Freight Advanced Traveler Information System (FRATIS) – Dallas-Fort Worth (DFW) Prototype

Final Report

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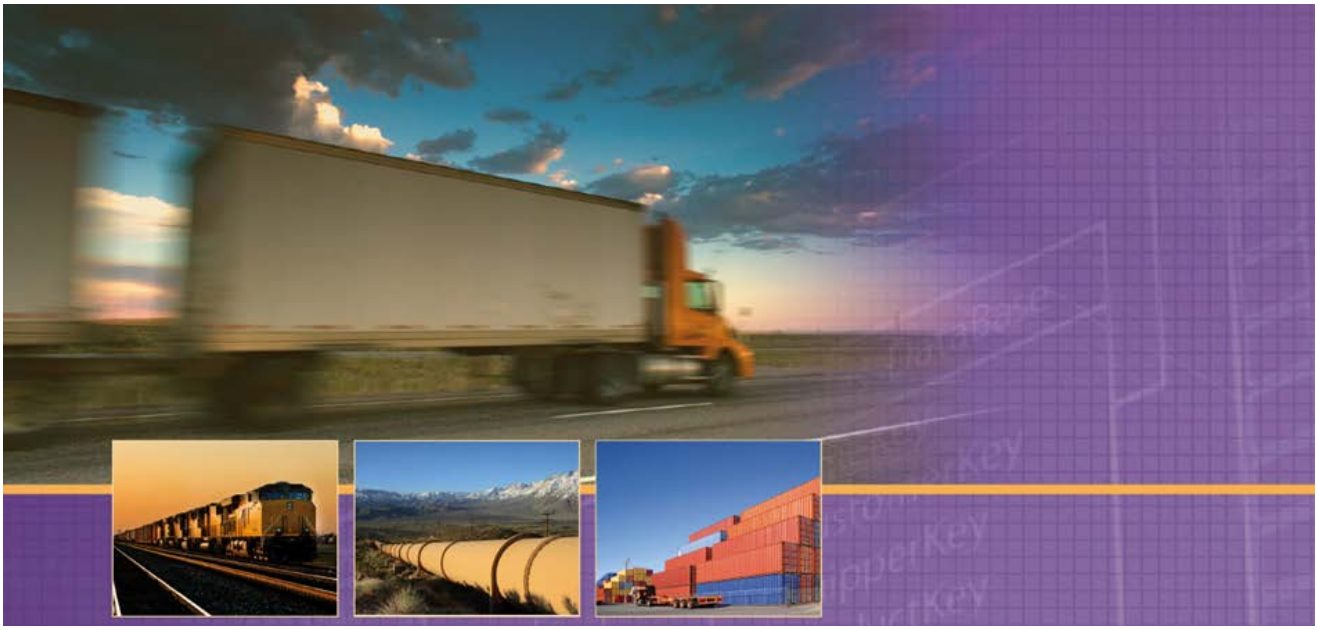

Leidos

U.S. Department of Transportation

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U.S. Department of Transportation
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16. Abstract

This is the Final Report for the FRATIS Dallas-Fort Worth DFW prototype system. The FRATIS prototype in DFW consisted of the following components: optimization algorithm, terminal wait time, route specific navigation/traffic/weather, and advanced notice to terminals. The high level architecture is described for each of the recommended component options. The Final Report summarizes the lessons learned from the prototype process, presents the analysis of the Dedicated Short Range Communication (DSRC) terminal queue time data, and discusses the opportunities for similar prototypes going forward.

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Acronym List

Acronym	Definition
4G/LTE	4th generation long-term evolution (4G/LTE)
AC	alternating power (AC)
AOP	Alternate optimization program (AOP)
ASD	after-market safety devices (ASDs)
API	Application program interface (API)
BNSF	Burlington Northern-Santa Fe (BNSF)
BSM	Basic Safety Message (BSM)
CFO	Chief Financial Officer (CFO)
C-TIP	Cross-Town Improvement Program
CSV	Comma separated value (CSV)
DFW	Dallas Forth Worth
DIT	Dallas Intermodal Terminal (DIT)
DLWC	drop load with chassis" (DLWC)
DMA	Dynamic Mobility Applications (DMA)
DMS	Data Management System (DMS)
DOS	disk operating system (DOS)
DOT	Department of transportation (DOT)
DSRC	Dedicated Short-Range Communication (DSRC)
ECL	empty container leg (ECL)
ED	export dray (ED),
FCL	full container leg (FCL)
FHWA	Federal Highway Administration (FHWA)
FTL	Full Truckload (FTL)
FTP	File transfer protocol (FTP)
FRATIS	Freight Advanced Traveler Information System (FRATIS)
FTP	file transfer protocols (FTPs)
GCCP	Gulf Consolidated Chassis Pool (GCCP)
Gmail	Google mail
GPS	Global positioning system (GPS)
GSM	Global System for Mobile Communications (GSM)
HOD	Hours of Duty (HOD)
HOS	Hours of Service (HOS)
HTML	HyperText Markup Language (HTML)
HTTP	HyperText transfer protocol (HTTP)
IMAP	Internet message access protocol (IMAP)
IMCG	Intermodal Cartage, (IMCG)
I/O	Input/Output

Acronym	Definition
IP	Internet Protocol (IP)
ITS	Intelligent Transportation System (ITS)
JPO	Joint Program Office (JPO)
JRE	Java Runtime Environment (JRE)
LL	live load (LL)
LTL	Less-than Truckload (LTL)
MAC	media access control (MAC)
NASCO	North American Strategy for Competitiveness
NCTCOG	North Central Texas Council of Governments (NCTCOG)
OSADP	Open Source Application Development Portal (OSADP)
PAI	Productivity Apex, Inc. (PAI)
PII	personal identifiable information (PII)
POC	Point of contact (POC)
RDE	Research Data Exchange (RDE)
RESTful	Representational State Transfer (RESTful)
RSU	roadside unit (RSU)
SMTP	Simple mail transfer protocol (SMTP)
SQL	Structured Query Language (SQL)
TCP	transmission control protocol (TCP)
TFHRC	Turner-Fairbank Highway Research Center (TFHRC)
UP	Union Pacific
USDOT	United States Department of Transportation (USDOT)

1 Introduction

This report summarizes the prototype deployment and results in the execution of the Freight Advanced Traveler Information System (FRATIS) Small-Scale Testing program in the Dallas-Fort Worth (DFW) region of Texas (FRATIS-DFW), which was funded by the United States Department of Transportation (USDOT) Intelligent Transportation System (ITS) Joint Program Office (JPO). This report was prepared by Leidos, aka 'the development team' (the prime contractor for the effort), with inputs from Tiffany Melvin of the North America Strategy for Competitiveness (NASCO), who was the stakeholder engagement lead.

