ADVANCED TRANSPORTATION AND CONGESTION MANAGEMENT TECHNOLOGIES DEPLOYMENT (ATCMTD) FINAL REPORT

FRATIS Modernization

2025 Final Report to the Secretary

DRAYFLEX

prepared for
FEDERAL HIGHWAY ADMINISTRATION

prepared by
LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

SEPTEMBER 2025

Metro

Notice

Nonbinding Contents

Quality Assurance Statement

FREIGHT ADVANCED TRAVELER INFORMATION SYSTEM (FRATIS) MODERNIZATION

Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Final Report

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List of Acronyms

API	Application Programming Interface
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
CARB	California Air Resources Board
CV-AERIS	Commercial Vehicle Applications for the Environment: Real-Time Information Synthesis
DrayFLEX	Drayage, Freight, and Logistics Exchange
EMFAC	Emission Factors
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRATIS	Freight Advanced Traveler Information System
GHG	greenhouse gases
IT	Information Technology
ITS	Intelligent Transportation System
mph	miles per hour
MTO	marine terminal operator
POLA	Port of Los Angeles
POLB	Port of Long Beach
SE	systems engineering
TMS	truck management system
USDOT	United States Department of Transportation
VMT	vehicle-miles traveled
ZE	zero emissions

1.0 PROJECT SUMMARY

1.1 Project Description

In Los Angeles County, the Port of Los Angeles (POLA) and Port of Long Beach (POLB), collectively known as the Port Complex, are the two largest ports in the Nation, first and second respectively, and combined are the ninth-largest port complex in the world, handling 40 percent of the Nation's containerized import cargo and 30 percent of containerized exports. These ports are supported by over half a billion square feet in warehousing space and serviced by 1,000 trucking and drayage companies. The existing and growing freight traffic in the region strains the area freeways' limited capacity, resulting in traffic congestion, safety concerns, and spillover traffic onto local roadways, while the diesel-fueled trucks compound air quality and health impacts on communities, many of which are historically disadvantaged.

Infrastructure expansion options to address this expected increase in freight volumes are challenging in Los Angeles County. The future levels of freight are expected to cause severe truck congestion issues which will affect the entire Los Angeles region. More specifically, this will include truck traffic delays in and near the Port Complex, as well as general traffic congestion on highways and arterials across the region due to the continued increases in regional truck traffic. Increased truck traffic will generate negative regional effects related to air quality, noise, and safety. Additionally, freight delays themselves have a negative economic impact on the private sector.

Figure 1. Truck delay locations in the project primary impact area.

Source: Metro 2021 Los Angeles County Goods Movement Strategic Plan.

In 2013, the Los Angeles County Metropolitan Transportation Authority (Metro) and the Gateway Cities Council of Governments led one of the first prototype tests in the Nation for a Freight Advanced Traveler Information System (FRATIS) application to help improve freight transportation in the area, particularly near POLA and POLB. Due to the success of the prototype, in 2014 the FRATIS project was expanded and updated with a limited deployment of trucks. This project represents the third phase of FRATIS for Metro, in cooperation with the Federal Highway Administration's (FHWA) Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program. The FRATIS concept was included in the Gateway Cities Technology Plan for Goods Movement (Container Moves Productivity Improvement and Freight Traveler Information Dissemination) and the Gateway Cities Strategic Implementation Plan.

This FRATIS project was rebranded as the Drayage, Freight, and Logistics Exchange (DrayFLEX) and was developed as a pilot project to provide trucking companies the ability to more efficiently, and in realtime, plan container pick-ups and drop-offs at the Port Complex, taking into consideration traffic, incidents, wait time at the terminals, proximity, and a variety of other factors. DrayFLEX used available information from truck management systems (TMS), trucking companies, and other traveler information sources to improve drayage dispatch processes (which are largely manual), increase truck operational efficiencies, and provide truck drivers the best routes to use to and from the ports. The intent was to deploy DrayFLEX across multiple trucking companies to improve safety, reduce congestion, emissions, and fuel use, integrate traveler information, and reduce costs. DrayFLEX was developed as two unique but related systems called DrayFLEX Core and DrayFLEX-Trip.

DrayFLEX Core—The DrayFLEX Core was primarily focused on "optimizing" the dispatching of trucks to maximize their utilization in the delivery of customer orders and return of empty containers. DrayFLEX Core was integrated with a TMS for order information, appointment information, truck/driver availability, and equipment management information, as well as turn time and truck location from GeoStamp. GeoStamp leverages location data and predictive analytics to deliver throughput, terminal turn times, and other supply chain and logistics data to its clients. GeoStamp is a part of WiseTech Global which develops and supports multiple TMSs, including Trinium which is one of the more widely used TMSs in Southern California. This development approach allowed the DrayFLEX Core optimization engine to more efficiently allocate trucks and drivers to appointments, increasing trucking company operational efficiencies and reducing vehicle-miles traveled (VMT), fuel use, and emissions. The key features of DrayFLEX Core included:

- Instant best-match load assignments with redispatch options when changes arise en route
  - Trip monitoring
  - Move alerts
- Automated dispatch workflow and optimization
- Chassis availability and matching

- Empty container returns
- Integration with TMSs
- Performance reporting and dashboards

DrayFLEX Core was implemented as a Software-as-a-Service application deployed to the Microsoft Azure cloud. DrayFLEX Core's primary information source was the trucking company's TMS via Application Programming Interfaces (API). Other data or tools needed for DrayFLEX Core optimization included GeoStamp for real-time wait times at terminal gates and truck locations, empty container return data from the terminals, and Microsoft Bing for estimated travel times. The DrayFLEX Core system was designed and developed to accommodate trucking companies of any size with minimal to moderate coordination with a trucking company's Information Technology (IT) staff to implement the data exchange. Customizations specific to each trucking company also are available for optimization priorities (e.g., driver hours, customer preferences, etc.). A standard Google Chrome browser could be used to access the DrayFLEX Core Web interface with secure login capabilities.

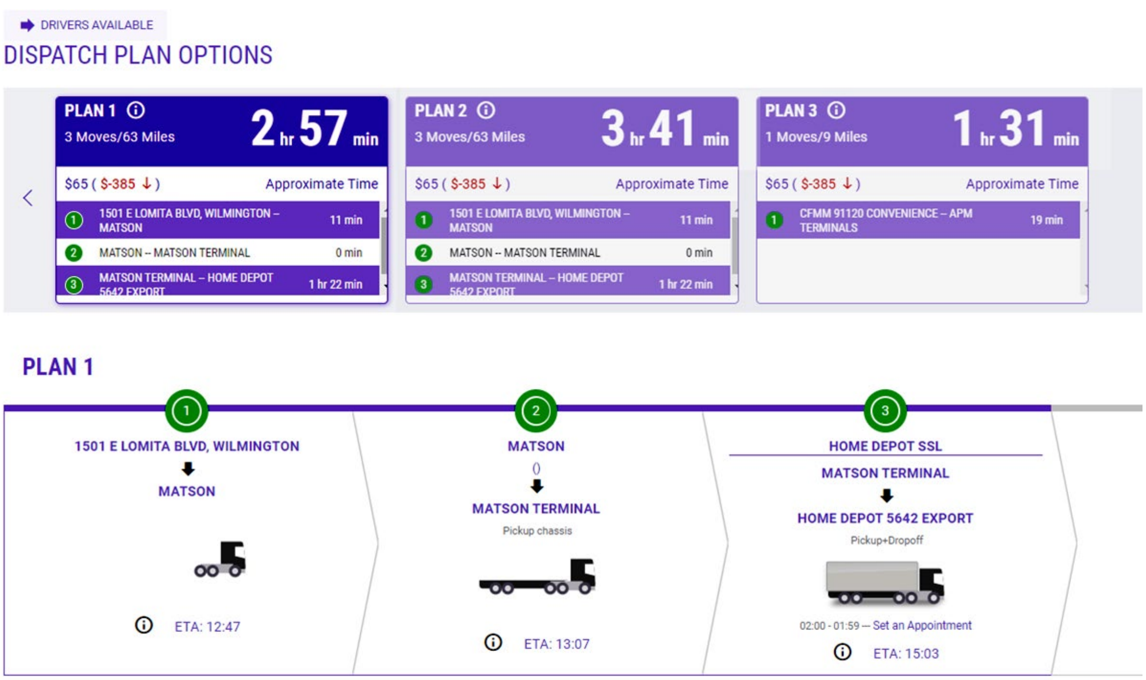

Figure 2. DrayFLEX Core example dispatch option for a driver.

Source: DrayFLEX Core.

DrayFLEX-Trip—DrayFLEX-Trip was a mobile application (iOS and Android) for truck drivers, providing turn-by-turn route options and en route alerts. The DrayFLEX-Trip app generated route options for the destination and appointment/arrival time based on the current traffic conditions, estimated fuel use, terminal gate wait time, and prohibited truck routes. Incident and slowdown ahead warnings and speed advisories were provided en route via audible alerts to the truck driver. From the perspective of truckers, the DrayFLEX-Trip app worked the same as other smartphone-based navigation programs such as Waze or Google Maps, except it provided truck-specific route guidance. A website also was developed to provide performance reporting information. DrayFLEX-Trip key features included:

- Fastest or more fuel-efficient route options
- Turn by turn routing based on truck profile
- Estimated time of arrival and appointment on-time arrival information
- Favorite locations
- Restricted route notifications
- Audible incident alerts
- Audible speed notifications
- Slow-down-ahead notifications
- Terminal wait and turn times
- Trip summary and ratings

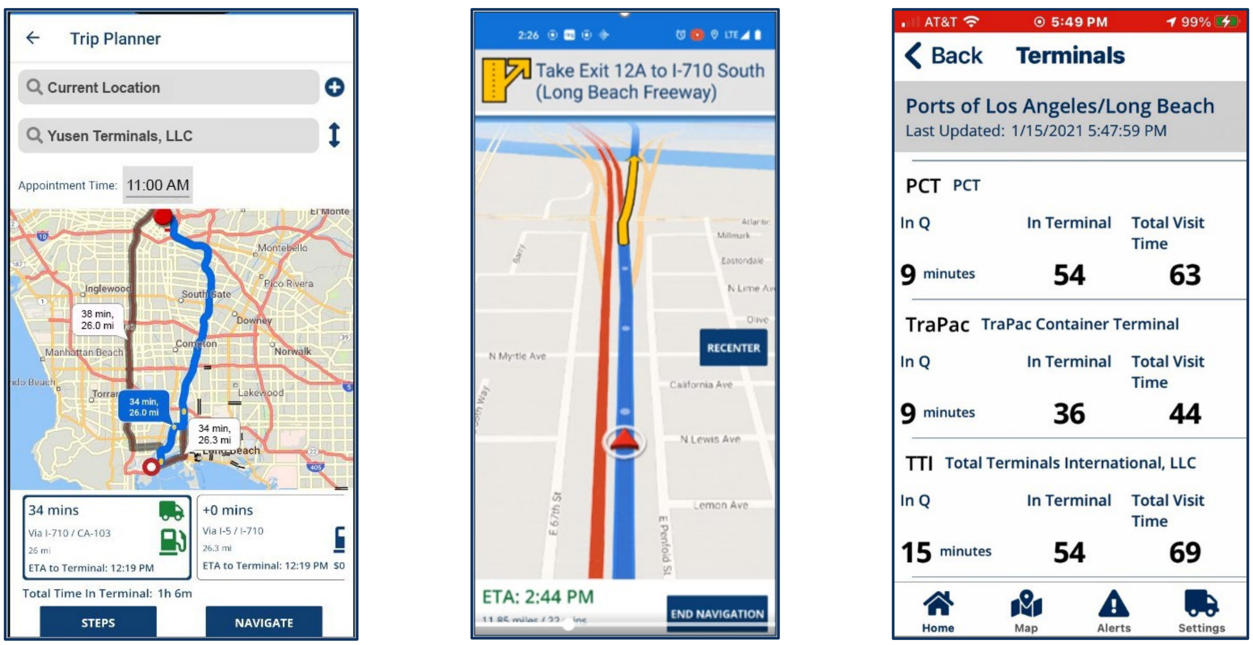

Figure 3. DrayFLEX-Trip example screens.

