Enhancement of Cross Town Improvement Project (C-TIP) Drayage Optimization Proof of Concept Application

Final Report

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16. Abstract

This report summarizes the analysis methodology, results, and lessons learned from the deployment of the Enhanced Cross Town Improvement Project (C-TIP) Drayage Optimization Proof of Concept Application. The system was deployed in the Los Angeles/Long Beach area to five licensed motor carriers. The objective of the project was to provide solutions to help reduce the number of truck trips and improve the congestion problem over the Los Angeles and Long Beach transportation network. This document describes in detail the findings and the results obtained in this project.

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Table of Contents

List of Tables

List of Figures

Executive Summary

In 2013 Productivity Apex implemented the Cross Town Improvement Project (C-TIP) Drayage Optimization Proof of Concept Application in Memphis, Tennessee and in 2014 the Los Angeles-Gateway Freight Advance Traveler Information System was deployed by Cambridge Systematic in partnership with Productivity Apex to improve truck operations in and around ports and other freight intermodal facilities. Implementation of the current C-TIP project included targeted system enhancements based on learnings from these previous deployments. Some of the key system enhancements are listed below:

- Integration with participants' legacy systems.
- Development of a Driver Mobile Application.
- Integration with Traffic Services for algorithm travel time calculations.
- Inclusion of CoPilot® GPS for truck vehicle's routing considering real-time traffic conditions.
- Development of dynamic planning functionalities within the optimization engine.
- Development of an Online Portal and Open API for Marine Terminal Notification.

Following development and implementation of these enhancements, the project team initiated deployment of the new system with five drayage companies and three Marine Terminals as required by the project. The team performed training and completed the initial setup for the five selected drayage companies which originally committed to participate in the project. During the implementation phase, the project team found resistance by these companies to fully use the system consistently. Furthermore, participants did not distribute system-related tablet devices to their drivers although being provided with fully-configured tablets and extensive training on the entire system by the project team.

Reasons cited for lower than expected use of the tool by drayage companies included inaccuracy of data supplied to the C-TIP application from their operations, end-user resistance to changes in legacy route configurations, concerns regarding inter-system security, and internal resource limitations.

In the case of Marine Terminals, participation could not be secured notwithstanding the multiple meetings held for this purpose. As a mitigating measure, an online portal was created that could be securely accessed by Terminals, including an open application programming interface (API) to allow for connection of legacy systems. This online portal provided in-advance and real-time terminal transaction notifications.

After review of these issues, the project team worked with one of the participant drayage companies to secure operational data to allow for comparisons of performance before and after use of the FRATIS system. This method of assessment resolved the operational concerns, and provided a means for development of operational metrics for assessment of the impact of the enhanced C-TIP application. The resulting analysis yielded a consistent 14% average reduction in miles traveled through use of the application.

During the deployment of the system the project team gained great insight into the operations of these companies and the opportunities and challenges that arise when deploying this technology. Among the findings the team concluded that a more comprehensive approach on training with the provision of content using multiple media like videos and frequently asked questions (FAQs) repositories within the tool proved effective. However, there were challenges when customizing the system in a way that would meet expectations from multiple users and stakeholders. Finally, human factors and operational dynamics in this complex environment are still some of the constant barriers found in these deployments.

Throughout the course of the current project, new functionalities and technologies were developed and delivered that filled the gaps identified from previous deployments and provided a superior user experience. In addition, a more comprehensive understanding of operational challenges and opportunities in the drayage industry was achieved. Analysis of live operational data showed that the employment of a planning and optimization system like FRATIS can yield numerous benefits such as a 14% reduction in average total miles driven, with potential impact on key factors such as productivity and overall cost efficiency.

1 Project Overview

Truck movements in urban areas have a significant impact on regional congestion as well as air quality and fuel use. Freight movements via trucks may represent only a small portion of total traffic volumes on the nation's highways; however, because of their size and performance characteristics (e.g., idling, acceleration), freight movements generally have significantly greater effects on congestion, road wear, and air quality as compared to most passenger vehicles. For this reason one of the main goals of this project was to provide a solution that would help reduce the number of truck trips and improve the congestion problem over the Los Angeles and Long Beach transportation network.

In 2013 and 2014 respectively, the US Department of Transportation funded a Cross-Town Improvement Project (C-TIP) and the Freight Advanced Traveler Information System (FRATIS) for improving truck operations in and around ports and other freight intermodal facilities. As part of this project, the C-TIP optimization algorithm and FRATIS were enhanced and expanded in order to build a Corridor Optimization for Freight (COfF) in Los Angeles. These applications, which resulted from the above mentioned projects, are used to create optimum routes that reduce the number of unproductive moves for trucks in drayage operations. Also, as part of the scope of this project, additional enhancements were made to these systems which included the development of a Driver Mobile Application and the development of a dynamic planning feature used to re-optimize drayage moves throughout the day using real-time data updates. Additionally, Marine Terminal Operators (MTO) and Licensed Motor Carriers (LMC) communications protocols were enhanced by developing a web based portal to communicate data to marine terminals regarding transactions and truck arrivals. Finally, as part of this enhancement, the Driver Mobile Application was deployed on mobile tablets to project participants as On-Board devices for drivers.

1.1 Understanding Drayage Operations

The Ports of Los Angeles and Long Beach move near 8.8 million 20-foot equivalent units also known as TEUs (CY 2016) and 6.8 million TEUs (CY 2016) respectfully; they are the first and second largest ports in the US and together represent the world’s tenth busiest port complex by container volume. Many of the goods coming from the port are destined for stores and factories in the region and others are distributed throughout the country. These movements are possible thanks to drayage routes used by motor carriers to transport intermodal containers between pick up and drop off locations.

Drayage moves are usually defined as shorthauls and consist primarily of local roads that connect shippers with receiver facilities. Drayage firms receive container requests for pick up at intermodal facilities and delivery at distribution centers. Some of these moves may have appointments both at the pickup or the receiver side, and based on this information and other parameters discussed throughout this report, companies determine the routing and schedules for assigning orders to drivers. Trucks are then dispatched to these facilities where, if they arrive with an export container, they will proceed to a drop-off location and wait for yard cranes to load containers onto cargo ships. Trucks arriving with an empty chassis or as bobtail are processed and directed to a container pick-up location. Bobtail trucks would proceed to a chassis pick-up location before being loaded an import container. Drivers would then take the import containers to their receivers where they would wait for cargo to be unloaded from the truck, or perform what is known as “drop and pick” where trucks will drop the trailer/container and pick it up at a later time. After dropping import containers, drivers usually pick up empty boxes from previous moves to be returned to specific locations determined by the steamship lines.

These operations are repeated into a cycle and are these ever-changing dynamics which create a high degree of uncertainty for drayage operations.

1.2 System Evolution

The Los Angeles COfF prototype evolved from previously deployed systems funded by the US Department of Transportation such as C-TIP and FRATIS. These systems were developed and deployed with the common purpose of improving freight operations subject to many constraints that different environments experience (e.g., congestion, insufficient communication among parties, etc.) and constitute the base for the COfF system. A short description of previous deployments is provided below.

C-TIP was deployed in Memphis, Tennessee in 2013 with the participation of one motor carrier. The main objective of the C-TIP pilot project was to develop and deploy a solution to minimize unproductive freight moves. During this project an optimization algorithm was developed that allowed for the assignment and sequencing of freight orders in a way that minimized driven miles, given several operational constraints. These constraints included orders appointment time, the driving and duty hour limits for drivers, the starting location and earliest start time for drivers, and the overall configuration of each order. The algorithm was deployed through a web interface where dispatchers entered the orders manually and ran the optimization on the day before execution. After the completion of the optimization run, the user was provided with the capability to manually modify any orders' assignments and sequencing based on their preferences. The optimized orders were then sent to drivers through an on-board device which consisted of a TomTom Pro 7150 unit in this project; drivers could then see their itinerary and update the status of the order in real time. The system was implemented successfully and generated significant operational improvements in Memphis with a 13% reduction in bobtail miles and a 21% reduction in required fleet for executing the same number of orders.[1]

After the successful deployment of the C-TIP pilot project, other FRATIS pilot project deployments were initiated and were successfully completed in three locations: Los Angeles/Long Beach Area, South Florida, and Dallas - this time with the participation of one licensed motor carrier and a single marine terminal in LA/Long Beach, one LMC in South Florida, and two LMCs in Dallas. Given the specific characteristics found in each of these environments, the tool was modified and enhanced to take into consideration some of the most important constraints presented in those locations. The Los Angeles deployment was characterized by the involvement of a marine terminal for exchanging information between the systems for real-time updates regarding order and container status. Also traffic information, marine terminal waiting times, and turn times were integrated into the optimization algorithm when

[1] Development of a Cross Town Improvement Project (C-TIP) Drayage Optimization Application (USDOT; September, 2013)

generating a solution to account for the heavy traffic congestion in the area. However, in the Los Angeles deployment the user had to do manual data entry for entering orders into the system[2].

