One of the goals of this project was to implement artificial intelligence (AI) to optimize the system performance of the automated stacks. After the gate closes, the automatic stacking cranes move containers into their optimal position for the next day's work. When the truck driver for the 6:00 a.m. appointment shows up to the stack, the container needed is in the best optimal position at the top of the stack nearest to the truck. The stacking cranes can move that container quickly to the truck with the next container directly underneath for the 8:00 a.m. appointment. Without AI, a stacking crane might handle a container multiple times before it gets into its optimal resting spot. The AI algorithms attempts to "think" many moves ahead instead of just the next container move. These algorithms can also be used in conjunction when delivering a container from the stack to the truck and can be measured in the total average time it takes to deliver a container either with or without AI.

Reduced Costs

There are two direct major activities impacting the goal area of cost reduction. The first activity relates to reducing truck turn times. As truck turn times are reduced, operating hours can also be reduced. The annual operating hours per gate transaction will be utilized in measuring this goal. The second activity impacting reduced costs relates to increasing stack efficiency as the number of re-handles to retrieve containers are reduced. Re-handles to retrieve are defined as the number of container moves required to deliver a container. If an import is buried under four other containers, the number of re-handles to retrieve the target container would be four. Ideally, zero is the best number of re-handles to retrieve a container, as it would mean that the crane can gantry directly to the target container, lock into it, and deliver the container without any additional moves to complete the task.

Real-time Integrated Traffic Information

Using API and/or a subscription service directly with The Port enables trucking companies to integrate their back-end dispatching systems to programmatically access information from The Port for a myriad of use cases ranging from customs holds, to container availability, to the last free day for pickup.

The mobile application provides integrated real-time transportation information to truckers to make informed travel decisions. The information allows truckers to access truck reservation information directly instead of calling their dispatcher and inquiring about container or reservation information.

The evaluation methods for the real time integrated traffic information are difficult as The Port does not have direct access to the truck dispatching systems to see trucking company improvements and costs savings. We measured the number of transactions that are being requested and record the data usage.

Institutional and/or Administrative Benefits

One of the stated goals of the grant project is to share the experiences of implementing a port reservation system that can provide institutional knowledge to other ports and port stakeholders. To measure this goal, the port has compiled the “Truck Reservation System - Best Practices Summary” for publication and dissemination.

3. Evaluation Results

This section will highlight the detailed quantitative and qualitative evaluation results. Data limitations, including external factors that may have impacted the evaluation findings are also described within this section.

Improved Safety

The deployment of a terminal reservation system at The Port of Virginia has had a major impact to the health and safety of motor carrier patrons. According to blueoceana.com, an organization that tracks fatalities in all marine cargo facilities world-wide, a leading cause of death occurs when pedestrians are struck by moving equipment or vehicles. Pedestrian safety has always been a concern in the landside transfer zone. With heavy machinery moving cargo containers and large trucks traversing the port facilities, it is not a safe environment for pedestrians. With a reduction in truck turn times, truckers are more likely to stay in the cabs of their vehicles, and this decrease in truckers leaving the cabs of their vehicles reduced the terminal's risk score by 81 percent.

At the Port of Virginia, hazards are ranked according to potential consequence and probability of occurrence, with the risk to motor carriers who are on foot in the transfer zones being listed as the #1 out of 45 key risks from 2014-2019. The Port of Virginia Health and Safety department performs quarterly audits of many hazardous conditions and behaviors, one of which is the metric that states, "While waiting to back into a lane, brief coordination with other motor carriers to determine who will back-in next is acceptable for up to two minutes, then drivers must be in their cab." In the years prior to the implementation of a terminal reservation system at Virginia International Gateway, this line item on the quarterly audit failed 12 out of 13 times. Immediately following implementation of the TRS in 2019, the compliance rate increased significantly through 2021, passing with an average compliance rate of rate of 98.8 percent. As a result of this success with the TRS, the #1 key risk of truck drivers on foot being struck by another vehicle or equipment has been removed from the active list of key risks at The Port of Virginia. These lessons were also taken into consideration when re-designing and reconfiguring NIT's automated terminal. A solution to engineer out this problem was deployed utilizing a separate staging area that holds trucks until a parking space at the transfer zone is available. The staging area solution eliminates the need for drivers to exit their trucks to coordinate who should be next to occupy a transfer zone parking space. The Port's goal is always to make sure the community comes to work and makes it home safely and this initiative brought us much closer to that vision.

The following is a systematic, standardized approach that places a numeric value to an exposure situation considering the following factors:

> Risk score = Likelihood of Occurrence; Table 3.1 (Exposure + Number of People; Table 3.2) x Consequence Severity (Table 3.3) x Probability (Average of Physical and Organizational Factors; Table 3.4)

In using the formula, the numerical ratings or weights assigned to each factor in Table 3.1 are based upon the judgment and experience of the investigator making the calculation. The second element (factor), EXPOSURE, is defined as the frequency at which the employee is doing the task or frequency at which he/she is exposed to the hazard/event as reflected in Table 3.2.