Source: DrayFLEX-Trip.

1.2 Project Scope

Through the data exchange and integration of different trucking industry and traveler information sources, DrayFLEX Core and DrayFLEX-Trip were intended to improve the coordination of freight movement to and from POLA and POLB, translating to reductions in freight congestion and fuel use, and improvements in air quality for the region.

DrayFLEX Core and DrayFLEX-Trip development were completed per the project design in 2021, with all intended features available. DrayFLEX Core was developed through an iterative Agile development process. As planned, several design releases were developed and reviewed by the project team and the trucking company stakeholders. Through regular coordination and communication with the project stakeholders, the DrayFLEX Core system was developed as an integrated backend software to major TMSs for drayage operators that heavily utilize a TMS in their existing business operations. Additionally, through the validation efforts of each release of the Agile process, additional capabilities requested by the trucking companies were added such as chassis matching and availability and empty container returns.

DrayFLEX-Trip was developed through the systems engineering (SE) process. The DrayFLEX-Trip system synthesized third-party traffic and incident data to provide truck operators with real-time routing information. Several options for accessing DrayFLEX Core and DrayFLEX-Trip applications were made with consideration of existing business models for the various logistic entities.

Due to the COVID-19 pandemic and its impact to the region's and Nation's economy, as well as a variety of other external factors such as company and staff transitions and acquisitions, port labor issues, etc. (see Section 2.7 for details), unusual and unanticipated freight and logistic operations impacted the deployment schedule for both DrayFLEX Core and DrayFLEX-Trip. The two ports saw significant fluctuations in container movement, resulting in resource constraints for the original project truck driver and dispatcher participants. Deployment was repeatedly delayed due to difficulty in obtaining trucking company participants.

DrayFLEX Core. Due to DrayFLEX Core's dependence on access to trucking companies' TMS, its development and pilot was completely reliant on entities outside of the project contract. Not only did COVID-19 pose trucking company resource-related limitations for supporting the project, it also resulted in several supply chain challenges with empty container movements, import/export imbalances, chassis availability issues, and excessive warehouse and distribution center inventory. As a result, the trucking company participants repeatedly needed new features added to DrayFLEX Core to meet their needs for a full pilot deployment. In addition, the project also was delayed by multiple trucking company champions and contacts shifting to different entities, a TMS crash and transitions to a cloud version, and a TMS being acquired and consolidated into a different entity requiring a shift to a different TMS and trucking company partner. At the end of May 2024, after multiple initial pilot attempts, the TMS company and project partners determined that trucking companies were not ready for this level of dispatch optimization. It was suggested that the dispatch optimization capabilities of DrayFLEX Core would have a greater potential for success if implemented as smaller steps within the TMS itself, not as a third-party tool as developed. As such, this project transitioned from an actual pilot deployment to a simulated assessment using data available from the DrayFLEX Core dashboard to assess a subset of the performance metrics. The original performance metrics that were not able to be assessed via the simulated approach included: Mobility—turns per truck per day and perceived congestion improvement; and Economic Benefit/Cost Savings—number of dual transactions, number of transactions, and moves per driver per shift.

DrayFLEX-Trip. While DrayFLEX-Trip was a pioneering idea when the project began in 2018, several new truck routing applications were made available to users over the design and development period, one of which is free and developed by truckers. Several recruitment efforts were conducted (social media, email or phone contacts to over 200 trucking companies, flyer handouts, raffles, etc.) but requests for and utilization of DrayFLEX-Trip were lower than planned. Over 40 users independently signed up for DrayFLEX-Trip licenses, of a 100 truck driver goal, with 20 actual trips performed. Due to the challenges with recruiting users and the limited utilization of DrayFLEX-Trip, in May 2023, FHWA approved the use of a simulated approach in order to assess a subset of the performance measures, in addition to the limited data from actual users. The following performance measure was not able to be assessed based on this change in approach: Safety—number of dangerous slow-down notifications. The analysis approach was modified for some of the other performance measures, including Mobility—travel time, Environment—emissions/greenhouse gases (GHG) and fuel use, Economic—fuel savings.

1.3 Project Timeline

Table 1 presents the overall DrayFLEX project timeline:

- Both DrayFLEX Core and DrayFLEX-Trip were developed with full functionality of their intended features.
- DrayFLEX Core was deployed for a trucking company but did not achieve pilot utilization as planned. Multiple attempts were made to conduct a live pilot, but the trucking company had resource limitations, required additional features or adjustments before they would use, or had other reasons for delaying or not being able to pilot the tool.
- DrayFLEX-Trip was deployed as a pilot but did not achieve sufficient utilization to perform quantitative analyses so it was transitioned to a simulated analysis for several of the performance metrics.
- Some of the DrayFLEX-Trip performance measurement included trips conducted as part of the testing phase.

Table 1. Project timeline.

Project Activity	Timeframe
Notice to Proceed and Project Kickoff	July 2018
Project Management Plan	July 2018–September 2018
Concept/Project Refinement	September 2018–January 2019

Project Activity	Timeframe
Stakeholder Engagement and User Needs	September 2018–June 2024
Systems Engineering Management Plan	Core: December 2018–April 2019 Trip: January 2019–May 2019
Concept of Operations	Core: January 2019–April 2019 Trip: January 2019–May 2019
System Requirements	Core: March 2019–August 2020 (Agile, iterative) Trip: May 2019–August 2019
System Design	Core: March 2019–March 2021 (Agile, iterative) Trip: June 2019–November 2019
System Development, Testing, Integration, Verification	Core: June 2019–April 2021 (Agile, iterative) Trip: February 2020–December 2021
System Deployment (development complete per design)	Core: Development complete April 2021 Trip: Development complete and deployed December 2021
System Operations and Performance Measurement	Core Simulation: August 2021–May 2024 Trip Pilot: January 2022–December 2022 (also included some trips performed during testing in 2021) Trip Simulation: September 2023–January 2024
Final Report	May 2024–February 2025

2.0 PERFORMANCE METRICS, EVALUATION METHODS, AND DATA SOURCES

Efficient goods movement through the Los Angeles region is pivotal to the quality of life for residents, and to the long-term economic health of businesses in the region. Residents benefit from improved air quality resulting from more efficient freight operations, while businesses benefit from lower costs associated with improved travel-time reliability, vehicle operating costs (e.g., fuel), and on-time deliveries, savings that they can then pass on to consumers. Examples of current inefficiencies include extended periods of truck idling and excessive trips by unloaded trucks.

To address the aforementioned regional issues, the following objectives were selected for the project: (1) improve traffic congestion in the port complexes, highways and arterials; (2) improve inefficiencies in the drayage system; (3) combat degradation of air quality; and (4) improve traveler information. These project objectives are further discussed in the following subsections.

2.1 Improve Traffic Congestion in the Port Complexes, Highways, and Arterials

Traffic congestion in and around the Port Complex is an issue that continues to plague the region. Within the Ports, truck turn times are lengthy and inefficient. An estimated 20 percent of truck turns at the Port terminals were over two hours both pre-COVID (2015) and post-COVID (2022). Often, the container yards experience uneven traffic flows and truck peaking. Additionally, I-710 South is severely congested; there are nearly 60,000 daily truck trips just along the corridor. The I-710 experiences recurring and nonrecurring incidents, much of which is due to a shortfall in capacity and road conditions. Initiatives have been put in place to alleviate the congestion in the area and at the Ports, such as the PierPass Program and the deployment of the Advanced Transportation Management Information System. These initiatives used technology to better manage the movement of vehicles within and around the Ports. However, even with these measures, congestion remains to be a major issue and will continue to increase. To alleviate the issue of congestion, the DrayFLEX Project endeavored to improve the flow of drayage information, trucking company efficiencies through dispatch optimization, and truck routing and information on traffic conditions.

2.2 Improve Inefficiencies in Drayage Operational System

There are several trucking inefficiencies that contribute to traffic issues in the Port Complex area, including—but not limited to—excessive wait times at the marine terminals; lack of information on traffic, container availability, and other conditions at the Port facilities; limitations associated with the TMSs and appointment systems; and communication issues existing between marine terminal operators (MTO) and drivers. DrayFLEX Core aimed to improve some of these inefficiencies by increasing the dissemination of data and communication between the various freight entities and systems, helping to reduce truck travel time and/or miles traveled, increasing dual transactions, and reducing turn times.

2.3 Combat Adverse Environmental Effects

Idling trucks pose a critical problem in and around the Ports. They account for nearly nine percent of the on-road diesel exhaust emissions. Furthermore, heavy-duty trucks are the single largest source of smog and pollution caused by exposure to toxic diesel particulates. This is partially due to the truck idling and a lack of operational efficiency inside the ports. Transportation technology can play a major role in increasing the efficiency of drayage movements. The DrayFLEX Project strived to provide optimization efficiencies, such as identifying location-based load matching and dual transaction opportunities, reducing bobtail operations. This could help reduce VMT and idling, and allow truck drivers to use their time more efficiently, which also results in reduced fuel consumption and emissions.

2.4 Improve Traveler Information

Information between MTOs, trucking company dispatchers, and truck drivers has been traditionally disjointed. Manual intervention is required since there are several different systems to manage trucking company assets, container availability, appointment windows, chassis availability, and traffic conditions. With the DrayFLEX Core system, there is more coordination and information sharing between the different systems allowing for more seamless and effective trip planning. In addition, DrayFLEX-Trip provides truck drivers with audible en route traffic alerts and notifications.

2.5 Alignment with U.S. Department of Transportation Strategic Goals

Table 2 below lists the U.S. Department of Transportation (USDOT) Strategic Goals applicable to this ATCMTD grant Project. Since the Project's ATCMTD grant award, the USDOT updated their Strategic Goals: Safety, Infrastructure, Innovation, and Accountability. Please note that not all USDOT Strategic Goals are applicable to the DrayFLEX Project and many of the real-world goals were unmet due to the aforementioned issues that arose due to COVID-19, company and staff changes, etc.

Table 2. DrayFLEX project's alignment with U.S. Department of Transportation strategic goals.

#	U.S. Department of Transportation Strategic Goals	Project Alignment
1	Reduced costs and improved return on investments, including through the enhanced use of existing transportation capacity.	Reduce costs and improve return on investments for the through drayage optimization (Core) and reduced fuel costs (Trip).
2	Delivery of environmental benefits that alleviate congestion and streamline traffic flow.	Alleviate congestion and improve traffic flow through the optimization of drayage processes (Core) and improve truck routing and speed advisories (Trip).
3	Measurement and improvement of the operational performance of the applicable transportation networks.	Optimize the drayage operational system (Core); improve the movement of freight trucks (Trip).