This report will:

- Briefly summarize the prototype system
- Provide results of the analysis of key data related to the Dedicated Short Range Communication (DSRC) system components
- Provide the development team's lessons learned
- Provide the development team's perspective regarding potential next steps for future FRATIS and freight-related connected vehicle programs

Note that the quantitative findings regarding the performance of the FRATIS DFW test are being developed by an independent contractor and will be published by the USDOT separate from this document. In preparing and interpreting this document, readers should refer to three previous documents which provide the complete background and technical detail associated with the FRATIS DFW Prototype System goals and design:

1. Freight Advanced Traveler Information System Dallas-Fort Worth Demonstration Plan, June 2013, FHWA-JPO-14-178 (http://ntl.bts.gov/lib/54000/54400/54476/Fratis_FHWA-JPO-14-178.pdf).
2. Freight Advanced Traveler Information System Dallas-Fort Worth Software Architecture Design and Implementation Options, FHWA-JPO-14-177, http://ntl.bts.gov/lib/54000/54400/54475/Fratis_FHWA-JPO-14-177.pdf.
3. Freight Advanced Traveler Information System Dallas-Fort Worth As-Built System Architecture and Design (pending publication).

In addition, readers shoud reference both the USDOT's Open Source Application Development Portal (OSADP)[1] and Research Data Exchange (RDE)[2]. The OSADP contains the alpha version of the FRATIS DFW Optimization Program, Vesco. Certain pieces of data from the FRATIS DFW prototype will also be posted to the RDE at the conclusion of the task order.

The purpose of the FRATIS DFW prototype was to demonstrate a small-scale implementation of the USDOT's FRATIS bundle of applications; at the conceptual level, these included an intermodal drayage optimization application and a freight-specific travel planning and performance application. The DFW region was selected due to the size of the area (the fourth largest metropolitan area in the

[1] www.itsforge.net
[2] https://www.its-rde.net/home

United States) and the prevalence of dray traffic in the region due to the presence of multiple Class I rail terminals and the many container yards, distribution centers and warehouses that network with these entities. In addition, the Leidos team offered the opportunity to pilot the use of DSRC technology as a means to calculate queue time at a freight facility.

At the highest level, the performance goals for the overall FRATIS bundle of applications – regardless of demonstration location – included[3]:

Table 1. Summary of FRATIS Performance Measures

Performance Measure	Target
Number of bobtail trips	Reduce by 10%
Terminal queue time	Reduce by 20%
Travel time	Reduce by 15%
Fuel Consumption	Reduce by 5%
Level of criteria pollutants and greenhouse gas equivalents	Reduce criteria pollutants by 5% Reduce greenhouse gas equivalents by 5%

Source: USDOT

These goals are currently being assessed by the independent impact assessment team for each of the three FRATIS prototype demonstrations funded by the USDOT, DFW included. Additionally, once the DFW prototype site was awarded, the development team identified several goals in consultation with the local stakeholders and USDOT; these included:

- Reducing empty moves and bobtail miles
- Reducing the manual effort required for dispatchers to schedule orders
- Increasing fleet productivity due to improved efficiency – i.e., completing more orders with the same or fewer resources.
- Providing insight into queue times at local freight facilities
- Resolving sporadic, unpredictable queue times at gates
- Providing higher visibility for equipment information from steamship lines in terms of what types of containers were available for return to the participating container yard
- Giving advance notice to terminals regarding dray traffic destined for their facility
- Providing truck-specific routing tied to a driver's work orders and order origin, including destination and route
- Establishing a link between traffic, weather, and routing

The lessons learned and conclusions presented later in this document tie more directly to these targeted goals; these are presented in the test results and stakeholder summary sections of this report.

[3] USDOT *Freight Advanced Traveler Information System Assessment of Relevant Prior and Ongoing Research and Industry Practices, Final Report,* June 13, 2012.

The remainder of the document is organized as follows:

- Prototype Description (Section 2) provides a high-level overview of the elements of the FRATIS DFW prototype; this section is high-level as the more detailed 'As-Built' architecture and design document contains the detailed parameters for the overall prototype and each component of the prototype.
- Summary of Stakeholder Involvement (Section 3) provides a description of all users and stakeholders involved in the test; it also provides lessons learned from the perspective of the development team as noted in their specific experiences in DFW.
- Prototype Test Results and Benefits Achieved (Section 4) provides qualitative findings and lessons learned related to each component of the FRATIS DFW prototype. The analysis and findings for the DSRC queue time component is more quantitative in nature, as the development team sought to provide a comparison to the alternative Bluetooth/Wi Fi system.
- Conclusions and Recommendations (Section 5) summarizes the stakeholder and test lessons learned and provides the development team's recommendations regarding potential enhancements and expansion of the FRATIS concept and technologies.

2 Prototype Description

At the highest level, the FRATIS DFW prototype sought to improve the efficiency of operations within the two participating drayage companies, Associated Carriers and Southwest Freight International ('Associated' and 'Southwest'). Associated and Southwest were the primary private-sector freight participants, along with the Intermodal Cartage Group in Wilmer, Texas (IMCG-Wilmer), a container facility and drayage company.

The means to achieving these improvements for these participants tied directly to the individual components of the prototype system:

1. The drayage optimization component sought to reduce bobtails and minimize miles traveled while also reducing the workload of the dispatchers; ultimately, two alternatives were explored, as a different program was deployed to each of the two participating drayage companies:
    a. *Vesco* utilized the Productivity Apex, Incorporated (PAI) optimization algorithm with a Leidos-developed pre- and post-optimization process
    b. An *Alternate Optimization Program* (AOP) was built entirely by Leidos, and strictly sought to minimize bobtails
2. The terminal queue time component was intended to provide insight regarding the current and predicted wait time at IMCG-Wilmer. Two alternatives were explored:
    a. *Bluetooth/Wi Fi* was the primary technology deployed for both the baseline and prototype periods
    b. *DSRC and the Basic Safety Message* was a secondary solution explored for a limited pilot of one month as a proof-of-concept test
3. The advance notice to terminals provided insight to IMCG-Wilmer and the Burlington Northern – Santa Fe rail facility in Haslet, Texas regarding drayage traffic destined for their facility each day.
4. The routing, navigation, traffic and weather component was intended to provide real-time dynamic routing to each driver in conjunction with each work order, with traffic and weather provided as an overlay to this route.

In addition, the FRATIS DFW website (portal) provided separate, secure access to these applications to the three primary stakeholders. It allowed presentation and information sharing regarding certain data not originally included in the scope or vision, for example, the equipment availability at IMCG-Wilmer from the steamship lines.

The FRATIS DFW website included:

- Traffic and weather information (for dispatcher use)
- Display of the current and predicted wait time at IMCG-Wilmer
- Display of the IMCG-Wilmer yard status (which articulates what type of containers are being accepted at the yard that day)
- A link to the TomTom WebFleet user interface:

- Fifty TomTom Link 510 devices were deployed among the two drayage companies for evaluation purposes, and the drayage companies were given access to their WebFleet accounts for fleet monitoring purposes.

The final FRATIS DFW architecture diagram is presented in Figure 1.