Table 3.1 – Likelihood of Occurrence

THE HAZARD-EVENT OR EMPLOYEE IS EXPOSED, OCCURS;	RATING
Several times per day	5
Once per day	4
Once per week or more (but < once per day)	3
Once per month or more (but < once per week)	2
Once per year or more (but < than once per month)	1

Table 3.2 – Number of People Exposed to Hazard/Event

THE HAZARD-EVENT OCCURS, NUMBER OF PEOPLE EXPOSED;	RATING
100 or more people	5
50 to 100 people	4
20 to 50 people	3
5 to 20 people	2
Less than 5 people	1

The first element, CONSEQUENCE, is defined as the most severe likely consequences of the accident, from 100 points for a catastrophe down through various degrees of Severity to ten (10) points for a minor cut, bruise, or first aid treatment as captured in Table 3.3.

Table 3.3 – Severity of Event

DEGREE OF SEVERITY OF CONSEQUENCES	RATING
Death; or Loss higher than $5,000,000	100
Permanent/Partial Disability; or Loss between $1,000,000 - $5,000,000	70
Lost time > 60 days; or Loss between $100,000 - $1,000,000	50
Lost Time < 60 days; or Loss between $10,000 - $100,000	30
Medical Treatment; or Loss less than $10,000	10

The third element (factor) is the PROBABILITY that, once the hazard/event occurs, the complete accident sequence of events will follow with the timing and coincidence to result in the accident and consequences as reflected in Table 3.4. This PROBABILITY is determined by the CONTROLS that are in place, which will influence the likelihood for the incident to happen.

Table 3.4 – Probability of Event

PROBABILITY: COMBINATION OF PHYSICAL & ORGANIZATIONAL CONTROLS CRITERIA;	Rating
No Control Measure	1.0
PPE control	0.9
Administrative control	0.6
Engineering control	0.3
Substitution*	0
Elimination*	0

* Note: Only used to show when a hazard has been changed or for proposed controls.

Risk Score Calculation

Motor carrier operators are walking in the VIG transfer zone before backing into the lanes, creating a potential safety hazard. Table 3.5 shows an example risk score calculation for a safety-related issue.

Table 3.5 – Risk Level 2018 Assessment at VIG

Terminal	**Date Identified**	**Root Cause / Hazard**	**Exposure**	**No. of People**	**Severity of Consequence**	**Initial Risk**	**Control Measure(s) in place, related to the hazard**	**Probability**	**Risk Score**	**Risk Level**
VIG	2018	Turn Time, Terminal Historic Culture, Enforcement	5	5	100	1000	None	1	1000	Severe

Port of Virginia Operational Compliance Audit for VIG

While waiting to back into a lane, brief coordination with other motor carriers to determine who will back-in next is acceptable for up to two minutes, then drivers must be in their cab. To meet audit expectations, a minimum of 20 samples must be observed and recorded.

Table 3.6 – VIG Quarterly Operational Compliance Audit of Motor Carrier Transfer Zone

Year	Quarter	Total Observations	Out of Compliance	In Compliance	% in Compliance	Result
2018	Q1	45	11	34	75.6%	Unsatisfactory
2018	Q2	115	44	71	61.7%	Unsatisfactory
2018	Q3	175	22	153	87.4%	Unsatisfactory
2018	Q4	90	18	72	80.0%	Unsatisfactory
2019	Q1	89	13	76	85.4%	Unsatisfactory
2019	Q2	96	8	88	91.7%	Unsatisfactory
2019	Q3	92	12	80	87.0%	Unsatisfactory
2019	Q4	100	12	88	88.0%	Unsatisfactory
2020	Q1	75	3	72	96.0%	Satisfactory
2020	Q2	n/a	n/a	n/a	n/a	COVID
2020	Q3	88	0	88	100.0%	Satisfactory
2020	Q4	98	0	98	100.0%	Satisfactory
2021	Q1	107	0	107	100.0%	Satisfactory

The threshold for categorizing quarterly compliance as satisfactory versus unsatisfactory is a 95 percent compliance rate – see Table 3.6. Prior to the TRS-2 project, most of the compliance scores were in the "unsatisfactory" range (Q1 2018 – Q4 2019) and after the implementation of TRS-2, compliance scores rose above the 95 percent threshold to the "satisfactory" range (Q1 2020 – Q1 2021). See Table 3.7 below.

The risk score went from 1000, with a risk level classification of severe, in 2018 to a risk score of 140 in 2021 as represented in Table 3.7, which represents a decrease (improvement) of 86 percent. The key risk, "Motor carrier operators are walking in the VIG transfer zone before backing into the lanes", was officially removed from The Port of Virginia List of Key Risks Summary and classified as resolved in calendar year 2021.