#	U.S. Department of Transportation Strategic Goals	Project Alignment
4	Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety.	Operate as a mobile application providing truck drivers with recommended route and speed advisories to avoid traffic events and incidents.
5	Collection, dissemination, and use of real-time transportation-related information to improve mobility, reduce congestion, and provide for more efficient and accessible transportation, including access to safe, reliable, and affordable connections to employment, education, healthcare, freight facilities, and other services.	Utilize historical data to analyze recurring conditions and provide real-time data to trucking companies (Core). Provide route recommendations, incident and slowdown alerts, and speed advisories.
6	Monitoring transportation assets to improve infrastructure management, reduce maintenance costs, prioritize investment decisions, and ensure a state of good repair.	N/A
7	Delivery of economic benefits by reducing delays, improving system performance and throughput, and providing for the efficient and reliable movement of people, goods, and services.	Optimize the drayage operational system (Core); improve the movement of freight trucks and goods (Trip).
8	Accelerated deployment of vehicle-to-vehicle, vehicle-to-infrastructure, and automated vehicle applications, and autonomous vehicles and other advanced technologies.	N/A
9	Integration of advanced technologies into transportation system management and operations.	Use third-party data alternatives to provide recommended route options and speed advisories. The project does not integrate the applications into existing transportation system management and operations.
10	Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, and sustainable movement of people and goods.	Evaluate using actual truck management system (TMS) and simulated optimization data (DrayFLEX Core). Evaluate using a simulated approach based on actual trucking company move data (DrayFLEX-Trip).
11	Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges.	DrayFLEX was built off previous Freight Advanced Traveler Information System (FRATIS) projects. The intent of the project was to develop a solution for freight operators that could be commercialized for future application (Core and Trip).

2.6 Consolidated Goals

The goals and objectives for the project were consolidated into six overarching goals: mobility, safety, environmental benefits, operational efficiency, economic benefits, and traveler information. Performance metrics for the evaluation were selected based on several compounding factors, including availability of data, ability to automate and analyze, usefulness, value for assessing the performance, design and development of the DrayFLEX systems, and the impact of COVID-19 on the economy and movement of goods. To the extent possible, quantitative measures were selected where data were available; qualitative data supplemented quantitative measures. Adjustments also were made to reflect the simulated approach for evaluation of the project. As a result of the simulated approach, some quantitative measures were removed since data were not available. However, multiple additional measures were added to provide perceived impacts or benefits (marked with a "*" in Table 3 and Table 4). Table 3 describes the key performance indicators associated with each goal for the project performance assessment.

Table 3. Key performance indicators.

Overarching Goal	Description/Hypothesis	Key Performance Indicators—Core	Key Performance Indicators—Trip
Mobility	DrayFLEX will improve mobility and reduce congestion for the trucking community through optimization of truck trip planning and dispatching (Core) and improved truck routing capabilities (Trip).	• Vehicle-miles traveled (VMT) per move • Perceived reduction in bobtails* • Perceived reduction in terminal gate idling/wait times*	• Travel time • Perceived trip time improvement • Perceived congestion improvement
Safety	The DrayFLEX project will improve safety by providing information to the driver on traffic conditions (Trip).	N/A	• Perceived safety
Environment	Reduced congestion, bobtails, queues, and idling from the DrayFLEX project will result in environmental benefits, including reduced emissions and fuel use (Core and Trip).	• Emissions/greenhouse gases (GHG) • Fuel use	• Emissions/GHG • Fuel use • Perceived fuel use*
Operational Efficiency	DrayFLEX will improve system performance and operations for trucking companies through improved technology and systems (Core and Trip).	• Perceived system effectiveness − Dispatching time savings − Moves and transactions per day − Dual transactions − Reduction in bobtails* − Appointments missed or canceled*	• Perceived system effectiveness − Travel time improved − Fuel savings
Economic Benefit/Cost Savings	DrayFLEX will reduce costs and improve return on investments through improved fleet planning and dispatching (Core); and fuel savings (Trip).	• Perceived increase in dual transactions • Perceived increase in moves per day • Perceived reduction in bobtails* • Vehicle operating costs*	• Fuel savings

Overarching Goal	Description/Hypothesis	Key Performance Indicators—Core	Key Performance Indicators—Trip
Traveler Information	Traveler information from DrayFLEX will provide truckers with easier access to improved information for trip planning (Core) and en route alerts and notifications (Trip).	• Perceived customer satisfaction – App performance – Satisfaction ratings	• Perceived customer satisfaction – App performance – Satisfaction ratings – Driving experience

* Additional measures not included in the original Evaluation Plan.

As described previously, both DrayFLEX Core and DrayFLEX-Trip were evaluated utilizing a combination of a simulated pilot approach and a qualitative assessment of actual users (DrayFLEX-Trip) or trucking companies (DrayFLEX Core). Table 4 summarizes the data sources, methodology, and timeline associated with each of the performance measures. The performance measures made maximum use of automated data sources from the pilot and simulated conditions to the extent possible. Qualitative data were gathered through a trucker survey (DrayFLEX-Trip) and a questionnaire for the trucking company (DrayFLEX Core) based on their actual experiences using the tools. All of the features of DrayFLEX Core and DrayFLEX-Trip were available to the trucking company and drivers, respectively, for the qualitative feedback. The trucker survey is located in Appendix A.

Table 4. Performance measure data sources, method, and time period.

Category	Goal Area	Performance Measure	Data Method	Data Source	Data Collection Time Period	Sample Size (if applicable)
Mobility	DrayFLEX Core	Vehicle-miles traveled (VMT) per move	Quantitative data comparison	Actual and simulated moves—DrayFLEX dashboard	Simulated and baseline: August 2021–June 2022; February 2023–August 2023; October 2023–December 2023; February 2024, May 2024	Simulated = 68,311 moves Baseline (without) = 208,121 moves
	DrayFLEX Core	Perceived reduction in bobtails*	Questionnaire	Trucking company feedback	July 2024	Number (N)=1 (representative of the trucking company)
	DrayFLEX Core	Perceived reduction in terminal gate idling and wait times*	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX-Trip	Travel time	Quantitative data comparison	Actual trips—DrayFLEX-Trip dashboard	June 2021–October 2022	N = 106 trips (actual use during testing and pilot)

Category	Goal Area	Performance Measure	Data Method	Data Source	Data Collection Time Period	Sample Size (if applicable)
	DrayFLEX-Trip	Perceived trip time improved	Survey	Survey response in post-survey	January–March 2024	N=1
	DrayFLEX-Trip	Perceived congestion improvement	Survey	Survey response in post-survey	January–March 2024	N=1
Safety	DrayFLEX-Trip	Perceived safety	Survey	Survey response in post-survey	January–March 2024	N=1
Environment	DrayFLEX Core	Emissions/ greenhouse gases (GHG)	Quantitative data analysis	Actual and simulated moves—DrayFLEX dashboard	Simulated and baseline: August 2021–June 2022; February 2023–August 2023; October 2023–December 2023; February 2024, May 2024	Simulated = 68,311 moves Baseline (without) = 208,121 moves
	DrayFLEX Core	Fuel use	Quantitative data analysis	Actual and simulated moves—DrayFLEX dashboard	Simulated and baseline: August 2021–June 2022; February 2023–August 2023; October 2023–December 2023; February 2024, May 2024	Simulated = 68,311 moves Baseline (without) = 208,121 moves
	DrayFLEX-Trip	Emissions/GHG	Quantitative data analysis	Simulated trips—DrayFLEX-Trip dashboard	September 2023–January 2024	Simulated = 488 trips
	DrayFLEX-Trip	Fuel use	Quantitative data analysis	Simulated trips—DrayFLEX-Trip dashboard	September 2023–January 2024	Simulated = 488 trips
	DrayFLEX-Trip	Perceived fuel use	Survey	Survey response in post-survey	January–March 2024	N=1
Operational Efficiency	DrayFLEX Core	Perceived system effectiveness—dispatching time savings	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)

Category	Goal Area	Performance Measure	Data Method	Data Source	Data Collection Time Period	Sample Size (if applicable)
	DrayFLEX Core	Perceived system effectiveness—moves and transactions per day	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX Core	Perceived system effectiveness—dual transactions	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX Core	Perceived system effectiveness—reduction in bobtails*	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX Core	Perceived system effectiveness—appointments missed or canceled*	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX-Trip	Perceived system effectiveness—travel time improved	Survey	Survey response in post-survey	January–March 2024	N=1
	DrayFLEX-Trip	Perceived system effectiveness—fuel savings	Survey	Survey response in post-survey	January–March 2024	N=1
Economic Benefit/Cost Savings	DrayFLEX Core	Perceived increase in dual transactions	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX Core	Perceived increase in moves per day	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX Core	Perceived reduction in bobtails*	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX Core	Vehicle operating costs*	Quantitative data analysis	Actual and simulated moves—DrayFLEX dashboard	Simulated and baseline: August 2021–June 2022; February 2023–August 2023; October 2023–December 2023; February 2024, May 2024	Simulated = 68,311 moves Baseline (without) = 208,121 moves

Category	Goal Area	Performance Measure	Data Method	Data Source	Data Collection Time Period	Sample Size (if applicable)
	DrayFLEX-Trip	Fuel savings	Quantitative data analysis	Simulated trips—DrayFLEX-Trip dashboard	September 2023–January 2024	Simulated = 488 trips
Traveler Information	DrayFLEX Core	Perceived customer satisfaction • App performance—Satisfaction ratings	Questionnaire	Trucking company feedback	July 2024	N=1 (representative of the trucking company)
	DrayFLEX-Trip	Perceived customer satisfaction • App performance—Satisfaction ratings • Driving experience	Survey	Survey response in post-survey	January–March 2024	N=1

* Additional measures not included in the original Evaluation Plan.

For purposes of interpreting the quantitative simulated evaluation results in Section 3.0, the following provides additional details on how the data were compared:

- There are a number of parameters that go into optimizing the moves that will go into a route for a driver. Customer priority is a configurable field in the application where the trucking company can assign a value to each customer that will prioritize customers. Using trucker availability, employee and contractor status, truck starting location, empty container return service data, terminal wait time, as well as TMS data, DrayFLEX optimizes conditions to reduce bobtail miles and encourage dual transactions. In addition, travel times based on traffic conditions are considered to create the most efficient move.
- DrayFLEX Core VMT per move, emissions, fuel, and vehicle operating costs measures were based on actual trucking company moves without DrayFLEX Core (baseline) versus simulated moves with DrayFLEX Core. The DrayFLEX Core dashboard summarized the measures for the baseline (completed) moves and simulated DrayFLEX Core optimized (planned) moves by day for a defined period. The without (baseline) and with (simulated) DrayFLEX Core sample sizes vary because the simulated conditions only reflect plans for two trips for 100 drivers per day (200 trips per day maximum), whereas the baseline includes all of the moves completed by the trucking company from the TMS. As such, the quantified DrayFLEX Core results utilize the term “potential” estimated benefits since a consistent comparison was not possible. Extrapolation was used in some cases to estimate performance metrics. This is explained in more detail in Section 2.7.

- DrayFLEX-Trip travel time measurements were based on actual use of the application during testing and the pilot. The DrayFLEX-Trip dashboard recorded the estimated travel time for the trip option selected by the user, as well as the actual travel time for the user to complete the trip.
- DrayFLEX-Trip emissions and fuel measures were based on simulated use of the app. The project team input origins and destinations for actual trucking company moves from DrayFLEX Core into the DrayFLEX-Trip app. The DrayFLEX-Trip route options were recorded by the DrayFLEX-Trip dashboard for each move, including the fuel savings. If a route option had lower fuel costs from the fastest route option, that was used to estimate the potential fuel savings.