In South Florida, as well as in the Dallas deployment, the major accomplishment was the ability to integrate with the company transportation management system (TMS) in a way that eliminated the double data entry problem. In South Florida, data migration was scheduled for automatically populating the system multiple times a day so that the participating trucking company always had the latest order status on their interface[3].However, in Dallas; the integration was accomplished by the manual upload of a flat file[4]. These two approaches provided a better understanding of the pros and cons of different mechanisms available for performing a more thorough integration of FRATIS with third party systems. Still, the integration in both these deployments was specific to the companies' TMS, and could not work with other systems.

Deployment of this technology in multiple locations led to many lessons learned that served as the genesis for the development of the COfF. Major enhancements were made to the prior systems based on the lessons learned and the deployment was expanded to include the participation of multiple stakeholders.

It is important to note that different stakeholders use the word C-TIP and FRATIS interchangeably – this is valid given that the FRATIS tool is just an evolution of the C-TIP Application. In the balance of this document we will be using FRATIS when we refer to the system that comprises this project.

The following section describes the major enhancements that were implemented in FRATIS based on experience gained from prior deployments and interactions with multiple stakeholders.

1.3 System Enhancements

1.3.1 Integration with LMC's dispatching and transportation management systems

During the development phase of this pilot project, several efforts were made to integrate the FRATIS tool with the order management and dispatching systems of the participating companies. However, access was not granted from vendors of these systems in order to accomplish a seamless integration. The reasons provided by the software companies for the denial of access were: conflict with current

[2] Los Angeles-Gateway Freight Advance Traveler Information System. Demonstration Team Final Report (USDOT; February, 2015)

[3] South Florida Freight Advance Traveler Information System. Demonstration Team Final Report (USDOT; May, 2015)

[4] Freight Advanced Traveler Information System (FRATIS) - Dallas-Fort Worth (DFW) prototype: final report (USDOT; May, 2015)

development of similar functionalities on their applications, restriction on the access to their APIs, and lack of technical resources on their end to assist with the integration. Given this scenario the project team developed a more standard approach that would satisfy data migration from any TMS using a comma-separated value (csv) or Excel formatted file report. Following this approach, a feature was developed for FRATIS users to upload a csv or Excel file to import orders. Nevertheless, the main challenge found using this approach was that not every user was able to generate the same formatted report. Each of these reports differed in file structure and data format. In order to mitigate this problem, the team developed a customized data-mapping module for each of the project participants called the Pre-FRATIS module that was used to standardize the format of their files to one that could be read by the FRATIS tool.

In addition to the development of data import capability in the tool, a data export functionality was also developed. This new feature allowed system users to generate a report containing the resulting order assignment and schedule plan from running the optimization algorithm. With this capability, users could print a file containing all the assignments and sequences and even upload it to their dispatching system to expedite the status update and order assignment in their systems.

The development of this new feature in FRATIS eliminated the need for data double entry that was experienced in prior deployments and provided a more streamlined operation of the tool.

1.3.2 Development of a Driver Mobile Application

During the development phase of the project, a mobile application was developed to provide drivers with an on-board system to receive their assignments and itineraries in real time. This application also allowed drivers to have access to their assigned orders in the optimized sequence for execution. Additionally, using the mobile application, drivers were now able to update orders status and location information for the assigned orders. Figure 1 and 2 show screenshots of the developed mobile application.

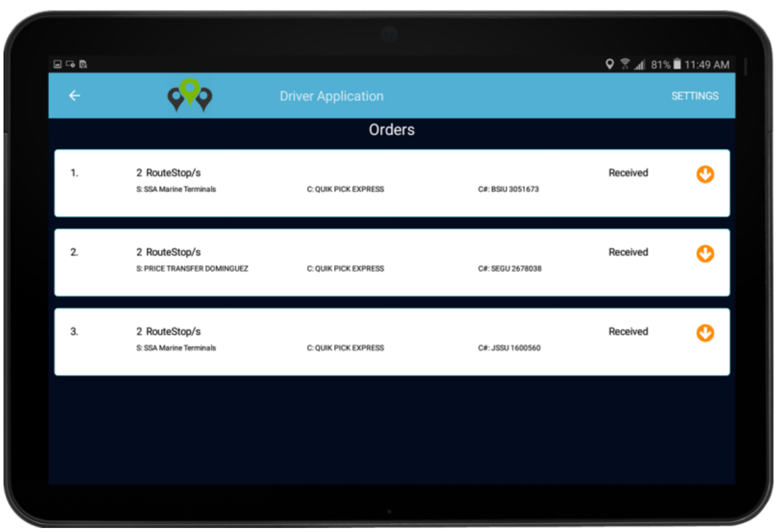


Figure 1. FRATIS Mobile App Screenshot with List of Assigned Orders

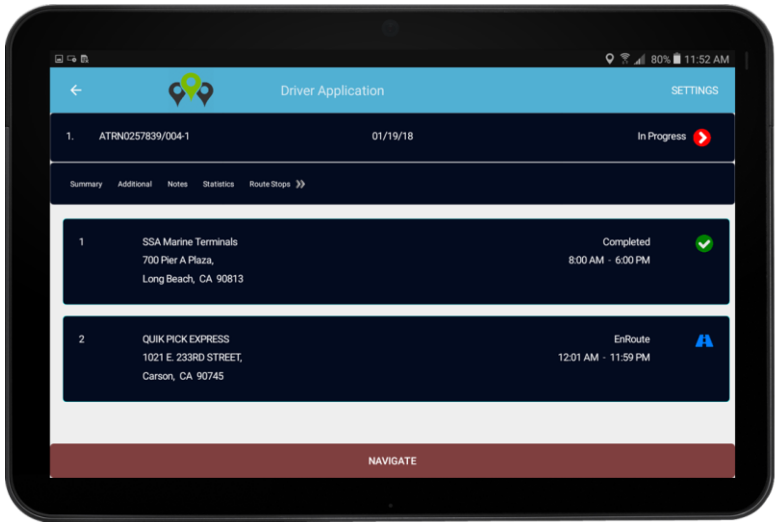


Figure 2. FRATIS Mobile App Screenshot with List of Stops in an Order

Below are the list of features and requirements developed in the mobile application:

- The mobile application was developed for both Apple operating system (iOS) and Android operating system. Hence, drivers from participant companies could access the mobile application from iOS and Android tablets and cell phones.
- The mobile application required that devices have data plan or internet connectivity through Wi-Fi to send and receive order data from the FRATIS tool. However, the application could operate without data signal with the only limitation of not being able to send and receive data in real time. Once data signal was available, the mobile application would synchronize with the web dashboard and update order status and driver information.
- The mobile application allowed drivers to access their assigned orders as well as the sequence in which they should be executed.
- The mobile application allowed drivers to update the status of the orders by indicating, when they were en route to an order, when an order was in progress, and when the order had been completed. All updates were synchronized with the dashboard tool, informing dispatchers of the order status.
- The mobile application captured GPS coordinates from the mobile device to locate drivers and use the data for dynamic planning (plan re-optimization) throughout the day with real-time driver information.

1.3.3 Integration with Traffic Services for algorithm travel time calculations

The project team integrated the FRATIS tool with historical traffic information in order to reduce the estimated travel time between locations. The team was granted access to the Regional Integration of Intelligent Transportation Systems (RIITS) database. The RIITS network is sponsored by the Los Angeles County Metropolitan Transportation Agency (Metro), and agencies like Caltrans, City of Los Angeles Department of Transportation (LADOT), California Highway Patrol (CHP), Long Beach Transit (LBT), Foothill Transit (FHT), and Metro contribute information collected through their own Intelligent Transportation Systems (ITS) to the network using the Los Angeles County Regional ITS Architecture and National ITS Standards. The network supports information exchange in real-time between freeway, traffic, transit and emergency service agencies to improve management of the Los Angeles County transportation system and better serve the traveling public (https://www.riits.net/).

The RIITS traffic data was selected because it contains thousands of data points throughout the region classified by date and time of the day. This information was key for its use in the FRATIS tool, given that historical data was needed to predict the travel time between two locations on specific day of the week and during each hour of the day. The tool used historical data from the previous 4 weeks to estimate travel times between locations on a given day and hour.

To accomplish this, the project team developed special queries to the traffic database so the required data could be obtained within the needed timeframe. This data was then processed and mapped to the route engine used by FRATIS in order to match the road waypoints from the two systems. Finally, a file was generated containing all the average delays categorized per day and time of day; this file was used by the FRATIS optimization algorithm to calculate the proper travel distances between locations when generating the optimized plan solutions.