Table 3.7 – Updated Post-Implementation Risk Score

Incident/ Event/ Report	Terminal	Date Identified	Root Cause/ Hazard	Exposure	No. of People	Severity of Consequence	Initial Risk	Control Measure(s) in place, related to Hazard	Probability	Risk Score	Risk Level
Motor Carrier operators are walking in the VIG transfer zone before backing into the lanes	VIG	2022	Turn Time, Terminal Historic Culture, Enforce-ment	4	1	70	350	Terminal Reservation System, Increased terminal capacity that has reduced turn time, and a Virtual enforcement program that cites motor carriers for being outside a truck.	0.4	140	Moderate

Improved Mobility

Before the mandatory reservation system was deployed at each of the terminals, The Port was unable to anticipate and organize cargo efficiently to facilitate import pickups. Containers were often moved multiple times based on the order truckers arrived at the gate and at the stacks, contributing to longer queues and longer wait times as reflected in Table 3.8. Baseline for TRS-1 is before the truck reservation system was in effect. Baseline for TRS-2 is after the truck reservation was put in place and before the enhancements for the TRS-2 grant were implemented. Without TRS-1 is the estimate if a reservation system was not in place. Without TRS-2 is the estimate with a reservation system, but without the TRS-2 enhancements.

Table 3.8 – Virginia International Gateway Annual Turn Times

Year	Total Moves	Total Visits	Total Minutes	Total Average Turn Times	Notes
2013	327,748	203,221	12,236,011	60.2	
2014	621,693	364,154	26,375,128	72.4	
2015	681,493	387,698	40,143,143	103.5	
2016**	618,066	399,444	30,917,748	77.4	
2017	642,509	411,859	32,164,376	78.1	
2018	667,808	420,820	38,042,128	90.4	Baseline for TRS-1
2019	704,219	443,300	17,493,622	39.5	Baseline for TRS-2
2020	763,749	456,827	17,209,434	37.7	Pre-COVID Logistics Crisis
2021	934,867	530,482	27,876,301	52.5	COVID Logistics Crisis
2022*	601,410	341,172	17,374,028	50.9	
2022 Est.	988,805	560,936	28,565,406	50.9	Estimated
2022 Est.	988,805	560,936	70,621,842	125.9	Without TRS-1 or TRS-2
2022 Est.	988,805	560,936	30,851,480	55.0	With TRS-1 & Without TRS-2

(*) Partial year data through August 10, 2022
(**) A previous version of this report included the 2016 Fiscal Year metrics, instead of 2016 Calendar Year values.

We use the following formulas to calculate the Estimated Total Moves, and Estimated Total Visits:

Total Moves / Number of days in the Partial Year = Average per day * 365 days/year = Average per year
Total Visits / Number of days in the Partial Year = Average per day * 365 days/year = Average per year
Total Minutes / Number of days in the Partial Year = Average per day * 365 days/year = Average per year

August 10 is the 222nd day of the year, so the math looks like:

601,410 / 222 = 2,709 * 365 = 988,805 Total Estimated Moves/Year
341,172 / 222 = 1,537 * 365 = 560,936 Total Estimated Visits/Year
17,374,028 / 222 = 78,261 * 365 = 28,565,406 Total Estimated Minutes/Year

The COVID Logistics Crisis caused a 39.3% increase in Turn Times (37.7 minutes * 39.3% increase = 52.5 minutes). We can use this increase to estimate what turn times would have been like if we hadn't done TRS-1 or TRS-2. The formula would be:

Baseline TRS-1 * 1.393 = estimated turn time average without TRS-1 or TRS-2
Baseline TRS-2 * 1.393 = estimated turn time average with TRS-1 and without TRS-2

The math would be:

90.4 * 1.393 = 125.9 estimated average turn time without TRS-1 or TRS-2
39.5 * 1.393 = 55.0 estimated average turn time with TRS-1 and without TRS-2

The total number of visits at Virginia International Gateway (VIG) in 2013 was 203,221 visits, with an average turn time of 60.2 minutes per visit as shown in Table 3.8. As volumes increased, turn times also increased. In 2016, before the first iteration of the Truck Reservation System (TRS-1) was implemented, turn times at VIG averaged 77.4 minutes as referenced in Table 3.9. The number of truck visits at VIG was 399,444 in 2016. The terminals were nearing capacity.

Table 3.9 – Existing 2016 Truck Processing Times During Each Stage of a Typical Trip

Trip Step	Step Description	VIG (minutes/vehicle)
1	Time spent at inbound portal and waiting in queue at the gate	13.8
2	Time spent at the gate arm waiting to be dispatched	5.1
3	Time spent being processed inside the terminal	52.0
4	Time spent at outbound portal and waiting in queue at the exit gate	2.9
5	Time spent at the exit gate arm waiting to exit	3.6
	Total Trip Time	77.4

In 2018 truck visits per month increased to 35,068 with turn times at 90.4 minutes on average for the year. As The Port began to implement the mandatory truck reservations and the first elements of TRS 2.0 technology in 2019, The Port began to see average turn times fall (39.5 min) while overall average monthly truck visits increased (36,942 truck visits per month). In 2020 with the deployment of additional TRS 2.0 enhancements, and focus on operational efficiencies, The Port of Virginia was able to handle an increase in truck visits beyond the designed terminal limits, averaging 38,069 visits per month with a reduced turn time of 37.7 minutes per visit. At the end of 2020 and throughout 2021 and 2022, the global shipping crisis caused havoc with the American shipping, port, and logistics industry. This is widely understood and documented. The Port of Virginia's quarterly reports for this grant covered this in detail during the crisis.