2.7 Data Sources, Challenges, and Extraneous Events

2.7.1 DrayFLEX Core Dashboard

The DrayFLEX Core Dashboard compiled data from DrayFLEX from August 2021, when the tool was ready for pilot deployment, through May 2024. During that time, approximately two simulated trip plans were generated for up to 100 truck drivers per weekday (up to 200 trips per day) for the intended pilot trucking company based on actual terminal appointments. This was a request of the trucking company intending to pilot DrayFLEX Core since it is only realistic to plan for up to two moves at a time due to various situations evolving over the course of a day. As such, some of the performance measures are not directly comparable and extrapolation was necessary for some of the performance metrics. Additionally, soon after DrayFLEX was available for deployment, the trucking company needed adjustments or new features added to the tool in order for them to proceed with the pilot. As such, DrayFLEX was being modified throughout the data collection period, with changes to the optimization or other features. In addition, there were several months when the actual completed trips were not available due to a TMS crash, the trucking company’s transition from software-based TMS to cloud based, and/or the API connection not working properly. As a result, several months worth of data needed to be excluded from the analysis.

Figure 4 presents an example view from the DrayFLEX Core dashboard. This example graphically presents the total miles traveled by day during the month of March 2024 for simulated moves (planned) and actual moves (completed, without DrayFLEX). It also includes completed against planned which were not applicable in the simulated analysis. Below the graph, monthly averages are available for several of the performance metrics such as average moves per day, total moves, dual transactions, average miles per move, dispatched drivers, and deadhead miles. Note that some of these metrics cannot be directly compared in the dashboard due to the simulation only planning for two trips per driver for 100 drivers as explained in the prior paragraph. In addition, some summary metrics were not available for the without DrayFLEX (baseline) conditions (e.g., deadhead miles, dual transactions) but were planned to be obtained from the trucking company during the pilot which did not occur.

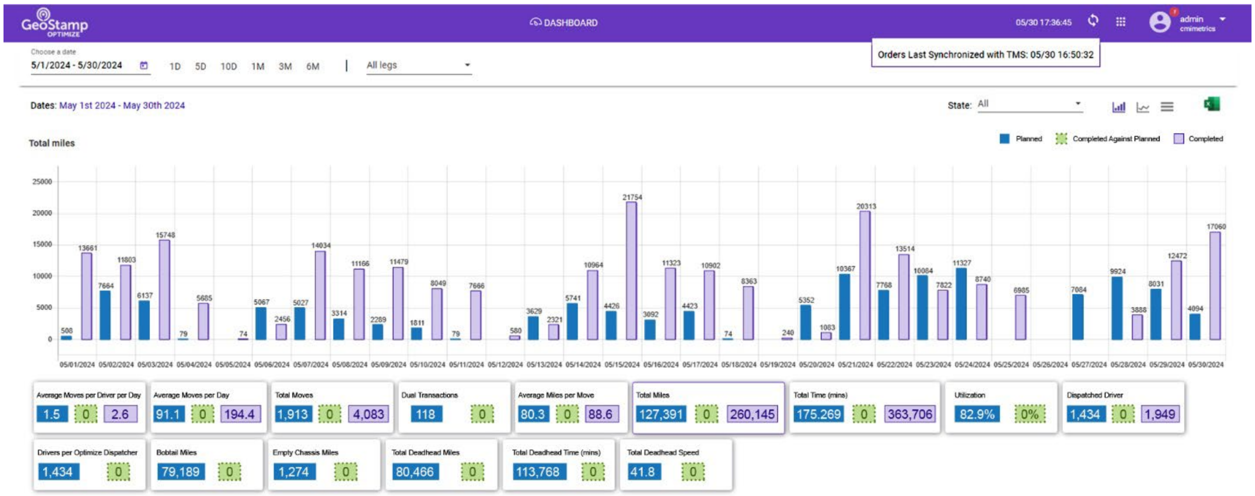

Figure 4. Example DrayFLEX Core dashboard view.

Source: DrayFLEX Core.

2.7.2 DrayFLEX-Trip Dashboard

The DrayFLEX-Trip dashboard collected data on actual completed trips by users (January 2022 through December 2022) and simulated trips from the testing phase (June 2021) through the simulation period (January 2024). Simulated trips involved the entry of a start and end location into the DrayFLEX-Trip app by the project team for actual moves from the DrayFLEX Core trucking company and the generation of trip route options. These options were saved, but since the trip was not actually performed, some of the originally planned data and performance metrics were not available (e.g., travel time, trip time reliability, percentage of users selecting more fuel-efficient route, etc.). While testing, pilot, and simulated trips were available in the dashboard, only trips generated during the simulation period were used for the emissions and fuel use performance metrics to better represent typical appointments for a trucking company.

Figure 5 presents an example view from the DrayFLEX-Trip dashboard of the number of users. Prior to pilot deployment in December 2021, the users consisted of project team members and testers. From December 2021 through June 2023, the users included truck drivers who registered to use DrayFLEX-Trip and a subset of the project team to perform updates and testing (approximately 10). Data for the trips entered into the DrayFLEX-Trip app were downloaded from the DrayFLEX-Trip dashboard to calculate the performance measurements, including estimated travel times, distance, and fuel use for the route options, and travel times for actual completed trips.

Figure 5. Example DrayFLEX-Trip dashboard view.

Source: DrayFLEX-Trip Dashboard.

2.7.3 DrayFLEX-Trip Survey

Thirty-nine independent users of DrayFLEX-Trip during the pilot were contacted via email for the DrayFLEX-Trip survey. The DrayFLEX project team made multiple attempts to obtain survey feedback, with reminders, between January and March 2024. The survey was made available in both English and Spanish and incentives were provided to encourage responses. Only one response was received so the perceived measures were based on that one user. Although there is insufficient data to support performance measurement conclusions associated with the DrayFLEX-Trip survey, the feedback was included in this report for informational purposes.

2.7.4 External Factors and Events

In addition to the challenges associated with the data sources, there were several confounding factors that make it difficult to isolate the benefits from DrayFLEX from extraneous events such as changes in the transportation network (roadway construction, changes in rail volumes), terminal operations, regional growth patterns, regional economy, weather, special events, port labor issues, COVID-19 impacts, etc. The following highlights some of the major external factors and events that may have impacted the simulated pilot and performance measure results for DrayFLEX Core and/or DrayFLEX-Trip, generally in chronological order:

- COVID-19 impact on typical goods movement and traffic flow delaying and impacting the pilot performance measurement activities (March 2020–August 2022).
- Delays and pilot company changes due to company acquisitions, staff champion departures, and data and staff resources and availability limitations (March 2020–June 2024).
- Trucking companies' requests and requirements for additional capabilities beyond the design (empty container moves, chassis availability, etc.) resulting in deployment delays (March 2020–June 2024).

- Federal Motor Carrier Safety Administration (FMCSA) 50-State hours of service waiver allowed truck drivers more flexibility when transporting emergency relief such as medical supplies, livestock/ livestock feed, food, paper products, groceries, fuel, etc. (March 2020–October 2022).
- COVID-19 impacts on trucking companies resulting in surge and extraordinarily high increases in container moves at the ports and port congestion (April 2020–August 2022). At the end of 2021, POLB recorded 15.7 percent year-over-year increase in twenty-foot equivalent units (TEUs) (the standardized unit of measurement for container cargo capacity), the highest in 110-year history. POLA realized a 13 percent increase over the prior year's record for TEUs.
- Envase Technologies acquired Profit Tools TMS requiring transition to a different TMS for integration and trucking company for the pilot (September 2020).
- Prior FRATIS project challenges and issues resulted in Trinium TMS hesitancy and slow, incremental development/integration/review cycles with DrayFLEX Core (September 2020–August 2023).
- Use of BlueCargo tool to search for available empty return appointments across all POLB/POLA terminals increasing efficiencies with appointments and dual transactions (August 2021–spring 2024).
- Adjustments to terminal operating hours at the POLA and POLB such as 24/7 operations Monday through Thursday (September 2021–August 2022).
- Shipping containers being dumped in or blocking nearby neighborhoods or being located at short-term container storage facilities increasing number of trips for container to reach its destination (October 2021–August 2022).
- POLA and POLB use of a variety of incentives and threats of costly fees (October 2021–August 2022).
- BNSF Railway and Union Pacific railroad’s rail backups in Chicago, rebates to encourage weekend drop-offs, surcharges on excess cargo, excessive rail container dwell times, shortage of rail cars, reductions in rail service, rail labor action strike concerns, etc. (October 2021–December 2023).
- Worker retention problems in U.S. transportation and warehouse sector (fall 2021–spring 2024).
- Supply chain disruptions, congested marine terminals, full warehouses, and chassis shortages (December 2021–March 2023).
- Russia-Ukraine crisis increased fuel-related costs, changing goods movement (e.g., consolidating shipments, changing modes, high owner-operator trucking costs) (February 2022–April 2023).
- Labor contract negotiations and delays, resulting ships diverting to East and Gulf Coast ports to reduce risk (March 2022–August 2023).
- Trucker Path route planning tool and new TMS. App built off crowdsourced feedback from drivers—route planning, available parking, weigh stations info, what to expect at docks, help drivers save on fuel costs, truck restrictions, etc. COMMAND TMS integrates with Trucker Path app to help manage drivers and assets, source loads, build jobs, dispatch, location and progress updates, scan

documents and create invoices. DISPATCH new service includes driver preference information—sends jobs to Trucker Path app to accept or reject a load (2022–June 2024).

- Trucking conditions crashed to pandemic lows—cost of diesel, per-mile rates, decline in imports, decline in durable goods and housing volumes, bloated inventories, decreases in consumer spending, high levels of employment, excess capacity (fall 2022–summer 2023).
- Intermodal shippers detained containers in early 2023 as companies tried to clear out overstocked warehouses of excess inventory (January–April 2023).
- WiseTech acquired Envase which meant increased controls over Trimble. Committed to supporting DrayFLEX deployment, operations, and performance reporting, etc. (February 2023–June 2024).
- HERE Tour Planning route optimization—takes into consideration operating costs (height, weight, cargo capacity, vehicle range), shift times, preferences, driver certifications, and other driver characteristics, and roads/streets, signage, bridge heights, and bike lanes. Live replanning, new arrival times, time savings, cost savings (August 2023–June 2024).
- Drought creating long queues of vessels at the Panama Canal delaying ships for hours to weeks (August 2023–May 2024).
- Labor uncertainty and contract negotiations/strike threats on East and Gulf coasts increasing West Coast volumes (2024).

3.0 EVALUATION RESULTS

The following subsections contain the evaluation results for the DrayFLEX project, organized by goal and tool as summarized in Table 4 above. In cases where quantitative data were not available, qualitative data were collected using surveys, questionnaires, and observations.

3.1 Mobility

3.1.1 DrayFLEX Core

Vehicle-Miles Traveled per Move

One of the key anticipated benefits of the DrayFLEX Core system was potential for reductions in VMT per move for trucking companies through the dispatch optimization best-match feature which considered a variety of information, including real-time location of the available trucks and drivers, container origin and destination locations, appointment times, chassis availability, empty container locations, dual transaction opportunities, etc. A move involves a truck being dispatched to transport a container or trailer from one location to another; for drayage this is typically between the port and a facility for loading or unloading. A dual transaction is when a drayage truck brings in a container and takes one out in the same trip.

Figure 6 compares the average monthly VMT per move for the simulated planned trips versus the actual completed trips based on 23 months of usable data for this metric from the DrayFLEX Core dashboard. The simulated average monthly estimated potential reduction in VMT per move for the pilot truck company was 4.6 miles. This is likely a result of DrayFLEX Core optimizing moves based on best match of drivers and their location to container origin location (or chassis if needed), travel time and gate queue information, and dual transaction opportunities reducing bobtails. The “Without DrayFLEX” VMT values are based on a total of 208,121 completed moves over the 23 months (an average of 9,050 moves per month). The “With DrayFLEX” values are based on 68,311 simulated moves over the 23 months for moves from the same origins and destinations for a subset of the 208,121 completed moves (an average of approximately 2,970 moves per month). As described previously, the lower number of moves for the With DrayFLEX conditions is a result of only two moves for 100 truck drivers being simulated (per the trucking company request). Four of the months showed higher VMT per move averages for the simulated With DrayFLEX Core conditions which was likely due to feature additions and/or optimization adjustments requested by the trucking company which were evolving over the simulation period.