1.3.4 Provision of truck navigation with real-time traffic capability

Additional functionality developed in this enhanced version of the tool consisted of using real-time traffic information to navigate between stops. The project team used the third-party application Copilot® Mobile Navigation by ALK Technologies to provide this capability. This third-party application was integrated into the FRATIS mobile application so that drivers could easily navigate to different locations in their itinerary with the click of a button. When drivers click on the navigation button for the corresponding location, the Copilot® app opens and provides step-by-step directions considering real-time traffic, road closures, and accidents information in order to minimize travel time. Figure 3 shows how the applications were integrated:

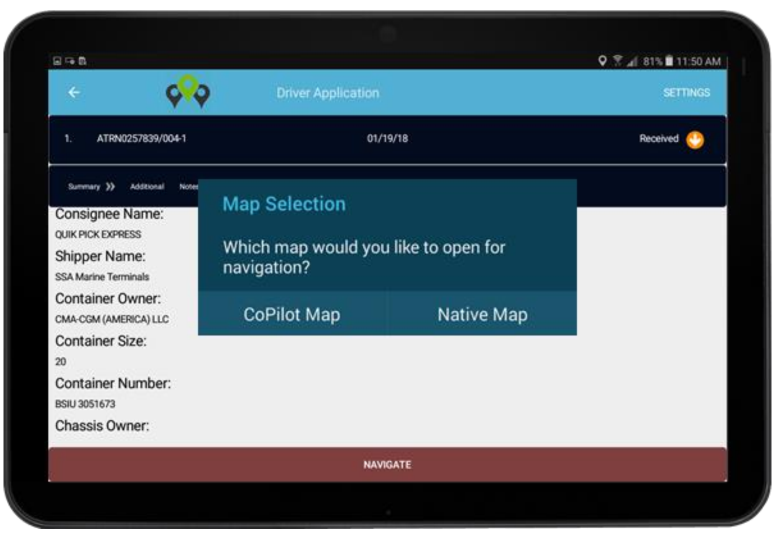


Figure 3. FRATIS Mobile App Screenshot with CoPilot Integration

1.3.5 Development of Dynamic planning feature for the optimization

The FRATIS dynamic planning feature was one of the most requested functionalities from previous pilot projects. This feature was developed in this phase and allowed users to re-optimize their plans at any time during the day considering the latest location of drivers, the updated status of each assigned order, and the remaining duty and driving time for each of the drivers in the plan.

Additionally, users could add and remove orders as well as drivers on a plan. This capability allowed for the incorporation of same-day or emergency orders on a day's plan, removal of drivers who cannot complete their assignment for any reason, and the reassignment of those orders to new drivers in the most efficient manner. Figure 4 below shows a plan itinerary containing completed orders updated through the driver mobile application.

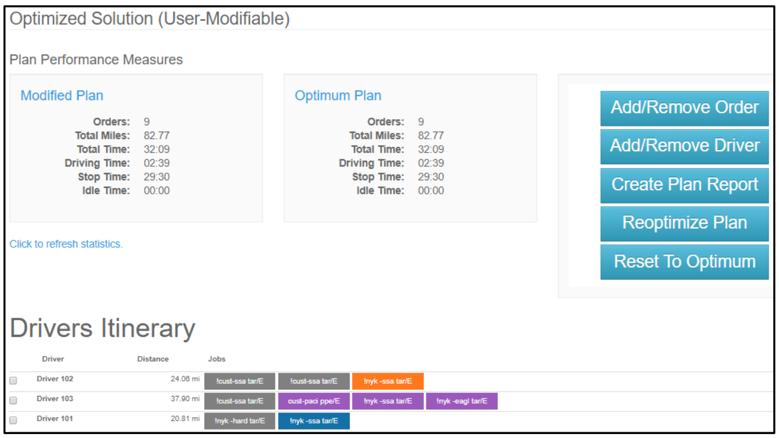
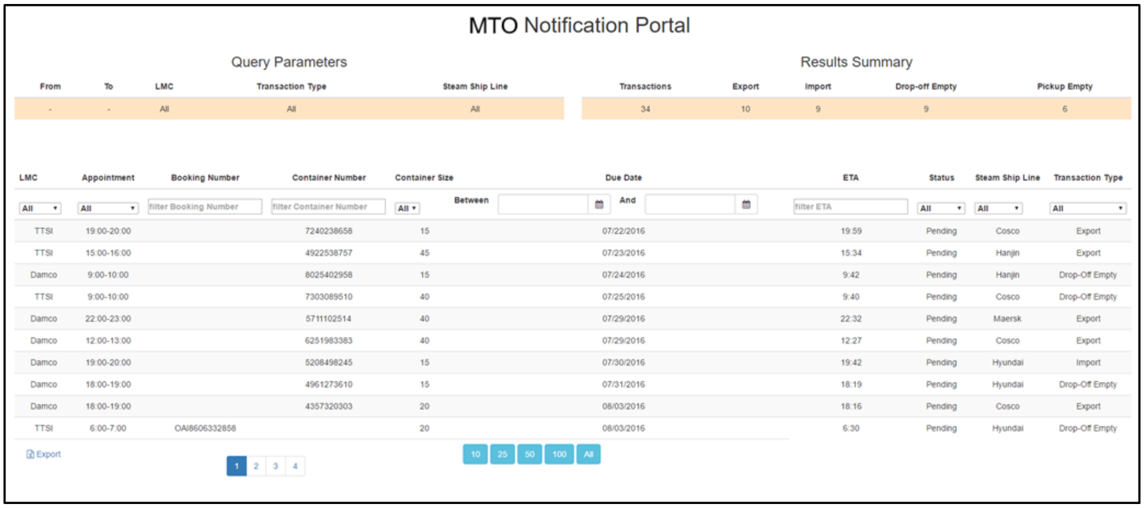


Figure 4. FRATIS Application Route Planning Screenshot

1.3.6 Development of an Online Marine Terminal Notification Portal and Open API

As part of the scope of this project, the project team tried to obtain the participation from at least three marine terminal operators; however, after attending multiple meetings with each of the terminals in both the ports of LA and Long Beach, requests for participation were rejected by each operator. Some of the reasons cited by the terminals were lack of time, lack of resources to dedicate to the project, and security concerns for integrating with their systems. Thus, in consultation with FHWA Program Managers, the project team devised an alternative solution to reach potential marine terminal participants. The new solution involved the development of the Online Marine Terminal Notification Portal, as shown in Figure 5, and an Open API as part of a system enhancement in this project. Terminals can be given access to this portal which provides detailed information including estimated arrival time of upcoming orders to their facilities. The portal also provides access to an open API that operators can use to integrate with their systems and access the same information as on the portal. This solution allows marine terminals to estimate the number of potential transactions at their facilities in advance categorized by type, carrier, shift, and steamship line. The information in the online portal is also updated once trucks start navigating towards the terminal taking current traffic conditions into consideration as long as drivers use the FRATIS mobile application. With this system MTO's can also identify LMC's transactions cancellations or no-shows in advance.



MTO Notification Portal

Query Parameters					Results Summary				
From	To	LMC	Transaction Type	Steam Ship Line	Transactions	Export	Import	Drop-off Empty	Pickup Empty
-	-	All	All	All	34	10	9	9	6

LMC	Appointment	Booking Number	Container Number	Container Size	Due Date	ETA	Status	Steam Ship Line	Transaction Type
All	All	filter Booking Number	filter Container Number	All	Between And	filter ETA	All	All	All
TTSI	19:00-20:00		7240238658	15	07/22/2016	19:59	Pending	Cosco	Export
TTSI	15:00-16:00		4922538757	45	07/23/2016	15:34	Pending	Hanjin	Export
Damco	9:00-10:00		8025402958	15	07/24/2016	9:42	Pending	Hanjin	Drop-Off Empty
TTSI	9:00-10:00		7303089510	40	07/25/2016	9:40	Pending	Cosco	Drop-Off Empty
Damco	22:00-23:00		5711102514	40	07/29/2016	22:32	Pending	Maersk	Export
Damco	12:00-13:00		6251983383	40	07/29/2016	12:27	Pending	Cosco	Export
Damco	19:00-20:00		5208498245	15	07/30/2016	19:42	Pending	Hyundai	Import
Damco	18:00-19:00		4961273610	15	07/31/2016	18:19	Pending	Hyundai	Drop-Off Empty
Damco	18:00-19:00		4357320303	20	08/03/2016	18:16	Pending	Cosco	Export
TTSI	6:00-7:00	OAI8606332858		20	08/03/2016	6:30	Pending	Hyundai	Drop-Off Empty

Export 1 2 3 4 10 25 50 100 All

Figure 5. Marine Terminal Notification Online Portal

2 Data Analysis

The data analysis in this project is intended to measure the impact and potential benefits that these type of technologies could have when applied to freight operations. For this purpose the project team collected order plans and execution data for four months of operation, and developed a series of modules that allowed comparing company manually generated plans versus FRATIS generated ones, and performed statistical analysis on these results to determine efficiencies gained by the use of the optimization tool.

2.1 Data Analysis Methodology

The project team received Excel files from one participant company for the months of July, August, September, and October 2017; other participants where disinclined to share detailed execution data about their operations. These files contained information including, but not limited to, pick-up and delivery time windows, order numbers, driver names and numbers, city codes, delivery dates, as well as pick-up and delivery street addresses. In total 101 days of data were provided by the participating company, with 85 days used for final analysis. Days were discarded for reasons including: insufficient data and data affected by holidays.