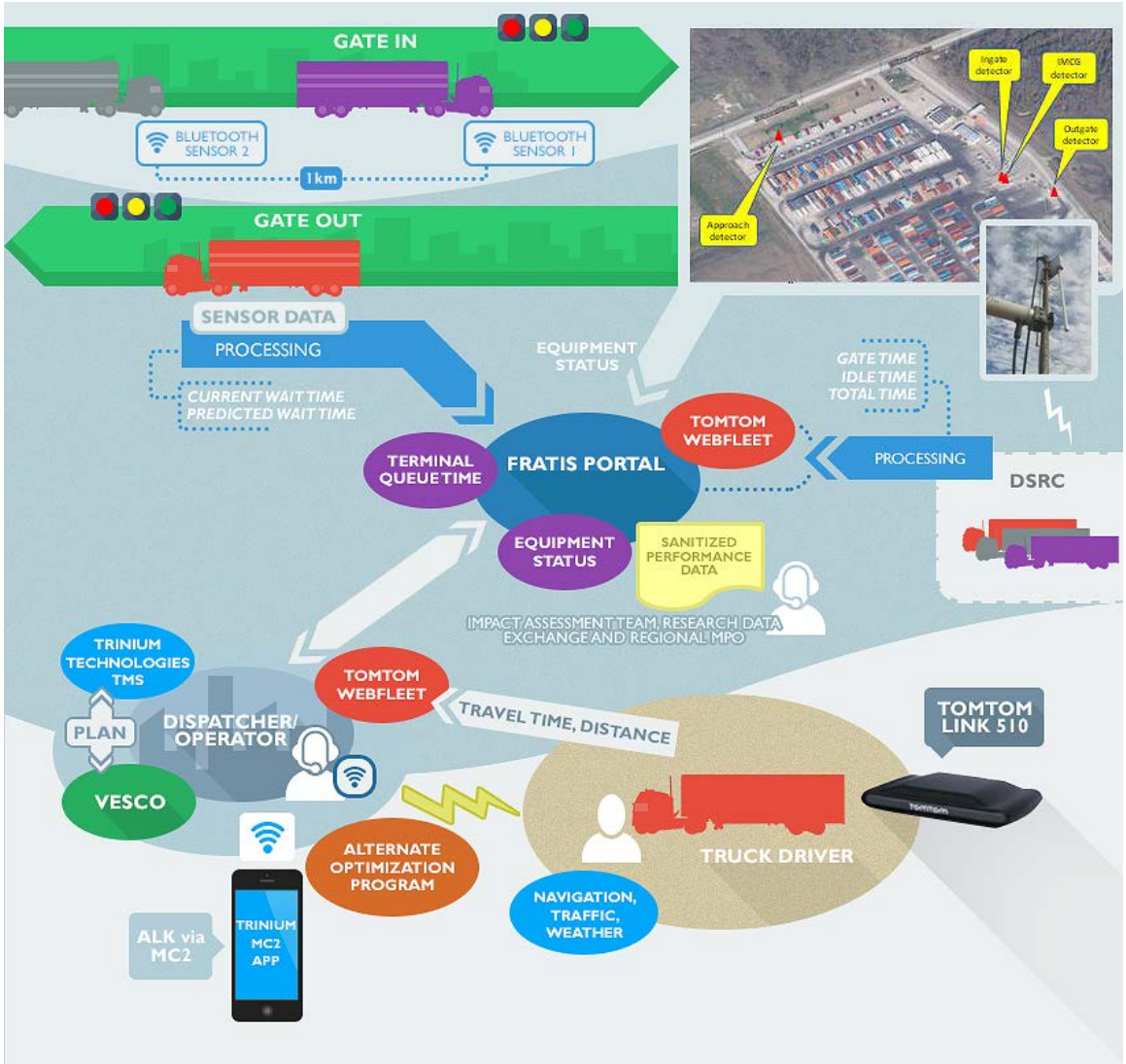

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Figure 1. Final FRATIS DFW Architecture

As mentioned with respect to the FRATIS DFW website, to collect data for the independent impact assessment, the development team also purchased and installed 50 in-vehicle TomTom Link 510 devices; 40 were installed in company and owner-operator vehicles at Associated while 10 were installed on company trucks belonging to Southwest. The Link 510 is a vehicle tracking device that uses external Global Positioning System (GPS) and Global System for Mobile Communications

(GSM) antennas. It delivers its driving and vehicle information directly to TomTom's WEBFLEET® back office application for viewing on a map, dashboard and in a comprehensive set of reports.[4] These devices and the WebFleet interface provided test data/metrics related to vehicle location and monitoring which was provided to both the drayage companies and to the impact assessment team. The Link 510 Tracking and communications specifications are as follows:

- Track fleet 10 seconds/1 minute (Global Positioning System, GPS)
- Trace fleet (GPS)
- Communication with Back Office (Global System for Mobile communications, GSM)
- Driving Behavior (input/output, I/O, cable)
- Driving and idling time (I/O cable)
- Ignition events (I/O cable)

Table 2 summarizes the FRATIS DFW prototype components. All components of the Vesco system have been packaged and released onto the USDOT OSADP and is available for download by registered users at www.itsforge.net.

Table 2. FRATIS DFW Components

Component	System	Developer/Owner	Notes
Software			
Pre-optimization processor	Vesco 1.0 Alpha	Leidos	Visual Studio 2012 platform C# development language Windows 64 bit operating system is required to compile the source code into libraries and executables.
Dynamic Link Library (.dll) from Productivity Apex, Inc. (PAI)	Vesco	PAI	
Post-optimization processor	Vesco	Leidos	
Optimization.jar	AOP	Leidos	Executable .jar file, opens with Java
Hardware			
Server	FRATIS Portal/Website	Leidos	Windows OS (4 GB RAM 150 GB HDD space) Glassfish Application Server version 3.1.1 MySQL DB version 5.5 Java version 1.6
Data Management System	DSRC Terminal Queue Time	Leidos	Same as FRATIS Server (above); development team utilized existing data management system in use through the Connected Vehicle Test Bed in Michigan.
After-market safety devices (5)	DSRC Terminal Queue Time	USDOT (Arada)	DSRC hardware was loaned to the development team through the USDOT for a temporary, 30-day period in January 2014.
Roadside unit	DSRC Terminal Queue Time		

[4] http://business.tomtom.com/en_gb/products/link/510/benefits/

Component	System	Developer/Owner	Notes
CrossCompass™ Readers (4)	Bluetooth/Wi-Fi Terminal Queue Time	Acyclica	
Acyclica CrossCompass™ Enclosures (3)	Bluetooth/Wi-Fi Terminal Queue Time		
Bi-Directional Antenna (4)	Bluetooth/Wi-Fi Terminal Queue Time		
Antenna Cable (4)	Bluetooth/Wi-Fi Terminal Queue Time		
TomTom Link 510	Impact Assessment	TomTom	Purchased through PAI (certified re-seller)

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Key schedule milestones in the overall FRATIS program and specifically within the DFW prototype are summarized below:

- Concept Development and Systems Engineering (Cambridge Systematics): October 2012 to December 2013
- FRATIS DFW task award: August 2012
- DFW Kickoff: September 2012
- DFW baseline data collection: July 2013, although certain pieces of hardware were installed and collecting data prior to this:
    - Installation of TomTom Link 510 devices was completed in April 2013
    - Daily files from the dispatch system used by both drayage companies contained all moves executed each day; this data collection feed was established in June 2013
    - The Bluetooth/Wi-Fi wait time equipment was installed in January 2013 and collecting data as of May 2013
- Baseline data collection continued through mid-2014 :
    - There were installation errors with the 40 Link 510 devices at Associated.
    - The development team conducted a troubleshooting process on these issues with Associated and PAI (as the re-seller) from July to December. In December 2013, several of the 40 devices were uninstalled and re-installed, resolving the issues.
- Development began in May 2013 and certain components remained in a rolling deployment status through June 2014:
    - The Bluetooth/Wi-Fi component required no modification after installation for baseline period. It was 'turned on' to users in February 2014
    - Advance notice to terminals was deployed in February 2014
    - The 30-day DSRC pilot was conducted in January 2014
    - Vesco was first rolled out to the drayage companies in the fall of 2013, but limited testing revealed necessary changes to the input files from the dispatch system. This required changes on the part of the dispatch system software provider (Trinium technologies) that could not be made until January 2014
- The official start of the prototype was marked by a 'ribbon cutting' event on December 19, 2013
- Prototype modifications:
    - The second deployment of Vesco was complete in March 2014 and tested by both drayage companies. Requested modifications were identified in April 2014. These enhancements were made and deployed to both drayage companies in early June 2014