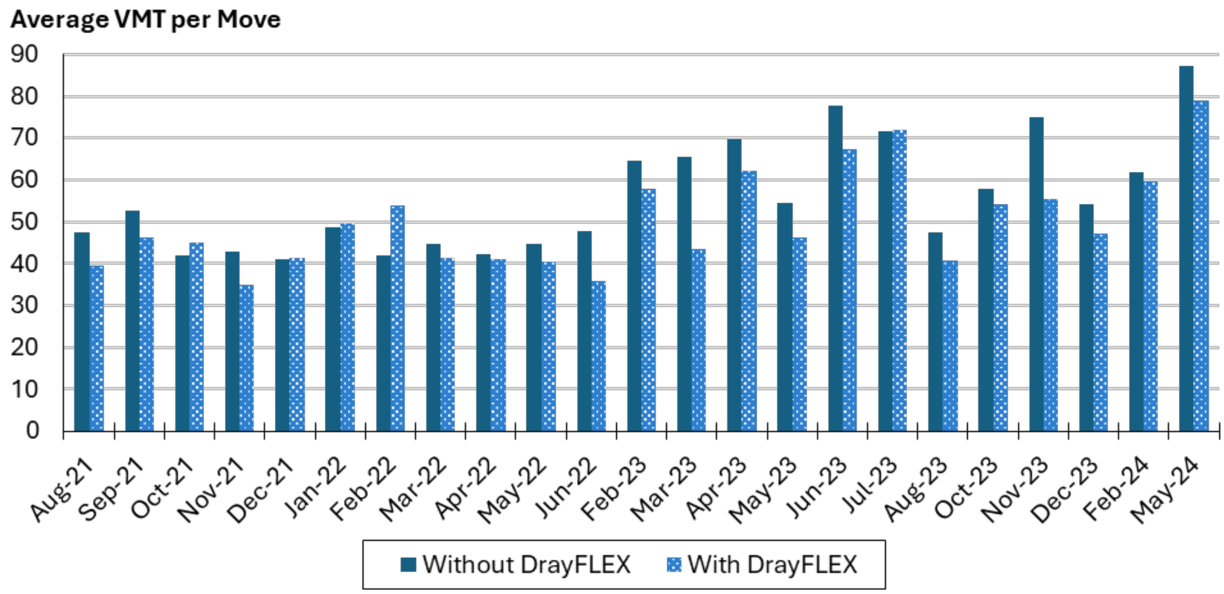

Figure 6. DrayFLEX Core average monthly vehicle-miles traveled per move.

Source: DrayFLEX Core.

Perceived Bobtails

The pilot trucking company was asked whether DrayFLEX Core was anticipated to increase or reduce bobtails. A bobtail refers to a cargo-carrying truck that is traveling without an attached trailer, often happening when a truck driver is sent out from dispatch to a container pick-up location. The trucking company indicated that DrayFLEX Core could not only decrease the number of bobtails, but also the time required by the trucking company to find the moves to decrease the bobtails and maximize revenue per truck.

Perceived Terminal Gate Idling and Wait Times

The pilot trucking company found the DrayFLEX Core tool helpful in identifying times when there are delays at the terminals/ports and that the increased dual transactions could help reduce congestion and the time in the terminal queues.

3.1.2 DrayFLEX-Trip

Travel Time

Based on a limited data set (106 trips) of completed trips using the DrayFLEX-Trip app by project team members during verification and actual users following deployment, the variability of the estimated trip times from DrayFLEX-Trip was compared to the completed travel time (Figure 7). The standard deviation was four minutes on an average trip distance of 19 miles. Note that the majority of the trips were performed in personal vehicles that travel faster than a typical drayage truck (maximum speed for trucks on California freeways is 55 miles per hour (mph)). The sample set in Figure 7 does not take this factor into consideration. As such, we would expect the negative values to be closer to zero and the variability to be lower. The positive values are more sensitive to congestion and less likely to be impacted by the speed limit of trucks.

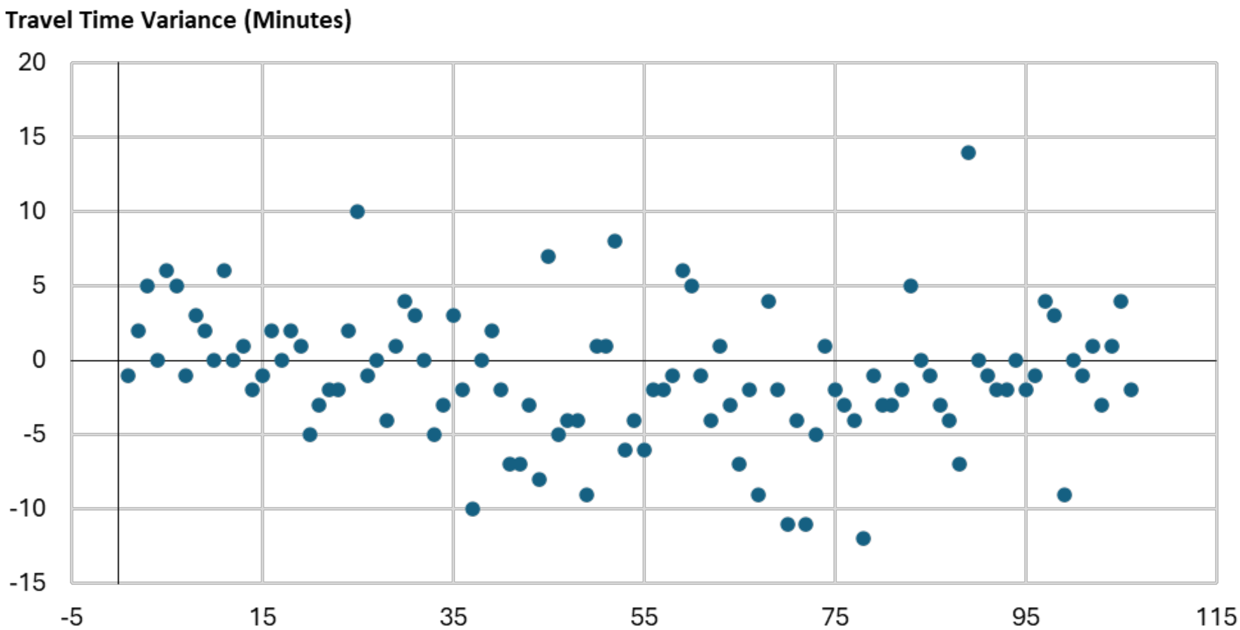

Figure 7. Comparison of estimated travel time to completed travel time.

Source: DrayFLEX-Trip dashboard.

Perceived Trip Time

Note: Since there was only one respondent to the DrayFLEX-Trip survey (N=1), no conclusions could be drawn from the data. The following is for informational purposes only.

The DrayFLEX-Trip survey asked actual users from the pilot deployment if their travel times improved while using the app with the following options: Much better; A bit better; About the same; A bit worse; or Much worse. The respondent indicated that the travel times were much better.

Users also were asked if incident alerts helped them travel faster or avoid delays with the following options: Yes, a lot, Yes, a little, No difference, No, it made it worse. The respondent indicated the DrayFLEX-Trip incident alerts helped them travel faster or avoid delays a lot.

Perceived Congestion

Note: Since there was only one respondent to the DrayFLEX-Trip survey (N=1), no conclusions could be drawn from the data. The following is for informational purposes only.

The survey respondent replied to two questions related to perceived congestion associated with the DrayFLEX-Trip app during the actual pilot. The user indicated that DrayFLEX-Trip 1) always effectively warned about congestion ahead and 2) rerouted away from heavy traffic areas.

3.2 Safety

3.2.1 DrayFLEX-Trip

Perceived Safety

Note: Since there was only one respondent to the DrayFLEX-Trip survey (N=1), no conclusions could be drawn from the data. The following is for informational purposes only.

The DrayFLEX-Trip user survey included three questions associated with two topics under safety:

- **Hard-braking.** The survey respondent indicated that they find themselves braking hard less often with DrayFLEX-Trips “slow-down ahead” alerts and the alerts have reduced close calls with other vehicles many times. Hard breaking may lead to a truck jackknifing or indicate a driver is following traffic too closely, increasing the risk of crashes.
- **Safety perception.** In general, the DrayFLEX-Trip survey respondent indicated that DrayFLEX-Trips alerts made their drive safer.

3.3 Environment

3.3.1 DrayFLEX Core

Emissions/Greenhouse Gases

Environmental benefits from DrayFLEX Core were measured based on the reductions in VMT per move using the 23 months of DrayFLEX Core actual completed moves and simulated pilot data. In order to provide a comparable analysis, the estimated VMT for the without and with DrayFLEX conditions were normalized by multiplying each of the monthly VMT per move values by the number of total moves for that month. Average emissions per move by month and type were calculated for the simulated pilot and actual completed moves data for the trucking company by multiplying the estimated VMT with and without by the emissions rate relevant to the year, speed, emissions type. Monthly estimates were averaged over the 23 months. For example, in September 2021, the estimated VMT per move for the simulated conditions was 46.3. This value was multiplied by the total moves for that month, 12,269 for a total VMT of 568,054. For CO_2, the VMT was multiplied by the emissions rate associated with the average speed (40.2 mph) and year (2021) for CO_2 of 0.0017235831, to result in a total of 979 tons. These were calculated for each month, with and without, and averaged.

Truck emissions rates from the California Air Resources Board (CARB) Emission Factors (EMFAC) for the Port Complex area (see Appendix B) were used for the analysis. Table 5 provides an estimate of the potential average monthly emissions reductions for the DrayFLEX Core simulated planned moves, versus the actual completed without DrayFLEX Core moves. Note that the emissions rates were updated for each year of the reporting period: 2021 EMFAC rates were applied to the August ’21–December ’21 trips; 2022 EMFAC rates were applied to the January ’22 to June ’22 trips; 2023 EMFAC rates were applied to the February ’23–December ’23 trips; and 2024 EMFAC rates were applied to the February ’24 and May ’24 trips. The estimated potential reduction in emissions is likely a result of DrayFLEX Core optimizing moves based on closely matching truck driver/location to container origin location (or chassis if needed), travel time and gate queue information, and dual transaction opportunities which reduce VMT.

Table 5. Estimated potential monthly emissions savings.

	CO_2/Greenhouse Gases (tons)	CO (grams)	NO_x (grams)	PM_{10} (grams)	$PM_{2.5}$ (grams)	SO_x (grams)
Without	843	140,370	1,432,510	9,110	8,720	7,980
With	741	95,530	1,209,590	8,560	8,190	7,020
Difference	102	44,840	222,920	550	530	960

Fuel Use

The fuel use performance measure is consistent with the emissions measure, using the same VMT, moves, and speed data and based on the EMFAC fuel use rates for trucks by year. Using truck fuel use rates from EMFAC, the average monthly estimated potential fuel use savings for the DrayFLEX Core simulated planned moves versus the completed moves is 9,105 gallons. Note that the fuel rates were updated for each year of the reporting period: 2021 EMFAC rates were applied to the August ’21–December ’21 trips; 2022 EMFAC rates were applied to the January ’22 to June ’22 trips; 2023 EMFAC rates were applied to the February ’23–December ’23 trips; and 2024 EMFAC rates were applied to the February ’24 and May ’24 trips.