During the analysis, the project team developed several modules to rearrange and condition the raw data for use by the FRATIS tool. Some of these modules are excel-based programs, and others are more complex tools using APIs like Google Maps. The modules developed are as follows:

- Distance Calculation Module: This is a tool used to calculate the distance traveled by drivers when provided with a list of addresses and scheduled times. This module was used for calculating the distances driven on the executed plans.
- Analysis Formatting Module: This module prepares raw data from the participant companies for entry into the Distance Calculation Module. This is accomplished by reformatting part of the data into a format recognized by the Distance Calculation Module.
- File Reconfiguration Module: The File Reconfiguration Module prepares raw data for use in a later step. This is accomplished by rearranging excel columns into a format readable by the Pre-FRATIS Module.
- Pre-FRATIS Module: This module takes the data coming from the File Reconfiguration Module and restructures the format of the orders into one that can be consumed by the optimization algorithm in the FRATIS tool. The Pre-FRATIS Module's main task is to break orders into their constituent parts, separating the pick-up and delivery stop locations into individual records associated to the original order.

To calculate FRATIS mileage, the following steps were performed:

1. The raw data provided by participant companies was trimmed to eliminate those shipments that took place outside of the day shift hours (5:00am to 5:00pm), and was then split into daily files.
2. These daily files were then fed through the File Reconfiguration Module to re-order and format the data as required by the Pre-FRATIS Module.
3. Next, the data was run through the Pre-FRATIS Module to separate the "drop off" and "pick-up" data within the orders and to complete the necessary reformatting of the data.

4. Following these two modules, the data was examined one final time for entries that might interfere with FRATIS. These included: deliveries taking place outside of the day shift, deliveries where the delivery time window was scheduled after the pick-up time window and addresses that are not in standard postal format.
5. Once the correct formatting had been verified, the data was uploaded to FRATIS where the optimization algorithm was run to determine the optimal route for each day's set of orders.

In addition to the FRATIS process outlined above, parallel work was undertaken with the provided data using the Distance Calculation Module to show the actual mileage executed while completing each day's set of deliveries. The Distance Calculation Module was developed to calculate the distance that trucks would have driven between locations using a configuration that prioritized highways and fastest truck routes. To do this, the raw shipment data was trimmed in an identical manner as above to eliminate those shipments that took place outside the day shift hours. It was then separated into weekly files instead of the previously used daily files. This, so it could be reformatted in the Analysis Formatting Module to rearrange Excel columns into a format that could be understood by the Distance Calculation Module. Finally, this processed data was run through the Distance Calculation Module to obtain the actual execution mileage.

2.2 Data Analysis Results

The FRATIS tool was designed to reduce the number of unproductive moves and minimize the travel miles for drayage trucking operations by using an optimization algorithm that considers numerous operational constraints such as appointment times, drivers driving and duty times' allocations, drivers starting locations and starting time, as well as historical traffic conditions, among others. In this project, the team focused specifically on the impact on the total number of miles because there was not enough information in the records provided by the participant TMS to breakdown the moves into bobtail, chassis, or loaded. The total number of miles is a key performance indicator of efficiency, productivity, and ultimately cost for a drayage operator.

Additionally, these results show the comparison between the company executed daily plans and the plans generated by FRATIS, representing the improved efficiency that could potentially be achieved using the FRATIS tool.

The tables below show the results and the data points used for the analysis, each representing a day of collected data as explained in the previous section.

Table 1 below shows the results obtained for the month of July.

Table 1. Data Analysis for July

Data Analysis Results for July	
Average Percent Miles Reduction	14%
Average Company Generated Plan Miles	1,763.15 mi
St. Dev. for Company Generated Plan Miles	537.76 mi
Average FRATIS Generated Plan Miles	1,514.07 mi
St. Dev for FRATIS Generated Plan Miles	483.83 mi
Potential Miles Reduction with FRATIS	4,483.46 mi
Number of Data Points Collected	23
Number of Data Points Discarded	5

Table 2 below shows the results obtained for the month of August.

Table 2. Data Analysis for August

Data Analysis Results for August	
Average Percent Miles Reduction	15%
Average Company Generated Plan Miles	2,006.54 mi
St. Dev. for Company Generated Plan Miles	431.39 mi
Average FRATIS Generated Plan Miles	1,700.83 mi
St. Dev for FRATIS Generated Plan Miles	412.45 mi
Potential Miles Reduction with FRATIS	7642.75 mi
Number of Data Points Collected	27
Number of Data Points Discarded	2

Table 3 below shows the results obtained for the month of September.

Table 3. Data Analysis for September

Data Analysis Results for September	
Average Percent Miles Reduction	11%
Average Company Generated Plan Miles	1,879.46 mi
St. Dev. for Company Generated Plan Miles	491.10 mi
Average FRATIS Generated Plan Miles	1,674.65 mi
St. Dev for FRATIS Generated Plan Miles	461.54 mi
Potential Miles Reduction with FRATIS	4,300.88 mi
Number of Data Points Collected	25
Number of Data Points Discarded	4

Table 4 below shows the results obtained for the month of October.

Table 4. Data Analysis for October

Data Analysis Results for October	
Average Percent Miles Reduction	16%
Average Company Generated Plan Miles	2,066.64 mi
St. Dev. for Company Generated Plan Miles	510.49 mi
Average FRATIS Generated Plan Miles	1,759.61 mi
St. Dev for FRATIS Generated Plan Miles	465.45 mi
Potential Miles Reduction with FRATIS	6,447.74 mi
Number of Data Points Collected	26
Number of Data Points Discarded	5

Table 5 below shows the overall results found in the study.

Table 5. Data Analysis Results

Data Analysis Results	
Average Overall Miles Reduction	14%
Average Company Generated Plan Miles	1,928.95 mi
St. Dev. for Company Generated Plan Miles	502.73 mi
Average FRATIS Generated Plan Miles	1,662.29 mi
St. Dev for FRATIS Generated Plan Miles	461.71 mi
Largest Improvement	30% (October 21st)
Smallest Improvement	2% (August 22nd)
Total Data Points Collected	101
Data Points Discarded	16
Potential Miles Reduction with FRATIS	22,874.83 mi

2.2.1 *Monthly Miles Reduction Comparison*

The following graphics show a comparison of the results found per month:

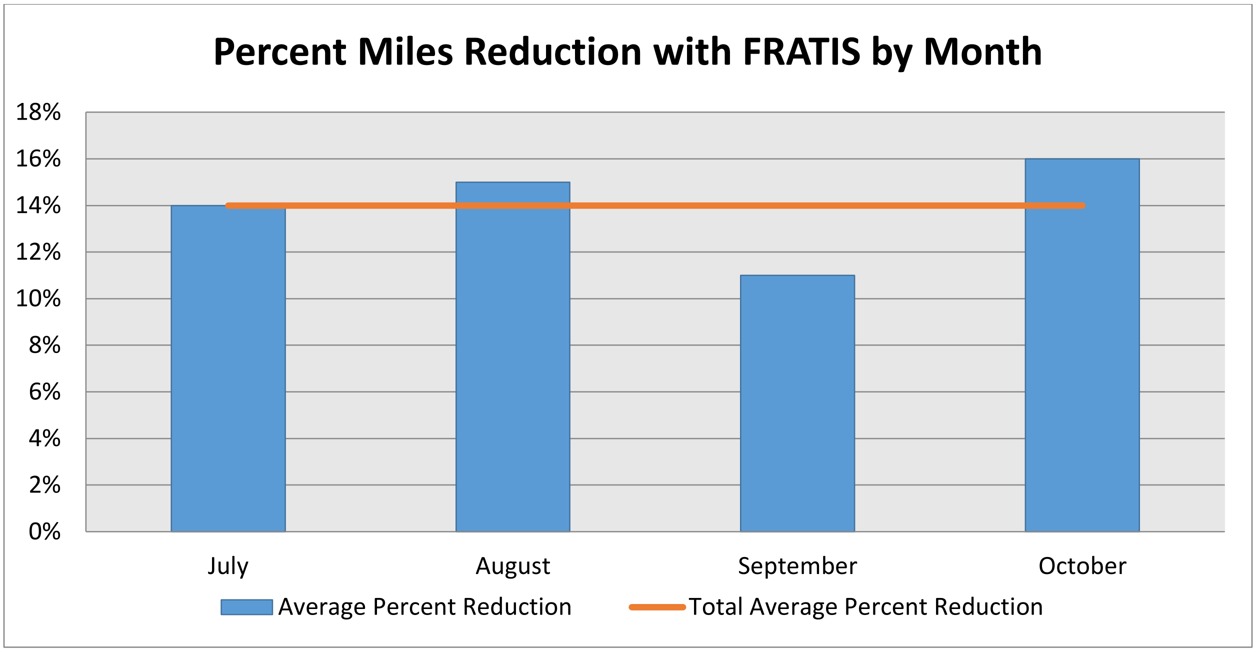


Figure 6. Percent Miles Reductions with FRATIS by Month

Figure 6 shows the average percent reduction in miles for plans generated by FRATIS for the months of July to October 2017. The month with the lowest reduction in miles was September at 11% and the largest was October at 16%. This results in an overall average miles reduction of 14%.