  - In August 2014, Southwest articulated their dissatisfaction with Vesco, leading to development of the AOP. The AOP was deployed in October 2014. Enhancements suggested by Southwest were added to the AOP in late October 2014
  - Also in August 2014, Associated provided feedback that their dispatch staff would not have time to manually run the program. At this time, the development team added functionality enabling the automatic generation of a daily plan each evening and a re-optimized plan the following morning. This enhancement was deployed to Associated in November 2014
- Prototype data collection:
  - The Bluetooth/Wi-Fi component began in February 2014 and concluded in October 2014, although 3 of the 4 readers remain online as of April 2015
  - The final version of Vesco began in November 2014, will conclude in May 2015
  - The AOP began in October 2014, concluded in April 2015
  - The advance notice to terminals component began in February 2014 and continued until in April 2015
- Testing concluded in May 2015

3 Summary of Stakeholder Involvement

The key participants in the FRATIS DFW prototype demonstration test are summarized below. The Federal Highway Administration (FHWA) technical manager, Mr. Randy Butler (former USDOT FRATIS Technical Manager) and Mr. Carl Andersen (current USDOT FRATIS Technical Manager) were involved as key federal-level stakeholders throughout the effort.

3.1 PRIMARY TEST PARTICIPANTS

3.1.1 Associated Carriers

Associated is based in Arlington, Texas, and their diverse operations include local cartage, two intermodal divisions, a regional and long haul dry van division, a freight brokerage division, and a warehousing division. Their Arlington facility is located between Union Pacific (UP) Dallas Intermodal Terminal (DIT) and Burlington Northern Santa Fe (BNSF) Haslet facility near Fort Worth. Figure 2 below presents a TomTom WebFleet map highlighting the location of Associated and the two key rail terminals. The green icons represent customer locations whose names are not presented within this document.

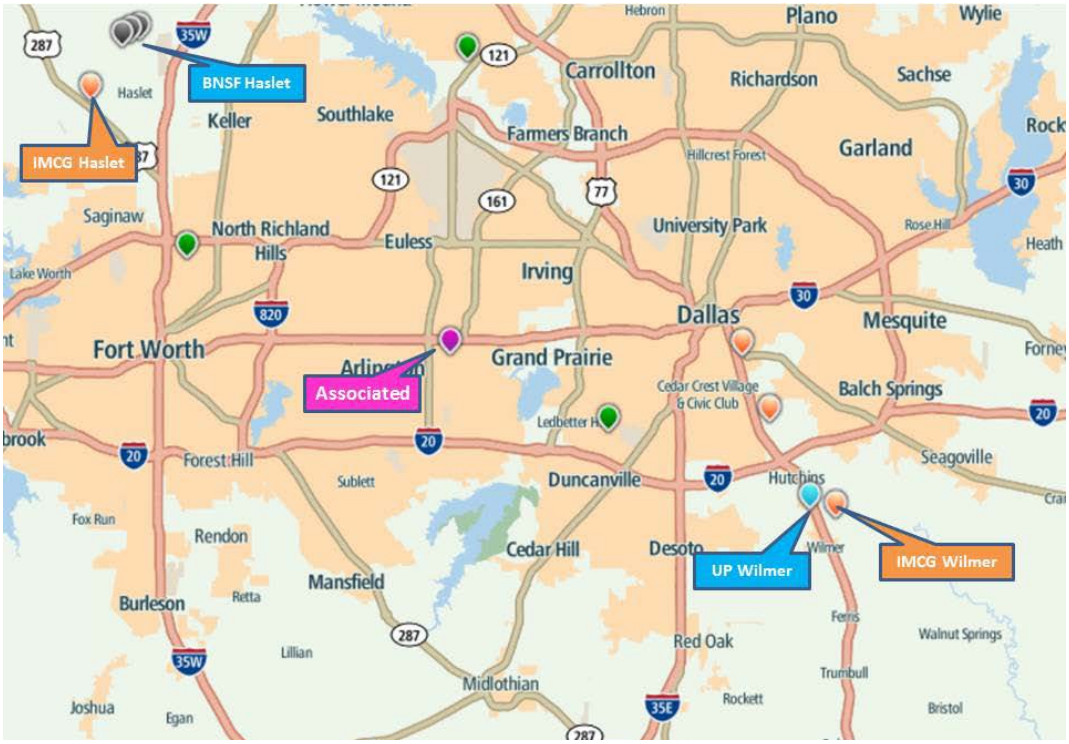

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Figure 2. Map of DFW Region

Associated's Arlington facility offers transload services for intermodal transloads in the Dallas Fort Worth area. Associated's fleet includes over 60 vehicles, approximately 35% are company drivers and the remainder are owner-operators.

Associated agreed to deploy both hardware and software for the FRATIS DFW prototype; 40 of their Arlington-based trucks were equipped with the TomTom Link 510 devices. In addition, they were key users of Vesco, providing in depth analysis and feedback throughout the rolling deployment of the program. They also agreed to provide data to the Advance Notice to Terminals component, which gave IMCG-Wilmer insight into Associated's trucks planning to call their facility each day. Associated's staff gave critical review and feedback regarding the optimized plans generated by Vesco throughout the rolling deployment, demonstrating their commitment to the prototype process. Their involvement and feedback helped the development team identify necessary changes to the Trinium dynamic queries that were providing inputs to the program. The team's primary point of contact was Lon Lloyd, Chief Financial Officer responsible for the overall management of their DFW facility. Jeromy Zeffer was the primary dispatcher and the key user of the optimized plans. In addition, Mark Pettway, Director of Safety and Recruiting, provided key support to the installation and troubleshooting for the TomTom Link 510 devices.

3.1.2 Southwest Freight International

Southwest provides ocean container drayage services from all rail terminals in the Dallas-Fort Worth metroplex with pick-up and delivery throughout the south, including Texas, Oklahoma, Arkansas and Louisiana. Their operations include local and interstate intermodal drayage, local and regional less than truckload (LTL) and full truckload (FTL) delivery, and dedicated driver/tractor contract work at customer distribution centers and a number of national accounts. Southwest employs 120 drivers, with a mix of owner-operator and company-employed staff. Southwest's fleet includes over 100 trucks, dry vans (48' and 53'), bobtail w/liftgates and tri-axle chassis for overweight 20' containers.

Approximately half of these vehicles, 50 trucks, operate locally. Their Dallas facility, located in South Dallas near the Union Pacific DIT, operates as a bonded U.S. Customs Centralized Exam Station. Figure 3 shows the location of Southwest relative to other points of interest in the DFW region.