3.3.2 DrayFLEX-Trip

Emissions/Greenhouse Gases

One of the primary features of DrayFLEX-Trip was the option to use a more fuel-efficient option to make a trip, if available as part of the routing options provided to the user. This simulated analysis used actual trucking company moves, from the TMS available within DrayFLEX Core, to enter the move origin and destinations into the DrayFLEX-Trip app. The baseline data utilized for this metric was the fastest travel time route option provided for each simulated trip. Most of the simulated DrayFLEX-Trip trips resulted in the more fuel-efficient option being the same route as the fastest travel time. The cases where there was a more fuel-efficient route option provided for the simulated trip were used to estimate this performance measure. The travel time and distance for both the fastest route and more fuel-efficient route for each trip available from the DrayFLEX-Trip dashboard were used to calculate VMT and speed for the emissions calculations.

Approximately 28 percent of the 488 simulated DrayFLEX-Trip trips for the trucking company had a more fuel-efficient route option available to select. Factoring the 488 simulated trips to a 9,050 monthly average moves for the trucking company, approximately 5,630 VMT may be reduced monthly by the trucking company when selecting the more fuel-efficient route. Monthly estimates of VMT for the trucking company were averaged for use for the without conditions (414,060), less the 5,630 VMT for the with DrayFLEX-Trip simulated conditions. The EMFAC rates for 2024 (Appendix B) for an average speed of 39 mph for the trips with a more fuel-efficient option were used to estimate the emissions by type. For example for CO_2, the 414,060 VMT for the without case was multiplied by the EMFAC emissions rate (.001719144), resulting in an estimated 712 tons. This was calculated for each emissions type, with and without DrayFLEX-Trip. Table 6 presents the estimated potential monthly emissions reductions from the simulated pilot for DrayFLEX-Trip.

Table 6. Estimated monthly emissions savings.

	CO_2/Greenhouse Gases (tons)	CO (grams)	NO_x (grams)	PM_{10} (grams)	$PM_{2.5}$ (grams)	SO_x (grams)
Without	712	49,501	567,433	4,819	4,610	6,741
With	702	48,828	559,718	4,753	4,548	6,649
Difference	10	673	7,715	66	63	92

Fuel Use

The fuel savings for the simulated pilot using DrayFLEX-Trip dashboard data was estimated to be $2,640 per month based on average monthly moves for the DrayFLEX Core pilot company of 9,050. This is based on the same set of data and approach used for the DrayFLEX-Trip emissions analysis.

Perceived Fuel Use

Note: Since there was only one respondent to the DrayFLEX-Trip survey (N=1), no conclusions could be drawn from the data. The following is for informational purposes only.

The DrayFLEX-Trip survey also asked users if they save fuel by following DrayFLEX-Trip's route suggestions. Options included: Yes, a lot; Yes, a little; About the same; or I use more fuel. The respondent indicated they save a lot of fuel using DrayFLEX-Trip options.

3.4 Operational Efficiency

3.4.1 DrayFLEX Core

Perceived System Effectiveness

Dispatching Time Savings

The trucking company indicated that when the requirements matched, DrayFLEX Core does decrease the amount of time to dispatch. However, due to the nature of the business, the system could not handle all of the requirements. The system could handle most, but not all of their dispatch needs.

Moves and Transactions per Day

The number of moves and dispatches would most likely stay the same, according to the trucking company. However, they indicated that DrayFLEX Core does have the potential to decrease the time the dispatchers spend on their jobs planning and executing the dispatches.

Dual Transactions

The trucking company stated that the number of dual transactions would most likely stay the same as this is inherent to their existing dispatching strategy.

Reduction in Bobtails

As described previously, the pilot trucking company indicated that DrayFLEX Core would reduce bobtails thus reducing the time spent doing nonrevenue movements.

Appointments Missed or Canceled

Ports use truck appointment systems at container terminals to help better manage the long queues that can appear at the terminal entry gates and improve operations within the terminal itself. Based on monthly data from GeoStamp/WiseTech during the project period, the average wait time at the 14 terminal gates at the Port Complex was 13 to 20 minutes with averages ranging from 4 minutes to 38 minutes. DrayFLEX Core incorporated both terminal wait times and turn times (total time spent by a truck within the port terminal gates) into its optimization engine to help identify best dispatching options based on the truck location, drive times, and other variables to ensure the container delivery or pick-up could be accommodated within the appointment window.

Based on their experience testing and reviewing DrayFLEX Core, the trucking company stated that since the tool incorporates real-time locations and delays in its planning, it could help to increase the number of appointments that are on time, decrease the number of appointments missed, and decrease the number of appointments canceled.

3.4.2 DrayFLEX-Trip

Perceived System Effectiveness

Note: Since there was only one respondent to the DrayFLEX-Trip survey (N=1), no conclusions could be drawn from the data. The following is for informational purposes only.

Travel Time Improved

As described in Section 3.1.2, the DrayFLEX-Trip survey respondent from actual use of DrayFLEX-Trip indicated that the travel times were much better as a result of the app. The user also responded that they changed their departure time as a result of DrayFLEX-Trip information.

Fuel Savings

As described in Section 3.3.2, the DrayFLEX-Trip user indicated they saved fuel due to the route suggestions from the app.

3.5 Economic Benefit/Cost Savings

3.5.1 DrayFLEX Core

Perceived Dual Transactions

As described in Section 3.4.1, the trucking company stated that the number of dual transaction opportunities would most likely stay the same as this is inherent to their existing strategy. However, they did indicate that DrayFLEX Core has the potential to decrease the time the dispatchers spend planning and executing the dispatches.

Perceived Moves per Day

As described in Section 3.4.1, the number of moves would most likely stay the same. DrayFLEX Core does have the potential to decrease the time the dispatchers spend planning and executing the dispatches.

Perceived Bobtails

The trucking company indicated that DrayFLEX Core’s ability to reduce bobtail time would maximize revenue per truck operations. In addition, DrayFLEX Core would decrease the amount of time dispatchers spend manually trying to reduce bobtails.

Vehicle Operating Costs

Utilizing the average estimated potential VMT reduced per move metric of 4.6 and the average number of moves per month for the 23 months’ worth of trucking company data for the simulated DrayFLEX

Core pilot (9,050 moves per month), vehicle operating costs were estimated using the USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*.[1] Based on this guidance, commercial trucks vehicle operating costs are $1.32 per mile. The estimated potential monthly vehicle operating costs savings for the simulated DrayFLEX Core pilot for the trucking company is $55,000.

Emissions

Based on the simulated potential estimated emissions savings above for DrayFLEX Core, Table 7 presents the estimated monetized emissions benefits based on USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* damage costs for emissions if the benefits were accrued in 2024.[2]

Table 7. Estimated potential monetized monthly emissions savings.

	CO_2/Greenhouse Gases	NO_x	$PM_{2.5}$	SO_x
Monthly Impact	102 tons	222,920 grams	530 grams	960 grams
Damage Cost (per metric ton)	$233	$20,100	$963,200	$53,800
Emissions Savings	$21,540	$4,480	$510	$50

3.5.2 DrayFLEX-Trip

Fuel Savings

As described in Section 3.3.2, the fuel savings for the simulated pilot using DrayFLEX-Trip dashboard data was estimated to be $2,640 per month when factored based on average monthly moves for the DrayFLEX Core pilot company of 9,050.

Emissions

Using the DrayFLEX-Trip simulated estimated emissions savings in Section 3.3.2, Table 8 presents the estimated monetized emissions benefits based on USDOT *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* damage costs for emissions if the benefits were accrued in 2024.[3]

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[1] USDOT. Benefit-Cost Analysis Guidance for Discretionary Grant Programs. December 2023. https://www.transportation.gov/sites/dot.gov/files/2023-12/Benefit%20Cost%20Analysis%20Guidance%202024%20Update.pdf.

[2] Ibid.

[3] Ibid.

Table 8. Estimated monetized monthly emissions savings.

	CO_2/Greenhouse Gases	NO_x	$PM_{2.5}$	SO_x
Monthly Impact	10 tons	7,715 grams	63 grams	92 grams
Damage Cost (per metric ton)	$233	$20,100	$963,200	$53,800
Emissions Savings	$2,045	$155	$60	$5

3.6 Traveler Information

3.6.1 DrayFLEX Core

Perceived Customer Satisfaction

App Performance

The trucking company stated that the DrayFLEX Core system operated as designed. However, the trucking company's evolving requirements did not always match with the tool and a significant effort was made to help address these misalignments. In addition, the system was reliable from a technical perspective.

Satisfaction Ratings

The pilot trucking company for DrayFLEX Core was asked to rank their satisfaction of the tool on a scale of 1 to 5, with 1 being very unsatisfied and 5 being very satisfied. Table 9 presents the results. The trucking company also indicated that if a system could be established to handle all of their complex and evolving requirements it would provide a lot of value. A few of the key improvements recommended by the trucking company included ability to configure chassis pool locations and incorporating electric truck information and charging times.

Table 9. DrayFLEX-Trip user satisfaction ratings.

Satisfaction Attribute	Rating	Comments
Usefulness of features and information	3	Would be a higher number if the system was able to account for all of the various business process requirements such as chassis pool requirements.
Accuracy of information	4	All of this information was available and in a user-friendly format
Timeliness of information	3	This information was available and created plans that met the requirements in most cases
Reliability	3	The system was mostly stable though it did slow down at times when trying to process many moves/dispatches or pull large data sets

Satisfaction Attribute	Rating	Comments
User-friendliness of the interface and features	4	The system has a nice interface and good features
Clarity of how the information is presented	4	The user interface is appealing and information is presented clearly
Dispatching experience	3	The system generates optimized moves and allows for click through dispatching
Overall experience	3	Overall the system is well designed and user friendly, though it did not meet all of our complex requirements.

3.6.2 DrayFLEX-Trip

Perceived Customer Satisfaction

Note: Since there was only one respondent to the DrayFLEX-Trip survey (N=1), no conclusions could be drawn from the data. The following is for informational purposes only.

App Performance

According to the DrayFLEX-Trip user survey results, the respondent indicated that the app always performed as expected and never encountered any issues or downtimes.

Satisfaction Ratings

The DrayFLEX-Trip survey asked users to rank their satisfaction of the app on a scale of 0 to 10, with 0 being extremely dissatisfied and 10 being extremely satisfied. The respondent gave each of the satisfaction criteria the highest possible score of 10 for accuracy, timeliness of information, usefulness, clarity, user friendliness, reliability, and overall satisfaction.

Driving Experience

The DrayFLEX-Trip survey respondent indicated that DrayFLEX-Trip improved their overall driving experience a lot.

4.0 LESSONS LEARNED, RECOMMENDATIONS, AND CONCLUSIONS

While the DrayFLEX project was not able to be piloted as originally planned, both DrayFLEX Core and DrayFLEX-Trip were designed, developed, and initially deployed as scoped and were able to be evaluated utilizing simulated approaches with valuable lessons learned. As described in Section 3, both simulated pilot DrayFLEX Core and DrayFLEX-Trip systems were estimated to realize benefits to trucking industry operations and people impacted by emissions and congestion in and around the Port Complex.

The project costs were $6,000,000. Based on the simulated potential emissions and vehicle operating costs/fuel benefits for the pilot trucking company for DrayFLEX Core and DrayFLEX-Trip, the estimated monthly benefits are $92,900 or over $1.1 million per year. This does not take into consideration other potential major benefits not quantitatively analyzed, including time saved both for truck drivers and dispatchers. Since onboarding new trucking companies to use DrayFLEX would be a considerably smaller portion of the original budget for the DrayFLEX systems, the simulated pilot for the trucking company was estimated to achieve savings to both trucking companies (fuel and operational efficiencies) and the populations impacted by the drayage trucking operations (emissions and reduced VMT).