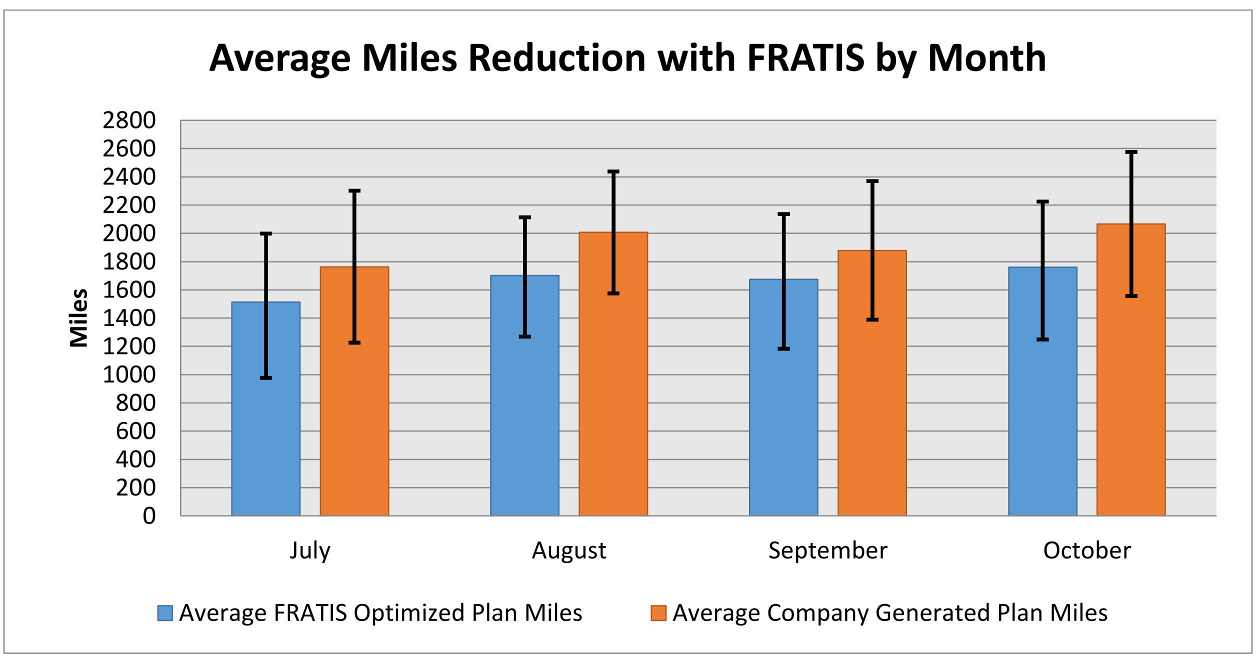


Figure 7. Average Miles Reduction with FRATIS by Month

Figure 7 shows the comparison between average FRATIS optimized plan miles and average company generated plan miles for July-October 2017.

2.2.2 *Daily Miles Reduction Comparison*

The following figures show the daily optimized plan miles and the company generated plan miles for each month in the analysis using the left axis. Data for days not shown were either not available or were discarded for the reasons discussed in the Data Analysis Methodology.