Southwest agreed to deploy both equipment and software as part of the FRATIS DFW prototype. They agreed to deploy 10 of the TomTom Link 510 devices. In addition, they were also instrumental in providing the feedback necessary to identify the correct settings for the Trinium dynamic queries that were providing the input files for Vesco. Likewise, their honesty and critical review of the optimization plans created by Vesco led the deployment team to the pursuit of the AOP which was suited specifically to Southwest's operational goals. Mr. Robert Hooks, Vice President and General Manager, was the key point of contact to support the FRATIS prototype testing.

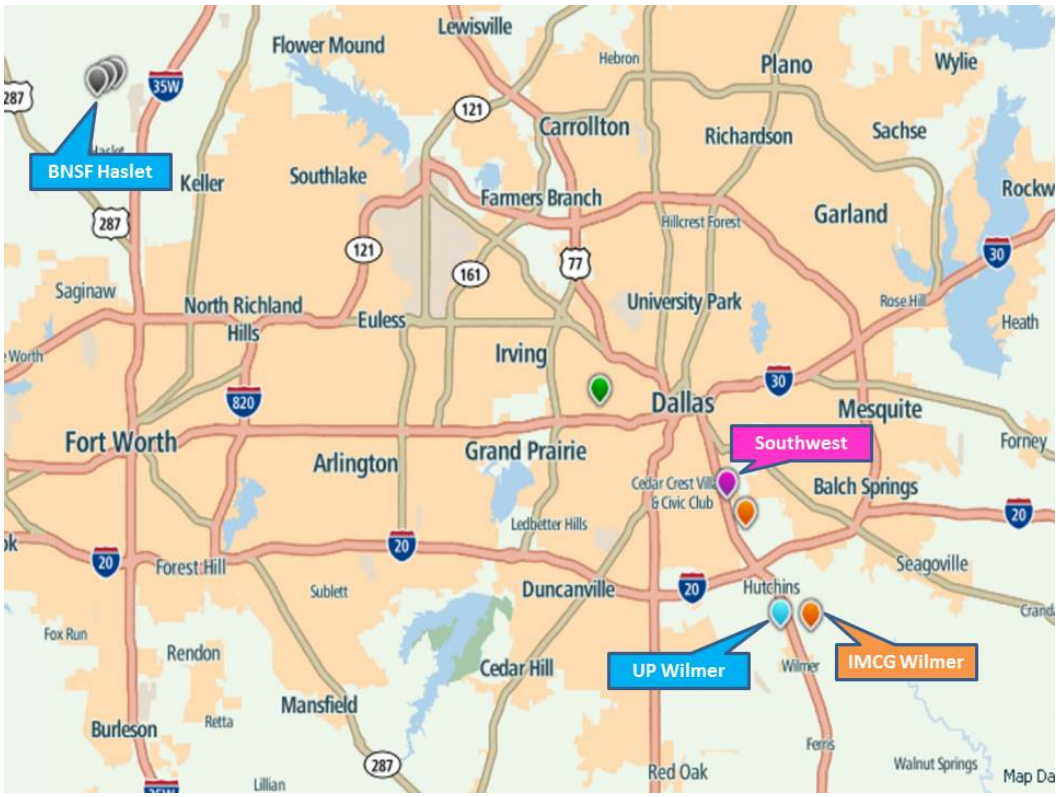

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Figure 3. Southwest Location

3.1.3 Intermodal Cartage Group, Wilmer, Texas Facility

Although the Intermodal Cartage Group (IMCG) is headquartered in Memphis, their Dallas, TX facility in Wilmer was identified by the FRATIS DFW prototype participating drayage companies as a potential area of opportunity for the terminal queue time component. Their facility in Dallas, located in Wilmer, TX was opened in 2010 and provides both container and chassis services as well as drayage services, including a fleet of approximately 150 drivers, including company drivers. Their Wilmer facility is located less than 2 miles from UP's DIT facility; the yard in Wilmer is a 100-acre facility, 68 of which are paved and lighted. There are six interchange lanes, and their storage capability allows them to stack containers 5 high. There are also 1,268 slots for mounted (chassied) containers, and 20 plug-ins for refrigerated (reefer units) containers. Their yard includes a chassis and grounded storage area. IMCG-Wilmer is the current container depot provider in DFW for various steamship lines, including the Gulf Consolidated Chassis Pool (GCCP) and the Chassis Link chassis pool. In evaluating the baseline data, the development team noted that both of the participating drayage companies had several loads each day destined for IMCG's facility.

The development team's key point of contact was Kim Wilson, formerly the terminal manager for the IMCG-Wilmer facility. Harrison Hoof, Vice President, also provided key approvals needed for the project. The IMCG staff was open to ideas for gathering terminal queue time, receptive to the installation of the Bluetooth/Wi-Fi terminal queue time system hardware and attentive when troubleshooting the units due to power outages and other environmental factors. In addition, Kim Wilson was especially open minded to the DSRC pilot test and worked to get the necessary approvals to test that concept at IMCG's facility and with 5 of their company drayage trucks.

3.2 DEVELOPMENT TEAM AND SUBCONTRACTORS

The development team included key subcontractors who provided the networking, contacts, and subject matter expertise:

- North American Strategy for Competitiveness (NASCO) provided networking and stakeholder coordination with all local DFW stakeholders (www.nasconetwork.com)
- The University of Memphis provided drayage operations subject matter expertise (www.memphis.edu/ifti/)
- PAI provided customization to the optimization algorithm within Vesco (www.productivityapex.com)

The FRATIS DFW Prototype also relied on several external vendors to provide multiple components, as outlined below:

- TomTom Link 510 devices and WebFleet subscription (www.tomtom.com for business information, and https://business.tomtom.com/en_us/products/login/ for WebFleet access)
    - PAI
- Bluetooth/Wi-Fi wait time hardware and software:
    - Acyclica (www.acyclica.com)
- Dedicated short-range communication (DSRC) equipment:
    - Loaned from the USDOT connected vehicle test bed
    - Radios and antennas: Arada Systems (Arada), www.aradasystems.com
- Dispatching software (inputs to optimization program and files with executed moves for baseline and prototype data collection):
    - Trinium Technologies (www.triniumtech.com)
- Real-time work order, routing, scheduling, traffic, and weather:
    - Trinium Technologies

3.3 OTHER INTERESTED PARTIES

Burlington Northern Santa Fe (BNSF) in Haslet, Texas was one of two recipients of the Advance Notice to Terminal Information, along with IMCG-Wilmer. The BNSF, although not a primary stakeholder, remained engaged throughout the baseline and prototype allowing the development team to contact them throughout the baseline and prototype periods, conduct site visits and in-person meetings. They also attended the prototype ribbon cutting in December 2013 and were open to meeting with the impact assessment team in March 2015, demonstrating their initial and continued support for the effort.