TRS 2.0 enhancements allowed The Port to operate at levels 25 percent above the design capacity for an extended period with a nominal increase in truck turn times. Thousands of containers were rerouted from other U.S. East Coast ports to Virginia because of our superior operating capabilities. While other ports saw turn times in the three-to-five-hour range, The Port of Virginia's turn times were within the 50-minute-to-60-minute range. This level of performance would have been impossible without the TRS-2 improvements.

Additional information can be found in section 1.1.1 of the "Best Practices Summary" document.

The goal of a reduction in turn times has been achieved and is directly attributable to the implementation of the mandatory reservation system. In 2021, the POV was able to move record gate volumes (1.63M gate transactions) at 50.2 minute total turn time for the calendar year. Of the 1.63M gate transactions, 530,482 truck visits were conducted at Virginia International Gateway with a turn time of 52.5 minutes. With cargo volumes up through calendar year 2022, this project has enabled The Port to continue to reduce total turn times.

Reduced Transportation-Related Emissions

Table 3.10 shows the Kilogram Emissions per 1000 truck visits to Virginia International Gateway.

Table 3.10 – Kilogram Emissions per 1000 truck visits

-	Visits	VOC	THC	CO	NOx	PM-2.5	PM10
2013	203,221	3.55	3.55	26.61	35.89	1.08	1.14
2018	420,828	3.00	3.00	22.49	30.33	0.92	0.97
2019	443,300	2.33	2.33	17.44	23.52	0.71	0.75
2020	456,827	2.22	2.22	16.65	22.45	0.68	0.72
2021	530,482	3.10	3.10	23.23	31.32	0.95	1.00
2022*	341,172	3.00	3.00	22.51	30.35	0.92	0.97
2022 Est.	584,866	3.00	3.00	22.51	30.35	0.92	0.97
2022 w/o TRS-1	584,866	4.80	4.80	35.98	48.51	1.47	1.55
2022 w/o TRS-2	584,866	4.06	4.06	30.41	41.00	1.24	1.31

* Partial year
VOC: Volatile Organic Compounds
THC: Total Hydrocarbon
CO: Carbon Monoxide
NOx: Nitrogen Oxides
PM-2.5: Particulate Matter of less than 2.5 microns
PM10: Particulate Matter of less than 10 microns

Data estimates from 2022 were extrapolated based on projected total visits (584,866). The Port was able to calculate the total time savings of appointment-based visits compared to non-appointment visits by operating day. The 2013 and 2018 baseline models were used to predict what changes in total minutes, turn times, and emission rates would have been in those years if TRS-1 and TRS-2 had not been implemented.

Based on the model, at a projection of 584,866 visits, 2022 estimated values without TRS-1 in place, would equate to 47,603,638 total minutes and an 81.4-minute total turn time, as referenced in the improved mobility Table 3.8. For 2022 estimated values without TRS-2, total minutes would be 40,233,095 at a 68.6-minute total turn time.

Using the projected total minutes and projected total visits, it is possible to calculate kilogram emissions per 1000 truck visits at The Port of Virginia by using the Environmental Protection Agency's Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks guidelines. We utilized the values in Table 2: Average Idle Emission Rates for Heavy-Duty Diesel Vehicles by GVW Class for VIIa classed vehicles. To arrive at the KG Emissions per 1000 truck visit pollutant values we used (((Total Minutes)*(POLLUTANT g/min))/1000)/((Total Visits)/1000)).

Emissions Damage Costs Saved per metric ton (Benefit Cost Analysis 2022 (Revised; Table 3.11):

Table 3.11 – Benefit Cost Analysis 2022: Metric Ton Emissions per year

-	Visits	THC	CO	NOx	PM-2.5
TRS-2 2022 Savings (Through 8/10/2022)	341,172	0.98	7.33	9.8892	0.2987
2022 Costs/Ton		N/A	N/A	$ 15,800	$ 761,600
Total Savings		N/A	N/A	$ 156,249.36	$ 227,489.92

Table 3.11 reflects data captured through August 10, 2022 for POV Truck Visits. For the purpose of calculating Emissions Damage Cost Saved per metric ton, we have assumed that TRS-1 is the baseline. Reductions in pollutants estimated in this chart are result of TRS-2 impacts relative to the TRS-1 baseline.

The technologies deployed directly reduce turn times and have a direct impact on reduction in truck idling at the terminals. By calculating the number of idling minutes saved, and using Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks values, we can arrive at cost savings values at the port based on the impact of this project. Using the Benefit Cost Analysis 2022 (Revised), we calculate a 2022 partial year NOx monetary savings of $156,249.36 and a PM-2.5 monetary savings of $227,489.92. Through partial year 2022, 0.098 Metric Tons of THC, 7.33 Metric Tons of CO, 9.8892 Metric Tons of NOx and 0.2987 Metric Tons of PM-2.5 were saved.