<u>Comparison of FRATIS Vs Company generated plan miles for July</u>

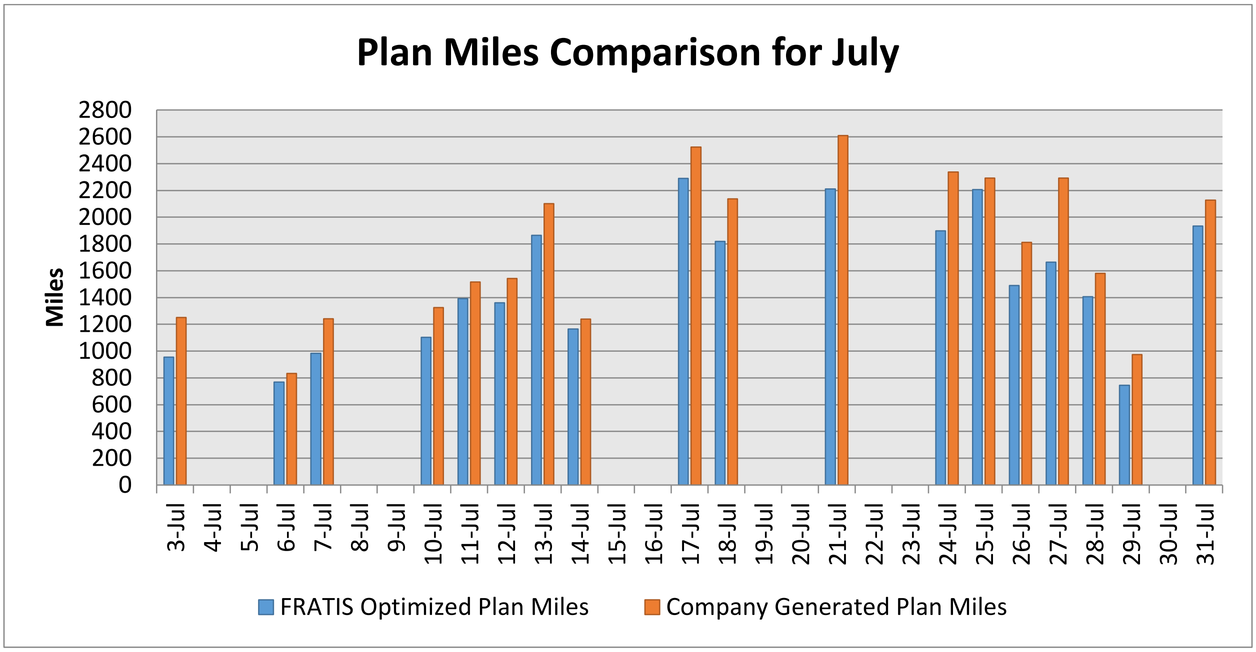


Figure 8. Plan Miles Comparison for July

Comparison of FRATIS Vs Company generated plan miles for August

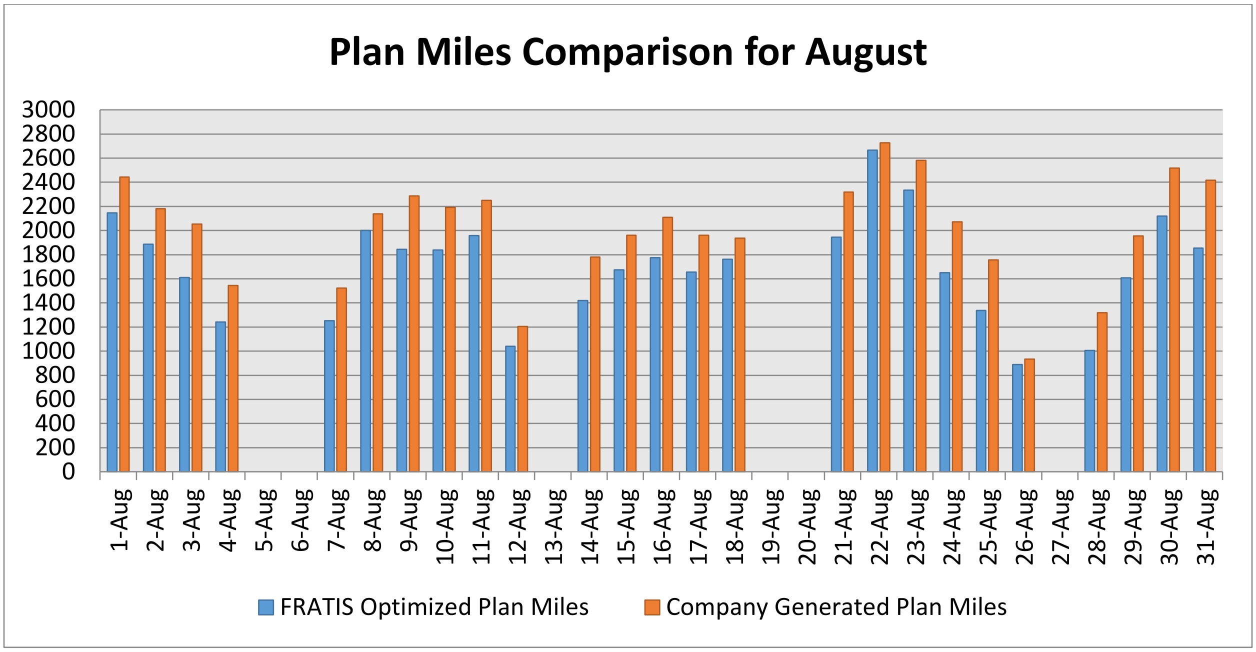


Figure 9. Plan Miles Comparison for August

Comparison of FRATIS Vs Company generated plan miles for September

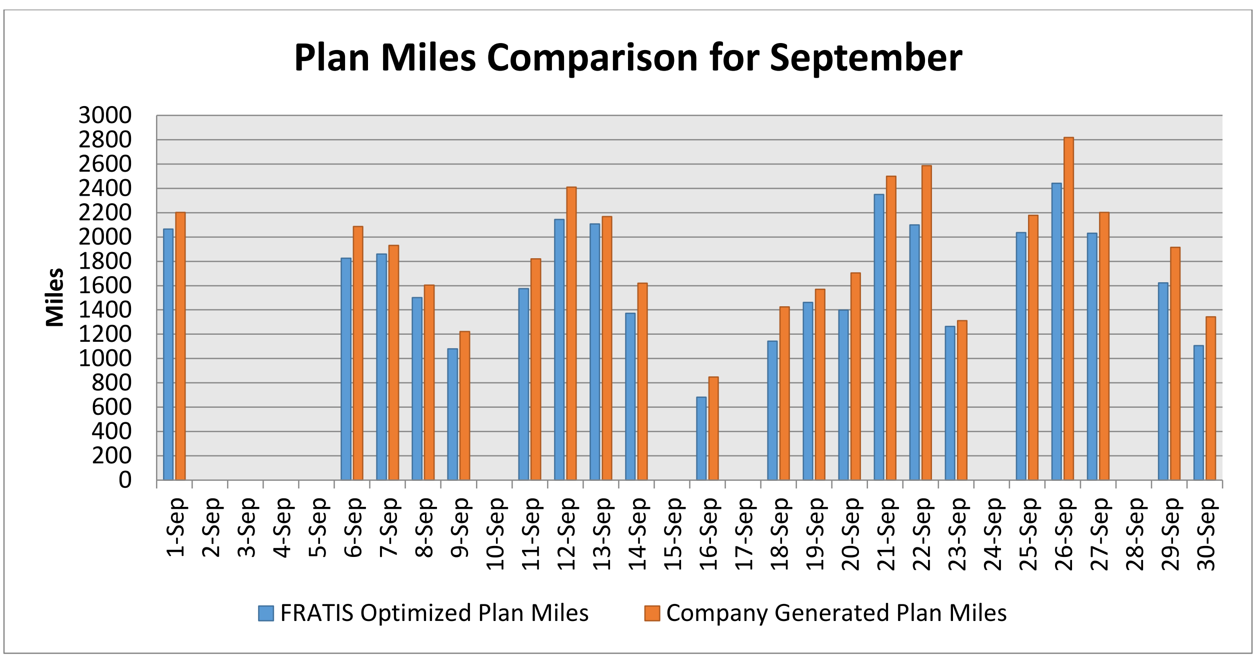


Figure 10. Plan Miles Comparison for September

<u>Comparison of FRATIS Vs Company generated plan miles for October</u>

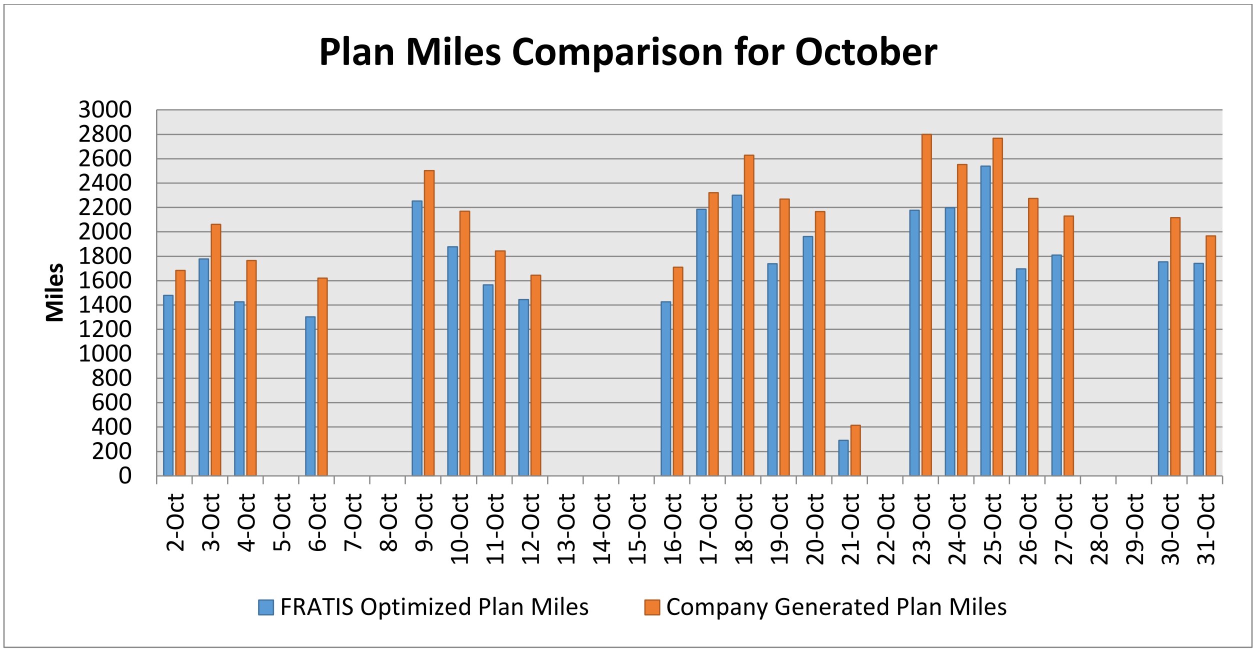


Figure 11. Plan Miles Comparison for October

The following figures show a comparison for the percentage in mileage reduction on a daily basis per month.

<u>Daily percent miles reduction for July</u>

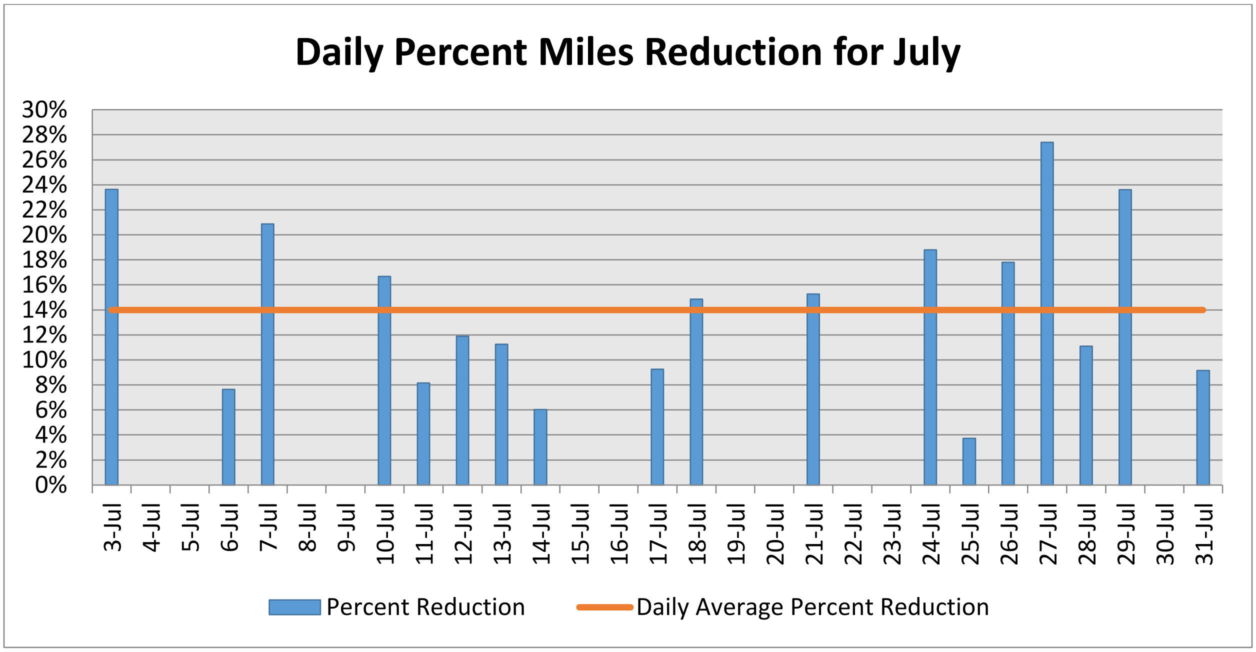


Figure 12. Daily percent miles reduction for July

Figure 12 shows the daily percentage for miles reduced after running the FRATIS optimization algorithm for the month of July 2017. The minimum value is 4% (July 25th), and the maximum 27% (July 27th). The monthly average miles reduction is 14%.