North Central Texas Council of Governments (NCTCOG) remained an interested party throughout the pilot. The NCTCOG has an active freight transportation component. The DFW region represents one of the largest inland ports in the nation, where freight is moved, transferred, and distributed to destinations across the State and around the world. In addition, North Central Texas has one of the most extensive surface and air transportation networks in the world, providing extensive trade

opportunities for the hundreds of motor/trucking carriers and freight forwarders operating in the DFW area.[5] Specific goals of the NCTCOG include:

- Improve the efficiency of freight movements;
- Establish processes for freight community input;
- Promote safety and mobility issues;
- Continue MPO involvement with freight industry groups;
- Monitor freight traffic throughout the region;
- Improve and ensure the safety of freight movements and hazardous materials truck routes;
- Reduce air quality impacts of freight movements;
- Evaluate accessibility of freight facilities; and
- Review intermodal and freight factors in project selection for rail and other investment studies.[6]

During the baseline stage, they provided input to the development team regarding data that would be useful for their freight planning. The development team remained engaged with the NCTCOG throughout the prototype, providing regular updates. Ultimately, the goals for the NCTCOG are longer-term in nature than the goals for the FRATIS DFW prototype. From a planning perspective, they were interested in observing the local routes traveled by participating drays, truck counts, and other truck-related travel data. The NCTCOG viewed the FRATIS DFW and similar pilots as a source of freight-specific data for their short-term plan (2-3 years out). Kevin Feldt was the primary point of contact that the development team worked with during the prototype.

3.4 SUMMARY OF STAKEHOLDER INVOLVEMENT LESSONS LEARNED

Perhaps one of the most useful aspects of small-scale prototypes is the documentation of lessons learned with respect to the project's successes, challenges and potential future opportunities. Some of these items relate specifically to the engagement and involvement of the stakeholders, while others relate specifically to development or test activities. This section is intended to summarize the challenges, solutions and lessons learned related to the stakeholder engagement activities during the FRATIS DFW prototype.

1. **Early identification of potential stakeholders is necessary for alignment of expectations and schedule mitigation once the prototype process starts.**

A big challenge in the FRATIS DFW prototype was the expectation that the prototype system could be designed and implemented within 6-9 months of award. The original period of performance for the project was 18 months, with 6 months of baseline and prototype data required by the contract. However, when dealing with new stakeholders as the team was in DFW, it is necessary to gather significant background to understand the stakeholders' operations, challenges, and opportunities. This is crucial to outlining the scope of their participation and clarifying what the stakeholders are willing to 'sign up' for. In addition, time is needed to meet and discuss the prototype design with the stakeholders' support entities/staff. In the case of the FRATIS DFW prototype, both drayage

[5] http://www.nctcog.org/trans/goods/
[6] http://www.nctcog.org/trans/goods/

companies utilized off-the-shelf dispatching software that the optimization component needed to interface to. The involvement of and coordination with Trinium was exceptionally valuable to the FRATIS DFW prototype, but it was at the expense of our schedule. While Trinium was a willing participant in the development process, the scheduling of their involvement was based on their internal development calendar, causing delays when work was needed by them to assist in the creation of the queries that generated the input files for the optimization program.

Another example of this was the ultimate routing, navigation, traffic and weather component that was utilized for the prototype. The development team was pursuing the use of an off-the-shelf application, but sought to integrate this application with the driver's work order created by the Trinium software. Once this was discussed with Trinium, it was noted that Trinium was readying the deployment of a routing solution tied to their existing web-based work order application, MC2. While this application did not fully meet all of the FRATIS DFW requirements, it was pursued to maintain the constructive working relationship with Trinium and to minimize the systems a driver has to use in the cab.

2. **First and second tier stakeholders are equally important in the design of prototype systems.**

The FRATIS DFW prototype that was ultimately deployed was slightly different from what was planned. This was due to the engagement of both first and second tier stakeholders. For example, the participating drayage companies both articulated the opportunity for a terminal queue time solution at one of the container yards in the DFW region. Ultimately, this led IMCG-Wilmer to sign on. This was the main goal in bringing IMCG-Wilmer on as a partner, but due to their high-level of engagement, their willingness to talk through their entire operation, the development team was able to identify additional areas of opportunity at IMCG-Wilmer and between IMCG and other participating stakeholders including:

- Identification of the equipment availability information received by IMCG-Wilmer from the steamship line; this information was added to the FRATIS DFW portal. This piece was not originally planned in the prototype design.
    - In addition, although IMCG's facility in Haslet did not have the Bluetooth/Wi-Fi wait time solution installed, they also provided this information for their Haslet facility for presentation on the FRATIS DFW website.
- IMCG authorized the installation and testing of the DSRC equipment necessary to pilot test the use of this technology for calculating terminal queue time. A RSU was installed at their facility, and they also authorized radios and antennas to be installed within 5 of their company drayage trucks. This eliminated the need for the development team to find a new stakeholder willing to test this technology.

3. **Conversely, the involvement of these second tier stakeholders can provide unexpected benefits to the prototype participants.**

The heavy involvement of Trinium provided benefits to the participating drayage companies that the development team did not anticipate. Perhaps the best example of this was at the start of the prototype. Associated Carriers was shopping for a dispatch software when the development team held their kickoff meeting and among the providers they were selecting from was Trinium. The use of Trinium by Southwest, the potential for integration between Trinium and the optimization program that was under development, and the availability of Trinium's work order application, MC2, led to the

decision to purchase Trinium. The installation was expedited to allow for the software to be up and running in time to begin the baseline data collection.

In addition, Associated and Southwest were able to receive the enhanced MC2 application much sooner than they would have otherwise due to their participation in the FRATIS DFW prototype and the need for this type of solution. Similarly, Southwest had been planning to move to a hosted version of the Trinium software prior to starting the DFW prototype. Once development activities began, the utility of using a hosted version of Trinium – which enabled Trinium to work dynamically with the development team and Southwest to create the queries needed to capture baseline, prototype and input data for the optimization program – was identified and Trinium was able to transition Southwest to their hosted service much sooner than they had planned.

Unfortunately, due to development delays and budget constraints, in addition to the drays hesitance, the development team did not completely integrate either Vesco or the AOP with the Trinium dispatch software. However, if this had been accomplished as planned, Trinium may have realized additional benefit; namely, because the optimization code developed for the FRATIS prototype is open source, it could be included as an add-on to their software. This capability could potentially make their softare more marketable to their user community. The option to complete this work going forward remains open.

4. **Prototypes should be willing to change course: the operating conditions within the stakeholder organization and user feedback should be a priority in design.**

A common factor when dealing with freight technology is the implemention of these solutions in the real-world environment. This may impact the time the participants have to participate in the development process, their usage of the prototype system once complete, and even the volumes of freight considered by the prototype system. The trucking/drayage industry is fast-paced and can experience frequent staff turnover, with dispatchers sometimes changing or leaving roles every few months. The FRATIS DFW prototype dealt with that early in the development process, when Associated had an intended dispatcher and potential user of the prototype, depart. Although this occurred when the development team was customizing the Vesco program to their operation, Lon Lloyd, Associated's CFO, stepped in immediately to answer questions regarding baseline data and order types within their Trinium system. For Southwest, Robert Hooks elected to be the primary user and interface for the development team, eliminating direct contact between the development team and his dispatchers. While this avoided any operational disruption with respect to the prototype, it provided a singular perspective for feedback regarding the prototype, which is not the ideal situation.