To estimate the cost savings of the TRS-2 improvements a simple model was created which baselines number of truck visits per day versus total turn time. The POV wanted to create an estimate of the impact of truck scheduling. To accomplish this, we had to compare it against a time when there was no truck scheduling (we picked 2013). Today, even the trucks that do not make appointments benefit from the structure that results from appointments made by other truckers. The model data was based on 2013 visits. The truck visit turn time is impacted by many different factors: total trucks on the terminal, number of containers on terminal, arrival patterns by time of day, day of the week, vessel arrival times, number of free days, warehouse loading, etc.

The TRS-2 improvements managed several of these factors and each contributes to the overall savings achieved by the new truck scheduling approach implemented as part of the grant. The Port selected the year 2013 since it predates TRS-1 and provides a baseline of truck on-terminal time against an uncontrolled baseline. Using data from 17 operating days in 2013 an equation was created that predicts the turn time based on 2013 operating dynamics. To be clear the development of the model could have been much more elaborate and could have taken other factors into consideration. Since that was not the primary goal of the work effort, we kept it simple. Virtually ANY person with marine terminal gate experience would agree that number of trucks per day and turn time are directly related to each other. The equation was then used to create a 2013 modeled turn time for all 188 operating days in 2022. In each case the modeled rate was different against the actual turn time to compute a savings in minutes as well as a savings in Kilograms (KG) of each of the pollutants (NOx and PM-2.5). The KG were converted to metric tons and the cost parameters from page 38 of US DOT Benefit Cost

Analysis Guidance for Discretionary Grant Programs (March 2022 Revised), see URL below, was used to monetize the savings. A spreadsheet with the derivation of the model, and the 188 days from 2022, and the savings calculation for each day and each emission constituent is available upon request. The accuracy of the approach can be debated but in the end our goal was to demonstrate that a savings was achieved versus how our terminal operated before we implemented truck scheduling. Most marine container terminals implement some form of traffic control. Our approach just happens to be leading edge. To be fair to the other terminals, a large part of the benefits of our approach is dependent on our automated container yard. There are only five automated container yards in the U.S. and two of them are located in Virginia. The non-automated yards will struggle to see the advantages of truck scheduling to the extent experienced by The Port of Virginia, but they will see some benefits – that is apparent in our results.

Concerning truck age data, the average truck age of all active and registered trucks within The Port of Virginia, truck registry is estimated at a 2010 engine year; the median engine year is 2012.

Additional information can be found in section 1.2.1 of the “Best Practices Summary” document.

(*)https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf

As noted above, the environmental impact is significant. On Tuesday, October 16, 2018, which represents a typical day in the fall of 2018, Virginia International Gateway, prior to mandatory reservation implementation, processed 2,893 gate transactions. On that day, the average total turn time for trucks was 96 minutes, with greater than 15 percent of truck visits in the two-to-four-hour range. In order to process that level of volume, the terminal opened at 0100 hours and did not close until 2200 hours, representing 21 total operating hours. Excessive truck idling was a constant feature of visiting the terminal.

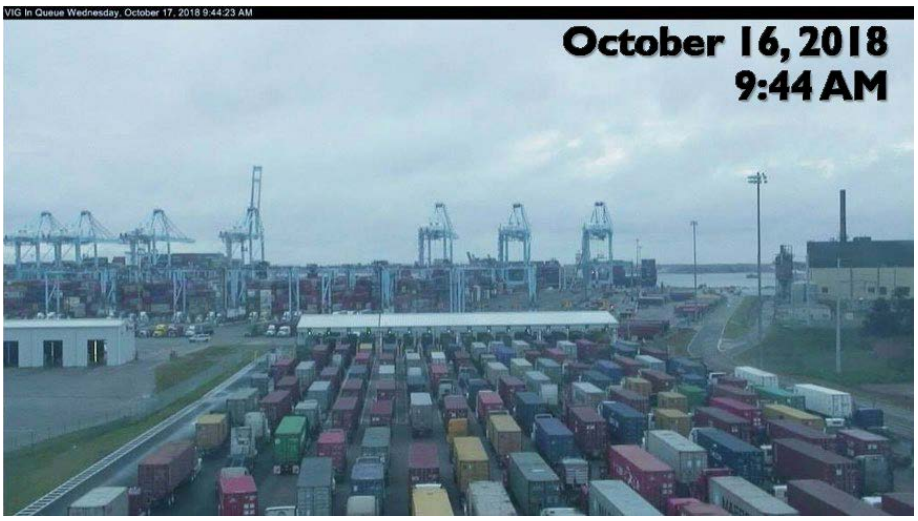

Figure 3.1: Picture of a typical day at Virginia International Gateway October 2019

One year later, on Tuesday, October 15, 2019, which represents a typical day in the fall of 2019, post-mandatory reservation implementation, we processed 3,768 gate transactions, a 30.2 percent increase, year over year. The operating window was reduced from 21 operational hours down to 14 hours (0300 to 1700) and had an average turn time of 36 minutes. Because of the technologies deployed, and despite continual yearly increases in in-gate volume, idling at Virginia International Gateway remains substantially reduced.