4.1 Lessons Learned

As described in Sections 1.0 and 2.7, the DrayFLEX project encountered several challenges resulting in the need to utilize a simulated pilot approach for the evaluation. The key lessons learned associated with the design and development, as well as deployment challenges, are summarized below. Some are unique to each tool, while others are applicable to both DrayFLEX Core and DrayFLEX-Trip.

4.1.1 Systems Engineering versus Agile Design and Development

DrayFLEX-Trip followed the SE approach while DrayFLEX Core utilized a hybrid SE/Agile approach. For DrayFLEX-Trip, the design and most of the development went smoothly from a SE perspective. However, it took a significant amount of time to perform and document each of the SE steps. During the user feasibility assessment, very few truck navigation apps were available and those that were did not have the features desired by the users. By the time the project went through the SE approach for design, requirements, and development, the trucking industry and vendors realized the need for many of DrayFLEX-Trips features and capabilities, and several free and paid comprehensive truck-trip navigation applications became available the market. Examples include: Trucker Path, TruckMap, and Hammer.[4,5,6] Google Maps, which is one of the most utilized navigation apps, also implemented a most fuel-efficient

[4] https://truckerpath.com/.

[5] https://truckmap.com/.

[6] https://www.hammerapp.com/.

route feature which was one of the primary features for DrayFLEX-Trip to help reduce emissions for the Commercial Vehicle Applications for the Environment: Real-Time Information Synthesis (CV-AERIS) aspect of the project.

With respect to DrayFLEX Core, the hybrid approach was invaluable to account for adjustments to user needs and developing a tool that was more integrated with the TMS and less of a stand-alone system. The trucking companies involved during development were critical to developing a system that would meet their needs, both from user experience and technical capabilities standpoint. Getting TMS support for information exchange and integration required a careful balance of understanding that the intent was not to develop a system that would compete with the TMSs, but to build upon them.

4.1.2 Technology

The DrayFLEX project was unique to many other grant projects in that it was software/app development rather than a traditional transportation or Intelligent Transportation System (ITS)/technology construction project. As such, there was no physical technology equipment to deploy out on the road or transportation facility to quantitatively and independently operate, test, assess, maintain, and evaluate. This posed several challenges for the DrayFLEX Project, including:

- **Ever-changing requirements and needs.** COVID-19 was a major contributor to this as the supply chain was severely impacted with unanticipated and never-experienced congestion issues, resource limitations, equipment availability and imbalances, etc.
- **Integration with disparate systems and information sources.** As a project that focused on sharing and using freight information, the DrayFLEX systems relied on data and information from a variety of sources and systems, each with their own structures, formats, stability, documentation, and quality issues. Obtaining assistance with and integrating with these systems required more effort than anticipated from both a technological and schedule/resources perspective. Since these entities were not being compensated for their integration effort, assistance with DrayFLEX was often the lowest priority.
- **Development and updates to other systems.** Both DrayFLEX Core and DrayFLEX-Trip were challenged by crashes, delays, updates, and other issues with the systems they integrated with. Updates to these other systems often impacted DrayFLEX and required unanticipated fixes and testing. There were numerous situations for DrayFLEX Core where TMS software crashes and other TMS changes caused API problems, data exchange, and other issues that the project team were often unaware of for days or weeks. This is why several months of data for DrayFLEX Core were not usable for the simulated pilot. DrayFLEX-Trip also was impacted by Trimble through their issues and limitations for support for the iOS versions of their tool and significant delays with the development and deployment of the dangerous slow-down ahead feature.

Other DrayFLEX Core technology lessons learned include:

- A cloud hosted solution is far superior to an on-premise server solution as it reduces the requirements for the client and technology teams.
- A simple and inviting web front-end is key to helping to create buy-in from end-users.
- Coding a solution for an environment of evolving an ambiguous requirements set does not allow for a one-stop solution.
- Processing power for the large data sets required many reworkings of the code and increasing cloud processing power to avoid slowing down the application.

4.1.3 People and Process

- Issues related to coordination with and reliance on other entities occurred throughout the DrayFLEX project causing significant delays to the deployment and completing a pilot. The project team believes multiple of these issues could have been reduced or avoided if financial compensation and contract mechanisms to deliver were available.
  - ***Trucking company issues.*** The project began with letters of commitment from trucking companies to participate in the delivery of the pilot of DrayFLEX. The project champions from some of those companies left to go to other companies, COVID-19 negatively impacted staff time to participate in the project, needs and requirements to participate in the pilot repeatedly changed, trucking companies converted to other TMSs for operations or updated their TMS from software to cloud-based systems, and trucking companies and TMS acquisitions.
  - ***Third-party data issues.*** Many of the third-party systems DrayFLEX needed to integrate with were challenged by delays in release of certain features (Trimble's dangerous slow-down ahead warnings), data quality and legal approvals to access and use the data (Southern California Association of Governments' restricted routes), and API/exchange support needs (TMS).
  - ***Pilot participants for DrayFLEX-Trip.*** Every effort within available resources for the project were attempted to recruit DrayFLEX-Trip pilot users. This included direct phone calls and/or emails to over 160 trucking companies operating in the Southern California region, social media posts, raffles, and distribution of flyers at Port terminal gates, truck stops, and food trucks in the Port Complex.
- A one-size-fits-all approach to optimize dispatching within the region is difficult as there are many sized companies with many different requirements.
- The Port Complex drayage market has many additional complexities such as chassis pool requirements, geographic (locations of pools, empties), and process shifts that are evolving all the time, making it difficult to program a solution.

- There are several challenges to instituting effective change management for modifications to the dispatching process from the legacy TMS to the optimization tool.
  - Dispatchers have ingrained processes within the TMS as well as outside tools such as spreadsheets that help to guide how/when dispatches are sent out and which drivers receive them. Adding another system into this decisionmaking process as well as potential conflicting information and recommendations can pose problems and doubts on which should be used.
  - The dispatch processes vary widely between employee truckers and contracted owner-operators. All of the possible considerations and customizations associated with this requires a significant amount of effort. For a pilot, requirements, capabilities, and limitations need to be established, communicated, and understood.
  - The process for establishing dispatches the night before for early the next morning caused significant reworking to the code in order to differ from the designed process of dispatch on demand.
  - Drivers may not want to go to certain locations or not be allowed to work on certain clients, which was addressed through the optimization tool.
  - Emerging client requirements for electric and low emissions trucks add additional complexity to the tool.

4.2 Recommendations

The following summarize the key recommendations associated with the DrayFLEX project:

- **Offer compensation for all project participants.** For future projects requiring significant collaboration or participation, reliance on other sources of information, or integration with other systems, it is recommended to include those entities as financial partners in the project so they are compensated for their time and effort. Without financial incentives and a contracted commitment for deliverables, it is very difficult to ensure involvement and completion of responsibilities, particularly with the extremely limited resource availability during COVID-19 and its impact on the trucking industry operations. This may require the accommodation for funds to be set aside without defined recipient(s) to engage and compensate needed support to design, develop, deploy, and operate the system, including compensation for pilot participants. In order to ensure schedule and delivery are a priority, contracts and compensation are needed.
- **Consider realistic prospects for DrayFLEX-Trip future/commercialization.** With other free route guidance (i.e., Google Maps and Waze) and vendor supported truck navigation systems on the market, DrayFLEX-Trip lacks competitiveness to continue beyond this project. DrayFLEX-Trip could not continue beyond the project without significant outreach, marketing, and funding or user fees to operate and maintain. In addition, most of the DrayFLEX-Trip features are now available within other navigation applications.

- **Define role of public-sector project in relation to private sector/industry.** After multiple attempts at improving freight traveler information and systems through FHWA's FRATIS program, it is still to be determined whether or not the public sector should play a role in private-sector information and technology improvements. While neither DrayFLEX Core and DrayFLEX-Trip will be commercialized in their developed form, both may have sparked private-sector investments and improvements to existing systems and tools that provide these capabilities to the trucking industry. Depending on the situation, potential future efforts may be more successful if existing, widely used vendor(s) are more directly involved throughout the design and development process, and compensated accordingly. Private-sector collaboration is challenging when there is a perceived competition. In addition, it was perceived that one of the public sector's roles is to provide data to the private sector for use in privately developed applications. While many transportation agencies ingest transportation data, this data can be useful for TMS providers or other application developers as well.
- **Proactively address perceived impacts to jobs.** Technology or other projects that involve automation or optimization need to be sensitive to real and perceived impacts to jobs. It is important that these types of systems are not intended to replace jobs, but improve their decisionmaking process and provide time to spend on other needed activities at their company.
- **Take small steps.** Related to the prior item, perceived impacts to jobs, DrayFLEX Core may have been more successful from a pilot and potential commercialization standpoint if less features were included; the trucking industry was not ready for this level of optimization. Change is difficult for many entities so taking incremental steps towards trucking company dispatching optimization may be a better approach. An incremental approach would allow companies to gain a better understanding on what change is included, how it works (less of a black box), and less perceived potential job impacts.
- **Integrate DrayFLEX Core features into TMSs.** In close collaboration with WiseTech, who owns/ maintains multiple TMSs across the world, including Trinium which is widely used by trucking companies in the Southern California area, multiple features of DrayFLEX Core will be considered into their TMSs, including:
  - A geolocation service that can aggregates data from various companies/geolocation applications to provide data to trucking companies, ports, and trucking associations nationwide and internationally.
  - Utilizing the geolocation service to match dispatches from client TMS systems to geolocation data in order to calculate delay time, convert those into billable charges, and write assessorial feed to a TMS system.
- **Leverage trucking company recommendations for future research.** The trucking company who participated most in the project also provided some feedback and recommendations for DrayFLEX Core.
  - Add ability to configure chassis pool locations.

- Include requirements and considerations for electric trucks such as charging times. Drayage trucks in California need to be zero emissions (ZE) by 2035 and the use of battery electric and hydrogen fuel cell trucks is increasing in the Port Complex area. Unique requirements associated with ZE trucks need to be included in dispatch optimization considerations.
- If a system could be established to handle all of our complex and evolving requirements it would provide a lot of value for us.
- Ensure that all of the requirements and processes are clear up front and that the system can address these.
- For less complex operations with one kind of driver, DrayFLEX Core may be useful as developed.

APPENDIX A

DrayFLEX-Trip User Survey

Dear DrayFLEX-Trip users,

Thank you for being a registered user of the **DrayFLEX-Trip** app. The pilot project has come to an end and we genuinely value your insights and experiences. We created this brief survey to better understand how the app impacted your driving and to learn from your feedback. The first 15 people to complete the survey will receive a $10 Amazon gift card. Let's get rolling!

A reminder about DrayFLEX-Trip: *DrayFLEX-Trip is a routing app specifically for truck drivers and works on both iPhones and Android phones. It helps drivers find the best way to or from the Ports of Los Angeles and Long Beach depending on whether the fastest route or saving on fuel is the priority. The app looks at traffic, incidents, roads where trucks can drive, and wait times at the terminal gates. It also warns drivers if there's a slowdown ahead. This app makes a truck driver's moves easier.*

Preliminary Question:

1. Have you used the DrayFLEX-Trip app for any of your trips?

- Yes—proceed to Question 5 on the next page
- No

If "No" is selected:

We're sorry to hear that. Please help us understand why you haven't used the DrayFLEX-Trip app.

2. Why didn't you the DrayFLEX-Trip app? You may select multiple options.

- It was too complicated to install.
- I could not figure out how to use it.
- I did not have time.
- I ended up using another routing app that I prefer.
- Other (please specify): ________________________

3. What would have encouraged you to use DrayFLEX-Trip? You may select multiple options.

- Direct download from the app store.
- More positive feedback from other drivers.
- Easier to use interface.
- Training or tutorials on how to use it.