Daily percent miles reduction for August

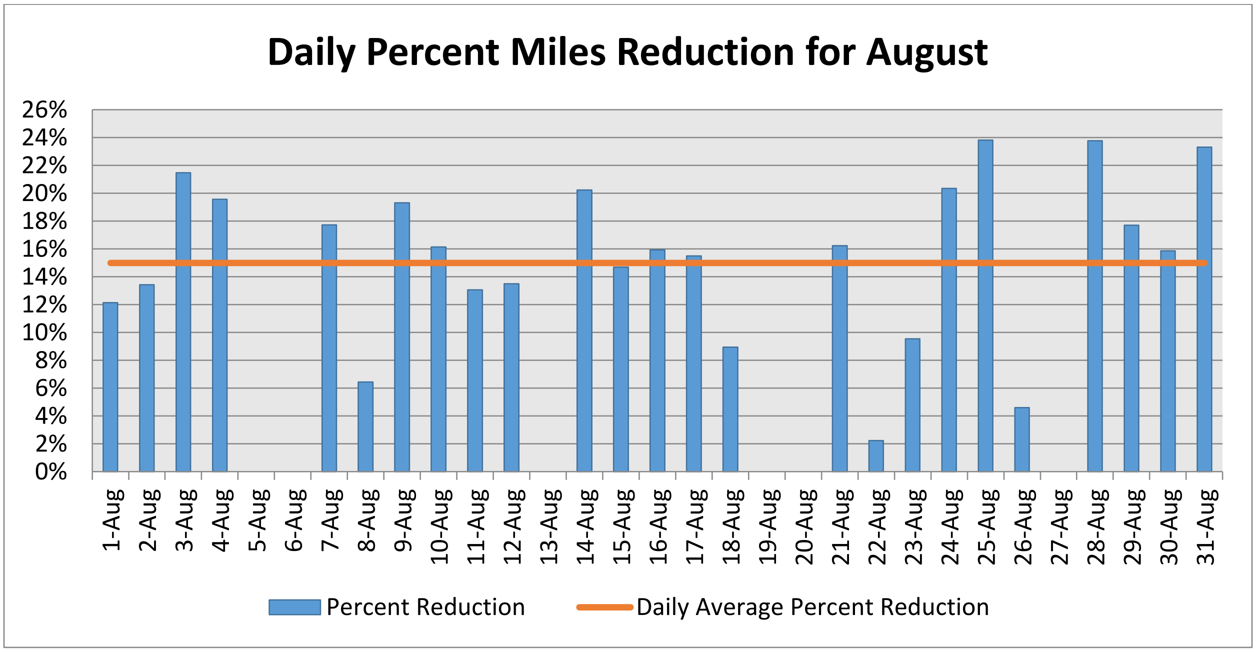


Figure 13. Daily percent miles reduction for August

Figure 13 shows the daily percentage for miles reduced after running the FRATIS optimization algorithm for the month of August 2017. The minimum value is 2% (July 22nd), and the maximum 24% (August 25th and 28th). The monthly average miles reduction is 15%.

Daily percentage miles reduction for September

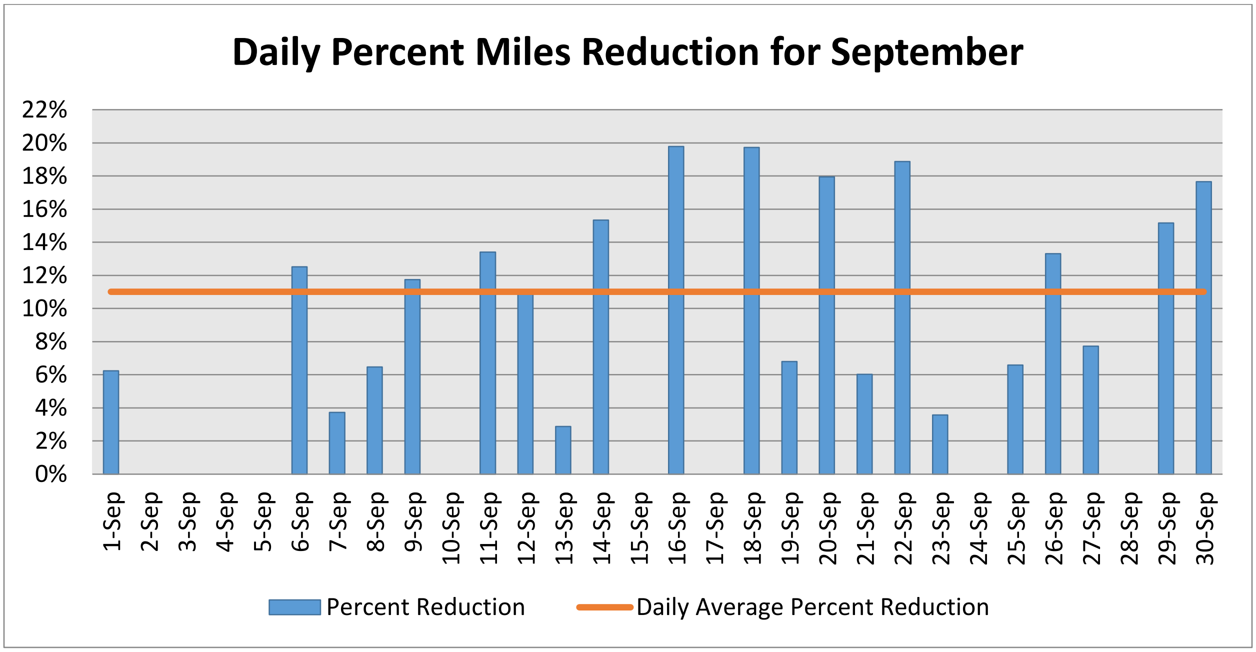


Figure 14. Daily percentage miles reduction for September

Figure 14 shows the daily percentage for miles reduced after running the FRATIS optimization algorithm for the month of September 2017. The minimum value is 3% (September 13^{th}), and the maximum 20% (September 16^{th} and 18^{th}). The monthly average miles reduction is 11%.

Daily percentage miles reduction for October

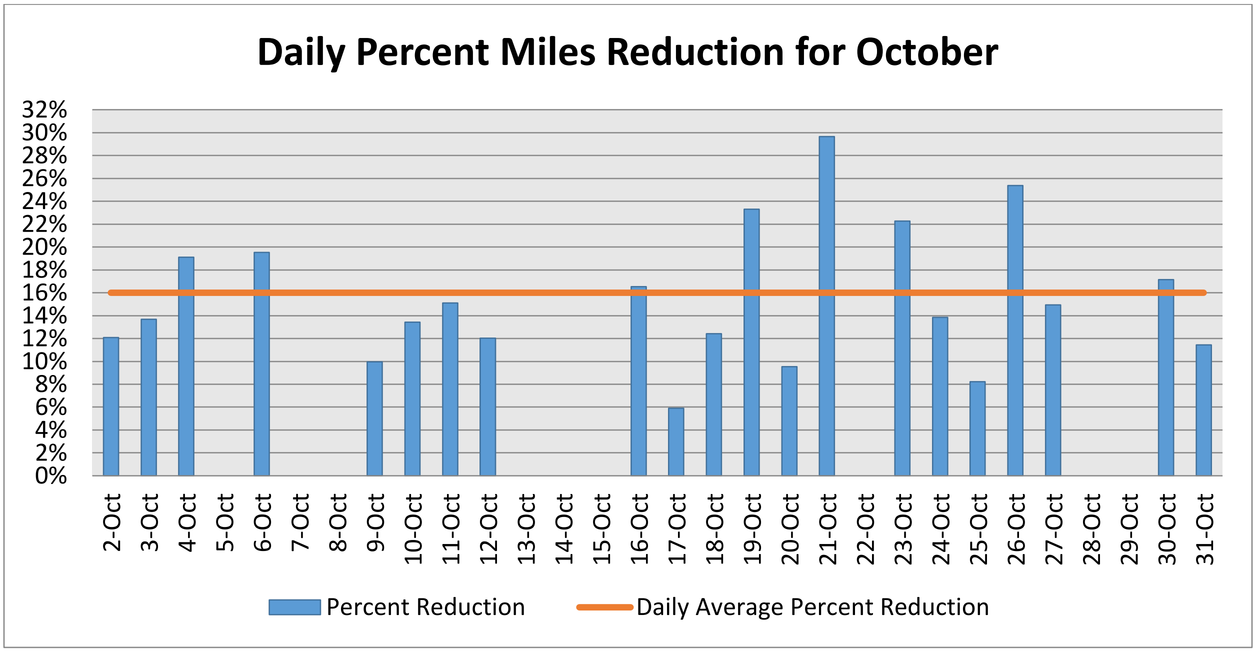


Figure 15. Daily percentage Miles reduction for October

Figure 15 shows the daily percentage for miles reduced after running the FRATIS optimization algorithm for the month of October 2017. The minimum value is 6% (October 17th), and the maximum 30% (October 21st). The monthly average miles reduction is 16%.

3 Lessons Learned

An important aspect of the project was identifying and documenting all the key lessons learned found throughout the multiple phases of its execution. Together with the quantitative data analysis performed in this project, these lessons learned are intended to represent important findings resulting from the deployment efforts of this technology in freight operations. In addition, these lessons learned provide guidance that benefit future projects.

3.1.1 Integrating with Trucking Order Management System provided more willingness to use the system and considerably reduced human errors during data entry.

In previous deployments of the CTIP application, participants suggested that integration with their order management system would be key to improving the adoption of the technology. This was a lesson learned stated in phase one of the FRATIS deployment in South California. Integration with the participating company's order management system was successfully accomplished and provided for a much easier interaction with the system to upload multiple orders to FRATIS, reducing this process to just a few minutes for an entire set of daily orders. This was near the same amount of time it previously took to enter a single order into the system. This functionality played a critical role in the increased use of the tool by participants in this phase and the reduction in human errors during data entry.