Despite volume increases, The Port of Virginia has been able to minimize truck idling on terminal due to the mandatory reservation system approach.

Optimized Multimodal System Performance

The Housekeeping proof-of-concept focused on measuring key performance differences between artificial intelligence-based housekeeping container stacks versus non-artificial intelligence-based housekeeping container stacks. A tool was developed to create a comparative analysis of stacks that utilized AI-based housekeeping versus stacks that did not. The analysis measured and compared the number of re-handles per import delivered from a given stack, a measurement of how many containers would be required to shift out of the way to lift a target container, machine gantry distances traveled for each import delivered, gross landside productivity and trucker wait time at the container stack. More improvements were made to the algorithms, and results from September 1, 2022 until October 31, 2022 show promising improvements, in table 3.12.

Table 3.12 – Artificial Intelligence (AI) Stack Time Improvements

Artificial Intelligence Stats	AI Total	Non-AI Total	AI Average	Non-AI Average	Percentage Improvement
Stacks	4	18	1.0	1.0	N/A
Delivery Import (DI) Moves	164	872	41.0	48.4	N/A
ALL Land Side Moves	529	2611	132.3	145.1	N/A
Land Side Crane Total Moves	945	4586	236.3	254.8	N/A
Water Side Crane Total Moves	827	4827	206.8	268.2	N/A
DI Rehandle (RH) Count	26	163	6.5	9.1	28.6%
DI Rehandle (RH) Time	54.40	397.42	13.6	22.1	38.5%
Total DI Move Time (ex-RH)	676.08	3784.33	169.0	210.2	19.5%
Total TEU	3977	17588	994.3	977.1	N/A
DI Total Distance	44347.30	221254.90	11086.8	12291.9	9.8%
DI Wait Time	3290.00	20337.00	822.5	1129.8	27.2%

Reduced Costs

The Port of Virginia achieved a reduction in operational gate hours while handling more cargo through its gates. In 2018 and 2019, The Port of Virginia gates were open 22 hours each day to keep up with cargo demand. After full implementation of mandatory reservations, we were able to decrease gate operational hours by 40.9 percent, down to 13 operational gate hours, while handling a 76.4 percent increase of in-gate container volume (2019 to 2021). It is important to note that all labor hours outside of the standard operating day are paid at a premium rate of time and a half or 1.5X of the normal labor rate. The process of handling containers (from the ship to the stack, within the stack, and to the truck) takes time and coordination from different Port systems. The artificial intelligence housekeeping enhancement for stack optimization will directly reduce the costs of operating The Port by reducing turn times and reducing the need for adding additional operating hours to accommodate additional capacity.

Rehandles vs average rehandles compares AI managed stacks to non-AI managed stacks. For the period beginning 9/1/22 through 11/14/22, the AI-managed stacks outperformed the baseline stacks. Performance has shown continued improvement as the AI model has been refined.

The stack housekeeping artificial intelligence proof of concept produced a measurable reduction in number of re-handles, reduction in gantry distances for truck deliveries, and enabled a net increase in deliveries per hour. On an average day the stacks that utilized Artificial Intelligence based housekeeping saw reduction in re-handles of domestic Imports (DI) by 28.6 percent. On an average day, The Port moves approximately 758 import containers, without the intention of delivering those containers to a truck. Based on the results from the proof-of-concept, we could potentially eliminate 218 unnecessary moves per day. Extrapolated out over the course of a year, leveraging an AI-based housekeeping approach could eliminate 55,154 wasteful container repositioning moves per year at VIG. The Port of Virginia will look to expand the AI proof of concept across all container stacks at VIG

and implement the same strategy at Norfolk International Terminals based on the results of this proof of concept at the conclusion of this project.

Additional information can be found in section 4.1.4 of the "Best Practices Summary" document.

Real-time Integrated Traffic Information

Providing integrated real-time transportation information to trucking companies and the Beneficial Cargo Owners (BCO's) is a goal of the grant project. These port stakeholders identified visibility needs that they would like to have tracked. Stakeholders desired two different delivery mechanisms for this data. First, a subscription service in which a BCO or trucking company would programmatically provide a list of containers that they are interested in obtaining current informational status. Second, the port would also provide programmatic access to current status of containers via an application programming interface (API). In this case, the port stakeholder would input a booking number, bill of lading, and a container number to request the current status of a particular container and the system would respond with the current event state. Success for this goal is the ability to onboard as many port stakeholders as possible, with a minimum of 10 BCO's or trucking companies receiving daily electronic feeds.

Externally facing websites are a great tool for communication of real-time transportation data to various stakeholders. Based on stakeholder feedback, additional interfaces for data delivery are of high interest. The Port of Virginia delivered the initial scope of data availability through API access and subscription service access. Through the onboarding process, discussions with various stakeholders generated new ideas and new opportunities to improve access to key data. The Port has added two additional endpoints for data consumption that focus on vessel schedule data and export booking data. An opportunity exists to establish a standard that all U.S. ports can adopt to improve accessibility and reduce development overhead necessary to utilize data integration. One of the major benefits to creating the API/subscription service is that The Port was able to comply with the Ocean Shipping Reform Act of 2022.