The biggest operational change allowed the development team to create a useful enhancement to the prototype design. In October 2014, Associated consolidated their Houston operations in the DFW office without a corresponding increase in operations staff. This significantly impacted the time that all staff involved, including Lon Lloyd, had to participate in the prototype. Associated continued to work with the development team to identify a means to continue their participation, which resulted in the development team enhancing Vesco to allow it to run automatically each evening and the following morning. Vesco automatically generates an optimized plan when files are received in an email inbox and then emailed them to a targeted list of recipients. Associated was incredibly happy with this feature, as it allowed them to continue using and referring to the plans when making their dispatches, yet freed up their staff from having to run the program themselves. The development team believes that this will be an incredibly marketable feature of the program, but it did negatively impact the prototype schedule since it took approximately 4 weeks to code and test this enhancement.

The conclusion to be made in the FRATIS DFW was that the development team felt compelled to satisfy the user needs as identified in the FRATIS Concept of Operations despite the fact that once the participants' needs were known, documented and understood, they didn't align completely with the higher level programmatic needs. For these types of small-scale demonstrations, the USDOT should maintain a high level of flexibility when it comes to the approach and design of the prototype, as the ultimate goal should be to maintain high usage among participants, thus increasing the potential for continued use and future adoption of these technologies. In addition, due to the required direction of the prototype to focus on the drayage optimization algorithm, in the end the development team felt that they worked too long to make this solution a success for Southwest. From the time the Vesco program was put into use at Southwest, although they continually reviewed the plans, they regularly expressed dissatisfaction with the results. The development team worked with Southwest and PAI to customize this program for Southwest from March 2014 to August 2014, and ultimately implemented a completely different optimization program for them. However, because this decision was made well into the prototype period, there was not sufficient time or resources remaining to add enhanced functionality to the AOP; potentially meeting even more of Southwest's needs.

5. **Finding the right stakeholders: although incentives help they do not completely guarantee buy-in. They have to be open to innovation and trusting of technology.**

All prototypes face this challenge, but this is the trade-off for involving real-world stakeholders, who execute and are involved in freight operations each day, 24 hours a day, and 7 days a week. As described in the preceding lessons, this can cause unanticipated delays and conflicts while also impacting the overall prototype design as the development team strives to accommodate the end users' operating constraints and internal goals. That said, the USDOT sought to structure the FRATIS prototype such that private industry would be enticed to sign on and provide continued, sustained involvement by mandating in the statement of work that any hardware purchased for the prototype could remain with the stakeholders who deployed it. In the case of the FRATIS DFW prototype, this included the TomTom Link 510 devices and the Acyclica Bluetooth/Wi-Fi readers.

The participating drays were given access to their TomTom WebFleet accounts upon start of the prototype in February 2014. Associated, having deployed Link 510 devices on 40 of their trucks, found the information and reporting in WebFleet to be especially helpful and accurate and provided a means for giving dispatchers accountability of their drivers, and in some cases, defending them. Associated's management and dispatchers reported they were logged on to WebFleet daily. Providing them access to these devices and back office user interface definitely contributed to their continued high level of engagement and provided a positive tradeoff when they occasionally became frustrated by the Agile development process by which Vesco was deployed. In addition, Associated remained open minded to the fleet-optimization objective function used by the optimization algorithm within Vesco, which basically says that the daily plan seeks to minimize miles traveled for the fleet, not for each individual driver. This objective shifts from the standard drayage operations, which typically try to optimize the routes for individual drivers' as opposed to the routes of the entire fleet. It was difficult for the drayage companies to transition to this objective; eventually, Associated saw that the optimized plans produced by Vesco achieved this objective and did improve the efficiency of their overall fleet, even though occaisionally individual drivers may have to carry an empty load or bobtail.

By contrast, Southwest was skeptical from the start regarding the ability of a program to create an optimized daily plan. Although Vesco minimized miles traveled fleet-wide, Southwest was unhappy with the number of bobtails within each drivers' daily plan; their primary goal was to reduce bobtails, not fleet miles traveled. The purchase and deployment of the TomTom devices did not provide

significant incentive for them to continue using Vesco once they began having issues with the daily plans it was creating. The Southwest POC admitted that he did not log into WebFleet regularly although he did note that the few times he did log in, he found the information on equipped vehicles to be helpful. If the budget had not been a factor, deploying additional Link 510 devices may have been useful since Southwest reported that WebFleet may have provided more utility had more vehicles been equipped with devices.

6. **Given the large number of owner-operators in the current drayage community, technology involving driver use and acceptance has to show benefit to the driver themselves as opposed to fleet managers.**

The core FRATIS applications, regardless of deployment location, require driver buy-in to fully achieve potential benefits – these applications being the drayage optimization application and the dynamic routing and navigation application. The drayage optimization application requires the driver to accept a change in his assigned work, while the dynamic routing component requires the driver to trust the recommendations regarding congestion and routing regarding his upcoming destinations. The drayage community includes many experienced drivers, and these are the most difficult individuals from which to obtain buy-in. Both of the DFW participating drayage companies recommended that when technology requires driver interaction and acceptance, it must demonstrate an improvement to the drivers' bottom line, especially when owner-operators are the majority of the staff for many companies. Therefore, prototype and pilot tests such as FRATIS must demonstrate a reduction in empty miles and a reduction in costs to the drivers themselves. It will be important for the quantitative benefits identified by the FRATIS impact assessment to be packaged for presentation to the driver community going forward. This type of packaged, marketing-type material could be provided to targeted drivers before beginning a prototype so that the negative perception regarding technology could be overcome before even starting a pilot or prototype. In addition, given the driver shortage many companies are facing, companies are limited in what can be required of drivers. As Southwest indicated to the development team, due to the lack of drivers, management may have to be more accepting of individual driver's quirks and operating habits.

Lastly, drivers have many negative perceptions regarding the technology that FRATIS explored:

- Link 510 devices carry the perception that the driver is being 'watched' and monitored and may suffer negative repercussions for his driving behavior.
- Dray drivers may have preferences regarding work hours and accounts they handle; when an optimization program recommends different assignments, this can cause the entire plan to be disregarded by the driver.

The benefits of these tools have to be carefully stated so as to counteract these negative perceptions. Both drays noted that company drivers are more accepting and open to the potential for technology, and the DFW team was fortunate that both of our participating drays did have a small percentage of company drivers who participated in our pilot. For freight-related technology applications to be a success, all levels of operation within the freight organization, from management to dispatcher to driver, have to be on-board and committed to the technology and the benefits it can provide.

7. **Small scale demonstrations, by definition, may not demonstrate enough benefit to maintain necessary stakeholder involvement.**

Given the scope of freight transportation in the DFW region, including just two small drayage companies, for a total of 50 trucks, does not register a significant impact within the region. The nature of freight transportation in the DFW region – with multiple freight terminals being called by drayage companies in the region – may make it difficult to register much quantitative benefit within the drayage community. Given the large number of destinations the drayage companies must serve, the optimization programs face a challenge in significantly reducing the number of bobtails, when it is necessary for some bobtailing to occur if there is no load at the destination of the prior order.

Likewise, expanding the scope of the terminal queue time pilot may have increased the impact of that system. Additional drayage companies could have been identified as recipients of the queue time information via the FRATIS DFW portal. Similarly, both of the participating drays identified additional facilities where wait time was a problem; although these facilities were approached and subsequently declined to participate, if the Bluetooth/Wi-Fi wait time technology had been deployed and the information been added to the FRATIS DFW portal, this would create a more robust picture of queue times at relevant facilities.