3.1.2 Different implementations of the same TMS existed among participants.

One of the challenges encountered during the integration of FRATIS with the Trucking Company's TMS was that although some of the participants were using the same system, its implementation was different for each company. This caused inconsistencies in the data format that affected the consumption of input data by the FRATIS tool. However, the team was able to achieve a successful integration with these systems by creating a middleware customized to read and translate the data configuration specific to each participant.

These differences in data format and system's implementation represent a challenge for integrating with solutions like FRATIS. In general, routing algorithms require certain degree of consistency in the data type and format. Hence, if each potential user has a custom implementation of a TMS, then additional tailored integrations will have to be completed to use these tools.

3.1.3 Having accurate order data is critical for performing successful route optimization.

One of the observations made during the deployment of the pilot was the lack of quality control in the order data for most users. An example of this was found most commonly in the order appointment time windows, with orders having the same appointment time for containers' pickup and drop-off locations; making it infeasible to meet the appointment for one of the locations. The FRATIS tool categorized those types of orders as invalid and the system did not allow including these orders into the optimization algorithm, causing disruptions in the process flow every time files with these types of orders were uploaded.

When implementing this kind of systems that are highly dependent on the quality and accuracy of the data it is important to account for cases where records may be invalid or infeasible to process. The way these types of issues were addressed in the project was by identifying all potential issues before and during the deployment of the tool and making data assumptions and data mapping each time one of these cases occurred. The downside of this approach is that it may cause alterations in the data between both systems.

3.1.4 Methods for assigning orders to drivers are too dynamic and change considerably per company, causing users to have different expectations of the tool.

Throughout the deployment phase of the project the differences in order assignment methodology between companies were evident. Each trucking company assigns jobs to their drivers based on multiple variables like:

- Number of imports available for pickup at terminals.
- Number of empty containers ready to be returned.
- Length of the trip, whether a move is a shorthaul or longhaul.
- Type of cargo, whether a move consist of dry or refrigerated cargo.
- Chassis ownership, whether the trucking company owns the chassis or it belongs to a pool.
- Driver's preferences.
- Customer requests and priorities.

All these different variables play a key role on companies' operations and represent challenges when developing a tool that will account for each user outcome expectation in a single routing algorithm. It may require custom implementations or configurations of the algorithm per user, which is difficult to accomplish within a pilot project. Although measures were taken to find a middle ground and develop the features that were common between participants, this issue represented a considerable challenge throughout the project.

3.1.5 New multimodal training approaches yielded significant benefits.

One of the lessons from previous deployments of the system was to provide dispatchers and drivers with more interactive training materials and increased "on-demand" support materials to address questions and concerns. During the training phase of the project several training session were scheduled and executed with each of the participants in the project. Before any on-site visit, agendas were sent and handed out to all participants and early access to the system was allowed, so users could get familiar with the interface and formulate questions to ask during training. Additional to on-site training at users' premises, the project team also performed live web video conferences with screen sharing every time critical issues were raised or a review on the use of the system was requested by users.

Furthermore, an on-line help and support page containing a series of frequently asked questions (FAQ) was developed and made accessible to all users. The project team also developed multiple videos showing how to perform all of the functionalities available on both the dispatcher dashboard and the driver's mobile application in a step by step fashion.

Providing these types of live training sessions and training materials had great impact on the perception of the tool by users.

3.1.6 Empty returns have too many unknowns in order to be optimized effectively.

One of the central objectives of using the route optimization in this project was to allow the participating trucking companies to plan for the efficient execution of their daily itineraries. Earlier stages of the FRATIS program determined that planning was key to obtaining operational improvements in these projects. However, in order to plan, it is necessary to have some certainty that is difficult to find in some operational scenarios of drayage business.

An issue in drayage that many companies face is determining where to return empty containers. This creates a series of costly problems like finding storage for empty containers and paying per diem charges if they are not returned on time.

Shipping lines and equipment owners determine the location where empties must be returned based on several factors, including: vessel departures, chassis availability, storage capacity, etc. However, although empties can often be returned to multiple locations, those locations could change multiple times a day depending on the size and type of the equipment.

Dispatchers find themselves struggling with the decision making process of selecting which Marine Terminal or depot an empty container should be returned to in order for their drivers to maximize productivity. Additionally, after dropping containers at a terminal whether loaded or empty, truckers are frequently asked not to leave the chassis at the terminal once containers are removed. However, no one will pay drivers to reposition those bare chassis to other designated drop-off facilities. Furthermore, some terminals prohibit drivers to enter the facilities with bare chassis and demand to show up bobtail when picking up containers. Failure to comply with these requirements may result in the inability to serve those drivers.

All these factors can create a dynamic environment that makes planning a challenge. During the deployment phase of this project it was realized that the main issue when executing the plan provided by the optimization algorithm was the uncertainty regarding the drop-off locations for empty containers. Although some of the companies updated drop-off locations last minute, later mid-day changes on these locations affected the plans generated by the tool.

3.1.7 Driver preferences play a big role when deploying a route optimization system.

As previously mentioned, the dynamic nature of the drayage environment makes solving drayage routing problems challenging. Human factor is one of the main variables contributing to the complexity of the environment. For example, over 80% of the drivers in the region are owner operators and serve as independent contractors. Therefore, dispatchers must consider drivers' preferences of specific routes when assigning orders to them. This adds another level of complexity to solving the routing problem as numerous other constraints such as appointment times, hours of service, and type of loads must be considered. To counter this problem, once the optimization is run, dispatchers often present drivers with alternative assignments to choose from.

3.1.8 Real-time dynamic planning requires real-time data updates.

Throughout the deployment phase of the project it was found that the constant change in daily operational conditions must not be underestimated when developing these kinds of technologies. Among the factors that are subject to uncertainty in drayage operations there is the stop time at pickup and drop-off locations, equipment availability at the intermodal facilities and marine terminals, waiting times and turn times at marine terminals, traffic conditions, road closures, to name a few.

This high level of uncertainty inherent in drayage operations requires a constant feed of real-time information in order to mitigate the constant change in conditions. Still, the concept of planning is of great benefit, not only because it creates a clear path to follow, but because it creates a sense of responsibility among the parties to commit to something that was methodically composed for everyone's benefit.

3.1.9 Nowadays drivers use too many mobile applications; adding an additional one is challenging.

One of the most significant factors observed throughout the project that had a significant impact on the use of the tool by drivers was the number of mobile applications they used. Drivers not only used the mobile application associated with their company’s TMS where they received the orders assigned by dispatchers, many of them also used a mobile application to track and report their hours of service. Additionally, especially in the Los Angeles/Long Beach port area, drivers access mobile applications from their phones to check on the waiting times at the different marine terminals. This helps them decide whether or not to accept orders going to a specific marine terminal, particularly for owner operators. Furthermore, some drivers use their own mobile phones to receive calls and text messages regarding orders.

Although companies who volunteered to participate in the project were made aware of the use of the driver mobile application, the team was met with resistance for the use of the FRATIS mobile application. Both managers and dispatchers had concerns over safety and productivity of drivers due to the use of an additional application, even though the app would lock when drivers were in motion and it required minimal manipulation for order status update.

4 Conclusion

The Los Angeles COfF prototype project evolved from previously deployed systems funded by the US department of Transportation such C-TIP and FRATIS. These systems were developed and deployed with the common purpose of improving freight operations subject to many constraints that different environments experience (e.g., congestion, insufficient communication among parties, etc.) and constitute the base for the COfF system.

The project included key enhancements to the previous systems including:

1. Integration with LMC's dispatching and order management systems.
2. Development of a Mobile Application.
3. Integration with Traffic Services for algorithm travel time calculations.
4. Integration between Mobile Application and Co-Pilot for truck vehicle's routing considering real-time traffic and road accidents.
5. Development of Dynamic planning feature for the optimization.
6. Development of an Online Marine Terminal Notification Portal and Open API.

Based on analysis with the enhanced application, evaluation against 101 days of operational data generated using legacy routing methodologies showed a consistent average 14% reduction in miles traveled from use of the application.

As a result of the project, key lessons-learned have been gained:

1. Integrating with Trucking Order Management System improved system usability and considerably reduced human errors during data entry.
2. Significant differences exist in the implementations of the same TMS by participants.
3. Order data issues and inaccuracies existed which required data cleansing efforts prior to use in optimization, and in some cases prevented use by the application.
4. Legacy processes for assigning orders to drivers tend to not be consistently applied and vary greatly from one company to another which is an impediment to consistent modeling in an automated system.
5. New multimodal training approaches yielded significant benefits. Content delivery methodologies including videos, FAQ repositories, and ongoing instructor-led training proved effective.
6. Driver preferences and use of existing mobile applications can pose a challenge to adoption of new similar technologies.
7. Certain types of orders such as empty returns contain numerous additional operating parameters that add new complexity to the planning process.
8. Real-time dynamic planning drives a need for real-time data updates to support of the planning and optimization process on an ongoing basis.

In summary, the current project represents solid progress forward from previous efforts. Potential operational benefits were demonstrated, and key lessons-learned were derived. Experience gained with multiple trucking companies will enable focused future efforts in this domain.

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