BCO and motor carrier interest in API capabilities is extremely high. There are opportunities for standardization that must be explored. The Port of Virginia's largest BCO works with over 27 domestic port terminals and is eager to develop API integration with The Port. However, they would rather avoid creating 27 different standards for integration. The POV has been very purposeful in our system design to be very tolerant of those different customer demands.

The Port of Virginia currently has 10 port stakeholders that are vetted and on-boarded to access information programmatically with our systems. To date there are 1.5 million transactions that have occurred without human intervention - see Table 3.13. The Port does not have direct access to the cost savings for these stakeholders, but the demand is growing every month, as we on-board more entities.

Table 3.13 – Programmatic transaction to Port Stakeholders

API Users	Feb 22	Mar 22	Apr 22	May 22	Jun 22	Jul 22	Aug 22	Sep 22	Oct 22	Grand Total
Cosco Shipping Lines								9	1,845	1,854
Dunavant Tracking						49	106		3	158
Expeditors	232,868	65,213	584	4			77			298,746
Flexport							12	26,956	134,491	161,459
International Paper	35	109		15	982	1,765	508	359	5,680	9,453
LL Flooring				86	111	3,001				3,198
Mohawk Industries									24,277	24,277
Rubber Meets Rd, Inc.		685	225	2,322	22,989	15,546	45,673	43,764	62,345	193,549
Splice		5	13	1,307	1,742	1	52	247	505	3,872
Terminal 49, Inc.		129,536	234,753	271,576	89,824	37,422	22,436	20,869	19,908	826,324
Grand Total	**232,903**	**195,548**	**235,575**	**275,310**	**115,648**	**57,784**	**68,864**	**92,204**	**249,054**	**1,522,890**

The creation of a mobile application has two distinct benefits. The first benefit is to enhance the trucker's off-terminal experience by enabling truckers to confirm a reservation or retrieve appointment status, container availability, or electronic interchange receipts (EIRs). The app also provides truckers with the ability to update minor elements of a reservation such as container number, to receive lane confirmation, and to supplement automatic truck identification where applicable, all from a mobile device. With the future release of TRS-3, the mobile application will also improve on-terminal experience, as the application will include GPS sensing on the terminal, stack availability information, stack queueing information, estimated time to container servicing, and trouble information. Other enhancements are planned for both the on terminal and off terminal experiences.

The port is currently in beta testing with the first release of the mobile application software. A formal survey will be conducted, and data will be collected at the end of this period. After completion, an addendum to the Final report will be added to share this information.

Institutional and/or Administrative Benefits

The Port of Virginia was able to fluidly handle additional volume while maintaining sub-60 minute total turn times consistently. Cargo re-routed from ports experiencing congestion was able to be absorbed without significant impact to port turn times.

The U.S. supply chain impacts of one port are inevitably felt at other points. To strengthen the entire U.S. network of ports, we must be open to sharing successes and failures. Through the course of this project, we have been afforded the opportunity to network with other U.S. ports specifically regarding their reservation system implementation efforts. We have also had the opportunity to speak with other ports who were exploring the possibility of implementing reservation systems. Implementing a mandatory reservation system requires an incredible effort from not only the port,

but also the motor carrier community, beneficial cargo owners, labor, and other stakeholders. Successful implementations will have continual positive impacts across the entire U.S. maritime supply chain.

4. Lessons Learned, Recommendations, and Conclusions

Innovative Aspects of Project

The Port is in the nascent stages of leveraging artificial intelligence and machine learning to optimize port operations. The proof-of-concept implemented as a part of this grant project is certainly noteworthy and innovative. The Port believes that there is an incredible opportunity for further develop the use of these technologies to improve port operations and marine terminal efficiencies. While our specific focus was on stack housekeeping optimization, there are many additional areas where AI and machine learning can be leveraged.

Improving port-specific data visibility was a key goal of this project. The development and deployment of the subscription service and API endpoint-access for container data enabled The Port of Virginia to successfully meet this goal for Beneficial Cargo Owners and port stakeholders. Improved access to up-to-date data has the ability to deliver improved efficiency for the supply chain. Our work on this aspect of the project has generated new ideas for additional areas to expand programmatic reach to include vessel schedule data and export booking related data.

Benefit-Cost Assessment

The benefits and savings derived from the deployment and operational costs associated with the project are notable. Once the core project was implemented, The Port was able to reduce operational gate hours at NIT and VIG by 40.9 percent while handling a 76.4 percent increase in total gate volume from 2019 to 2021. We would anticipate by reducing operational hours, subsequent benefits for maintenance and repair of equipment were also realized through reduced machine operating time, and improved access to preventative maintenance schedules. Our experience with the pandemic proved that container dwell is heavily impacted by a variety of factors, many of which are unrelated to operational excellence. This has caused us to reconsider dwell reduction as a side effect of the TRS system improvements.