- Availability in languages other than English.
- Other (please specify): ________________________

4. Do you have any other feedback you would like to provide about DrayFLEX-Trip?

____

Thank you for your feedback. We appreciate your honesty. If you have not used the DrayFLEX-Trip app, you can skip the following survey questions.

For those who selected "Yes":

5. While using DrayFLEX-Trip, did your travel times improve?

- Much better
- A bit better
- About the same
- A bit worse
- Much worse

6. Have the app's incident alerts helped you travel faster or avoid delays?

- Yes, a lot
- Yes, a little
- No difference
- No, it made it worse

7. Does DrayFLEX-Trip effectively warn you about traffic congestion ahead?

- Always
- Most of the time
- Sometimes
- Rarely
- Never

8. Has DrayFLEX-Trip ever rerouted you away from heavy traffic areas?

- Yes, always
- Yes, most of the time
- Sometimes
- Rarely
- Never

9. With DrayFLEX-Trip's "slow-down ahead" alerts, do you find yourself braking hard less often?

- A lot less
- A bit less
- About the same

- A bit more
- A lot more

10. Have the "slow-down ahead" alerts reduced your close calls with other vehicles?

- Yes, many times
- Yes, a few times
- Not really
- I've had more close calls

11. In general, do you feel that DrayFLEX-Trip's alerts make your drive safer?

- Much safer
- A bit safer
- About the same
- A bit less safe
- Much less safe

12. Do you think you save fuel by following DrayFLEX-Trip's route suggestions?

- Yes, a lot
- Yes, a little
- About the same
- I use more fuel

13. Is DrayFLEX-Trip performing as you expected?

- Always
- Most of the time
- Sometimes
- Rarely
- Never

14. Have you encountered any issues or downtimes with DrayFLEX-Trip?

- Never
- Once or twice
- A few times
- Often
- All the time

15. Have you made any changes to your trip as a result of using DrayFLEX-Trip?

- Changed departure time
- Changed route
- Decided not the make the trip
- Other (Please specify)_____________________________

16. On a scale of 0 to 10 with 0 being extremely dissatisfied and 10 being extremely satisfied, please rate all of the following for your use of the DrayFLEX-Trip app?

- Accuracy
- Timeliness of information
- Usefulness
- Clarity
- User friendliness
- Reliability
- Overall satisfaction

17. Did DrayFLEX-Trip improve your overall driving experience?

- Yes, a lot
- Yes, a little
- About the same
- Not at all

18. Do you have any details you would like to share regarding any of your responses or other information you would like to share regarding your experience with using DrayFLEX-Trip?____
____
____

19. Do you have any recommendations on how to improve the DrayFLEX-Trip app or features from DrayFLEX-Trip that you would like to see incorporated into other routing apps?____
____
____

Thank you for taking the time to complete this survey. Please provide your email or physical mailing address to receive your $10 Amazon gift card code.

____
____

Safe travels!

APPENDIX B

Emission Factors Emissions Rates

Emissions and fuel use rates for T7 POLA Class 8 diesel trucks operational in the Los Angeles subarea, aggregated for the calendar year 2021.

Speed (miles per hour)	SO_x (gram/vehicle-miles traveled (VMT))	$PM_{2.5}$ (gram/VMT)	PM_{10} (gram/VMT)	NO_x (gram/VMT)	CO (gram/VMT)	CO_2 (ton/VMT)	Fuel Consumption (gal/VMT)
0–5	0.038262942	0.04	0.04	14.64159526	3.61	0.0040406925	0.360953459650954
5–10	0.032930557	0.033520008	0.035035634	11.86507607	2.662919524	0.0034775752	0.310650410909167
10–15	0.027053322	0.028290416	0.029569583	8.984535111	1.739624075	0.0028569198	0.255207511538541
15–20	0.02360856	0.024925891	0.026052929	7.374781063	1.231624381	0.0024931416	0.222711351131378
20–25	0.021262908	0.022896559	0.02393184	6.30937071	0.915820513	0.0022454330	0.200583640412811
25–30	0.019454122	0.021935035	0.02292684	5.491405709	0.686685789	0.0020544193	0.183520459781729
30–35	0.018054651	0.021880479	0.022869817	4.860230304	0.513376984	0.0019066305	0.170318548535928
35–40	0.017019224	0.022667707	0.02369264	4.398385076	0.383675361	0.0017972860	0.160550846750031
40–45	0.016321302	0.024256661	0.02535344	4.09852405	0.288578904	0.0017235831	0.153966998253419
45–50	0.015944121	0.026621353	0.027825052	3.954026648	0.221456653	0.0016837517	0.150408868367423
50–55	0.015876485	0.029744371	0.03108928	3.964343504	0.177425526	0.0016766091	0.149770823281131
55–60	0.016210583	0.033797989	0.035326184	4.169901724	0.165486488	0.0017118909	0.152922534912608
60–65	0.016923097	0.038703362	0.040453357	4.546274256	0.177495974	0.0017871347	0.159644033269049
65–70	0.016923097	0.038703362	0.04	4.570213607	0.18	0.0017871347	0.159644033269049

Emissions and fuel use rates, for T7 POLA Class 8 diesel trucks operational in the Los Angeles subarea, aggregated for the calendar year 2022.

Speed (miles per hour)	SO_x (gram/vehicle-miles traveled (VMT))	$PM_{2.5}$ (gram/VMT)	PM_{10} (gram/VMT)	NO_x (gram/VMT)	CO (gram/VMT)	CO_2 (ton/VMT)	Fuel Consumption (gal/VMT)
0–5	0.037891635	0.03	0.04	14.34710567	3.3625873648	0.0040014813	0.357450737301157
5–10	0.032557154	0.030075306	0.031435178	11.48811911	2.4552638020	0.0034381425	0.307127908438087
10–15	0.026719436	0.025397303	0.026545657	8.597715861	1.5885536093	0.0028216603	0.252057801465116
15–20	0.023323108	0.022407171	0.023420324	7.019825332	1.1218503802	0.0024629969	0.220018536459541
20–25	0.021024561	0.020646405	0.021579943	5.953308456	0.8358430973	0.0022202628	0.198335195487052
25–30	0.019247173	0.019935281	0.020836666	5.120148269	0.6279818386	0.0020325648	0.181568205306863
30–35	0.017871915	0.020136176	0.021046645	4.476751334	0.4700561359	0.0018873330	0.168594710232944
35–40	0.016859925	0.021193113	0.022151371	4.007946598	0.3514471105	0.0017804636	0.159048106107968
40–45	0.016188422	0.023071646	0.024114843	3.707530748	0.2643311977	0.0017095506	0.152713477878849
45–50	0.015843014	0.02574937	0.026913642	3.5697543	0.2029452195	0.0016730744	0.149455076431316
50–55	0.01581409	0.029211206	0.030532007	3.594242946	0.1630447964	0.0016700199	0.149182220751042
55–60	0.016180802	0.033611859	0.035131638	3.816169839	0.1524718284	0.0017087459	0.152641597806304
60–65	0.016923158	0.038885699	0.040643938	4.213699905	0.1641603558	0.0017871412	0.159644612592794
65–70	0.016923158	0.038885699	0.04	4.235888017	0.1647281827	0.0017871412	0.159644612592794

Emissions and fuel use rates, for T7 POLA Class 8 diesel trucks operational in the Los Angeles subarea, aggregated for the calendar year 2023.

Speed (miles per hour)	SO_x (gram/vehicle-miles traveled (VMT))	$PM_{2.5}$ (gram/VMT)	PM_{10} (gram/VMT)	NO_x (gram/VMT)	CO (gram/VMT)	CO_2 (ton/VMT)	Fuel Consumption (gal/VMT)
0–5	0.036134083	0.01	0.01	11.45429527	1.5093355008	0.0038158780	0.340870870755388
5–10	0.030742768	0.009017945	0.009425696	8.311969513	0.9335066872	0.0032465375	0.290011906065530
10–15	0.025089261	0.007564235	0.007906256	5.57421334	0.5096164290	0.0026495085	0.236679541296444
15–20	0.021950654	0.006737927	0.007042586	4.303362337	0.3420606343	0.0023180612	0.207071489937688
20–25	0.019928093	0.006522795	0.006817727	3.334881552	0.2660156240	0.0021044722	0.187991668630622
25–30	0.018339329	0.007178148	0.007502712	2.501016353	0.2088605723	0.0019366935	0.173004064650993
30–35	0.017110072	0.008689595	0.0090825	1.852590976	0.1608790402	0.0018068799	0.161407868287484
35–40	0.016240322	0.011057137	0.011557092	1.389203815	0.1220710278	0.0017150314	0.153203079540090
40–45	0.015730079	0.014280774	0.014926487	1.111575186	0.0924365351	0.0016611481	0.148389698452108
45–50	0.015579342	0.018360506	0.019190687	1.019534734	0.0719755621	0.0016452298	0.146967724980242
50–55	0.015788112	0.023296333	0.02434969	1.113649204	0.0606881088	0.0016672766	0.148937159167787
55–60	0.01635639	0.029088255	0.030403497	1.395831156	0.0585741752	0.0017272885	0.154298001014743
60–65	0.017284173	0.035736272	0.037352107	1.860967522	0.0656337611	0.0018252656	0.163050250477816
65–70	0.017284173	0.035736272	0.04	1.870671803	0.0661832514	0.0018252656	0.163050250477816

Emissions and fuel use rates, for T7 POLA Class 8 diesel trucks operational in the Los Angeles subarea, aggregated for the calendar year 2024.

Speed (miles per hour)	SO_x (gram/vehicle-miles traveled (VMT))	$PM_{2.5}$ (gram/VMT)	PM_{10} (gram/VMT)	NO_x (gram/VMT)	CO (gram/VMT)	CO_2 (ton/VMT)	Fuel Consumption (gal/VMT)
0–5	0.035772296	0.01	0.01	11.60076134	1.4722472488	0.0037776733	0.337458063301809
5–10	0.030479382	0.009155381	0.009569347	8.385766883	0.9107224215	0.0032187230	0.287527248032192
10–15	0.024919135	0.007660673	0.008007054	5.584091773	0.4972837003	0.0026315426	0.235074659657047
15–20	0.021827193	0.006815698	0.007123874	4.291067424	0.3338291804	0.0023050234	0.205906822835646
20–25	0.019854737	0.006569885	0.006866946	3.319754139	0.2598673211	0.0020967255	0.187299658379545
25–30	0.01831333	0.007211757	0.007537841	2.486019605	0.2042895377	0.0019339479	0.172758798934741
30–35	0.017121508	0.008733393	0.009128278	1.836304757	0.1575171002	0.0018080875	0.161515741487064
35–40	0.016279269	0.011134792	0.011638258	1.370412239	0.1195500087	0.0017191444	0.153570486036513
40–45	0.015786615	0.014415955	0.015067781	1.089270168	0.0903882632	0.0016671185	0.148923032619475
45–50	0.015643545	0.018576882	0.019416847	0.992244518	0.0700318637	0.0016520098	0.147573381199562
50–55	0.015850059	0.023617573	0.024685455	1.080216605	0.0584808100	0.0016738184	0.149521531813162
55–60	0.016406157	0.029538028	0.030873606	1.354833398	0.0557351024	0.0017325442	0.154767484454171
60–65	0.01731184	0.036338246	0.0379813	1.811428266	0.0617947407	0.0018281872	0.163311239104512
65–70	0.01731184	0.036338246	0.04	1.820358487	0.0622731228	0.0018281872	0.163311239104512