As illustrated in the Reduced Environmental Impact section of this report, reduced environmental impact generates cost savings. Every minute of turn time that we are able to reduce or eliminate results in real reduction in environmental impact that can be quantified using the Environmental Protection Agency's guidance on Heavy-Duty Diesel average idle emission rates. This year, through August 10, based on 2022 guidance figures, we have been able to generate NO_x savings of $156,249.36 and $PM_{2.5}$ savings of $227,489.92.

Lessons Learned and Conslusions

A key lesson learned is to identify and engage all stakeholders early and continually. Broad market research and stakeholder engagement can help to identify the best solutions to focus your efforts. The solutions that we have implemented with this grant were broad changes to existing computer systems. Significant testing efforts and identification of edge cases must be employed and validated before implementing the solution. In the midst of a global container crisis, change was only implemented after careful consideration to minimize or mitigate impact to both operations and the current operational systems.

The Port of Virginia offers the following recommendations to future deployers:

- Develop a robust communications plan that includes all identified stakeholders.
- Build in the appropriate amount of time into your project schedule when working with cutting edge technologies and system changes that can impact the entire operational flow of an established terminal operation.
- Use lessons learned from operating in a pandemic to build remote-work strategies to minimize impact to project timelines.

The above items represent the lessons learned from the TRS-2 Enhancements (sponsored by this grant). For a full list of Truck Reservation System lessons learned, please refer to the “Best Practices Document”.

The successful implementation of this project has shifted the paradigm for how The Port of Virginia operates. We can no longer imagine an operational world without a mandatory reservation strategy in place. This project has allowed The Port to become better stewards of the communities that we inhabit by improving traffic flow in and around our facilities and by significantly reducing truck idling and carbon emissions associated with port operations. The benefits derived from this project have enabled the POV to remain one of the most fluid ports in the U.S. during both a global pandemic and through the supply chain issues of the last year. We are thankful for the opportunity to partner with the Federal Highway Administration in the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program.

Technology is ever changing, and the United States supply chain must rise to meet these challenges. Not only do we have to keep commerce moving, but we must also drive innovation and explore new technologies and strategies that advance continuous improvement of our Port ecosystems.

There are several benefits that are derived from the deployment of this technology. Chief among these benefits is the safety improvements with respect to the motor carriers on- terminal experience. The deployment of a terminal reservation system at The Port of Virginia has had a major impact on

the health and safety of motor carrier patrons. According to blueoceana.com, an organization that tracks fatalities in all marine cargo facilities world-wide, a leading cause of death occurs when pedestrians are struck by moving equipment or vehicles. Pedestrian safety has always been a concern in the landside transfer zone. With heavy machinery moving cargo containers and large trucks traversing the port facilities, it is not a safe environment for pedestrians. With a reduction in truck turn times, truckers are more likely to stay in the cabs of their vehicles, thereby creating a safer terminal experience. Our terminals are inherently safer as a direct result of this technology deployment. Our goal is always to make sure the community comes to work and makes it home safely. This initiative brought us much closer to that vision.

When we surveyed the stakeholders at The Port of Virginia, most of the Beneficial Cargo Owners (BCO's) requested better access to information when dealing with the port. This not only included timely access to visual events, but also data related to entering and departing The Port. The POV developed an application programmatic interface (API) and subscription service that allows for this to occur.

When we began this project, we were looking for the state-of-the-art reservation enhancements by surveying our beneficial cargo owners. The common refrain was the need for improved visibility and data availability. The desire for improved visibility and access lead us down the path of creating an application programmatic interface (API) and subscription service that are now available. As a result, stakeholders at The Port of Virginia are able receive critical business information more quickly, reducing internal cost and increasing efficiencies.

5. Appendix A

Table A.1 provides the different performance measurements based on the ATCMTD goal areas.

Table A.1: Performance Measurement Summary Table

Goal Area	Performance Measure	Data Method	Data Source	Data Collection Time Period	Sample Size (if applicable)
Safety	Hazards or Events that are safety issues.	Quarterly Observation and recording	Port Safety Director observations	Quarterly observations from 2018 until 2021	N=1082
Reduced Congestion and/or Improved Mobility	Turn Times through the Port	Annual Report Turn Times	Port Information Technology Systems	Annual Port Visits from 2013 until 2022	3.9 million truck visits
Reduced Environmental Impacts	Reduction in THC, CO, NOx emissions	Environmental modeling	Environmental model emission estimates	Baseline data and annual data	443,300 for Baseline (2018) 584,866 for est. 2022
Improved System performance (including optimized multimodal system performance)	Number of House Keeping Moves in the stack using Artificial Intelligence	Stack Move records	Port Information Technology Systems	September 2022 – October 2022	21,565 Stack TEU moves
[Effectiveness of providing integrated real-time transportation information to the public to make informed decisions	Number of programmatically transmitted transactions to Port State holders	Transaction Reports	Port Information Technology Systems	February 2022 – October 2022	1,522,890 transactions