While the previous lesson focused obtaining commitments within all levels of each participating freight organization, the conclusion being drawn here relates to including multiple types of stakeholders, and multiple stakeholders of each type. This would help to realize expanded types of benefits the prototype may realize.

8. Pilot and prototype tests should include flexibility within the planning process.

The statement of work of the FRATIS prototype and small-scale demonstration included many fixed requirements related to the applications to be considered and specific technologies to be included. The execution of a prototype, however, is constantly impacted by the input of the stakeholders, their operating environment and the participation of vendors and developers. Therefore, these tests must include flexibility to allow deviation from what is contractually-mandated in the statement of work. In the case of DFW, the development team was authorized to pursue the AOP with Southwest once they articulated that they would not continue their use of Vesco. However, the development team should have presented this alternative to USDOT for approval earlier in the prototype period, given that Southwest was consistently vocal about their dissatisfaction with Vesco. Prototypes can be planned and proposed but the operational changes and stakeholder needs that are gathered once the process begins can be impossible to predict yet important to include. Accounting for them in the design of the system may provide the greatest opportunity for high and consistent use of the system and maximize the benefits realized by participants.

4 Prototype Test Summary

4.1 TESTING SUMMARY

Each of the FRATIS prototypes followed the *Agile Development Methodology* which is characterized by continuous integration of the system and test-driven development. Especially important in this process is the frequent involvement of the key participants, in this case Associated, Southwest and IMCG, as well as the points of contact for systems that the prototype interfaced to, most notably, Trinium Technologies. Prior project documentation mentioned in the Introduction captures additional details of this process. As documented in the FRATIS DFW Demonstration plan, Table 3 summarizes the test hypotheses:

Table 3. Test Hypotheses

System	Components	Hypothesis
Freight terminal wait time	• Wi-Fi readers to detect devices passing strategic locations • Data analysis • Web site to display current and predicted wait times to dispatchers and other authorized users • Web service API to exchange wait time with optimization component	Dispatchers will use the information to avoid sending drivers to the terminal when there is a long wait time and they do not have an immediate time commitment at the terminal. Since carriers will be spreading their arrivals over a longer period the typical wait time will be reduced.
Carrier optimization	• Optimization algorithm • Order entry • Administrative tables • File transfer • Dispatch	The optimizer will create a daily plan that minimizes the number of trucks needed and minimizes bobtail miles. If the dispatcher follows the plan, the carrier will need fewer trucks and have fewer bobtail miles.
Congestion Avoidance Dynamic Routing of Trucks	• Routing • Navigation • Traffic • Weather	Drivers will take the fastest truck appropriate route that avoids traffic and weather related congestion. This will save driver time and reduce idling time.

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4.1.1 Optimization

When beginning the prototype process, the development team identified three objectives for the drayage optimization program:

1. Maximize value added moves
2. Minimize non-value added moves
3. Maximize load matching and back hauls

As discussed earlier, the development team deployed two different optimization programs: Vesco was used and tested throughout the prototype period by Associated; Southwest used Vesco from March to September 2014 and the AOP from October 2014 to April 2015.

4.1.2 Vesco

The optimization algorithm built by PAI is an "ant colony" algorithm, which is an algorithm for finding optimal paths that is based on the behavior of ants searching for food.[7] The theory behind this is that the base or initial state is such that the "ants" wander randomly as they search for food but over time, the shortest path is found and all ants eventually follow this path. In the case of the PAI algorithm, the objective function of the optimization is to maximize drayage operations efficiency, although numerous other constraints factored into the algorithm.[8]

Associated estimated that their staff used the optimized plans generated by Vesco approximately 15% of the time, and plans were generated twice daily Monday through Friday. The usage percentage is not the entire indicator of usage, however, as their dispatchers admitted that the plans gave them assignment ideas even when they were not following the entire plan. Due to the use of the Trinium dispatching software, their dispatch process is already somewhat automated. The initial prototype design planned to integrate the optimized plans generated by Vesco into Trinium's dispatch sequence screen, which would allow the dispatcher to view the plan in Trinium's user interface. However, Associated did not want to complete this integration until use and testing of Vesco had taken place. While there was confidence and an overall positive reaction to the plans created by Vesco, there was not a high enough level of confidence in the program for Associated to provide their authorization to complete this integration. In addition, Trinium, although willing to support, did not have enough time in their development calendar to complete this action within the prototype period.

High level feedback from the key dispatcher at Associated felt that the plans provided by Vesco the night before were helpful in identifying load sequences for drivers. The re-optimized plan, which was sent at 9 a.m. the next morning, was also helpful for the dispatcher to see how new orders received had been incorporated into the existing plans for their drivers. Although the integration to Trinium was not completed, the dispatcher opened or printed the plan from Vesco and referred to it in making his assignments. This allowed him to change the driver to which a recommended load sequence was assigned and other customization related to the availability of trailers and new orders received.

Issues with the plans created by Vesco noted by Associated included:

- Although the load sequences were useful in eliminating bobtails, sometimes Associated preferred to dispatch orders one at a time to account for the varying types of freight actions they deal with: drop and hook (where a container on chassis is dropped), quick live unload, slow live unload, etc. The times of these actions can vary greatly depending on the activity at the delivery site and can therefore make it difficult to plan for how long the action will take.

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[7] http://mathworld.wolfram.com/AntColonyAlgorithm.html

[8] A complete description of the optimization algorithm used by Vesco is contained in the FRATIS DFW As-Built System Architecture and Design Document.

- A majority of their work is drop and hook, but these can be the hardest to account for within Vesco because Associated does not have insight into when the container will be available, and thus, the appointment windows can be long; arriving at the start of the window may result in the equipment not yet being available.
- Although constraints relative to drivers were added to Vesco[9], it was still difficult to ensure a 'fair' distribution of work among Associated's drivers. Although Associated admitted that certain drivers are more reliable, due to workload and driver shortage, the need for all drivers still exists and work must be assigned to them.

From the perspective of the development team, the issues noted included:

- The quality of the input data from Trinium impacts the operation of Vesco. The dynamic queries created in Trinium created comma separated files. Much of the data in Trinium is manually entered by Associated's staff. Many times there were typos in the origins and destinations, or commas added to addresses. This caused issues with Vesco's operation because:
    - The administrative tables in Vesco scan the input files for the location name; any variance in this name may result in the location not being found in the table and thus, that order would not be scheduled. For example, the administrative table may contain a business name "Smith Warehouse"; if a user enters "Smith Warehouse Inc.", this location is different and not recognized by the program.
    - Likewise, because the data is comma separated, if a user enters a location "Smith Warehouse, Inc." this causes the rest of the data for that order to be pushed one column over. Vesco scanned each input file to ensure it contained all 30 columns of data – when data was delimited, the file contained more than 30 columns, and an optimized plan could not be generated.
- The nature of Associated's business is very dynamic which impacted the operation of Vesco. The best example of this was the number of new locations entered into Trinium each day by Associated. All of these locations had to be provided to the Leidos staff so that the location table could be kept current with the location information (name, street address, zip code, latitude and longitude), allowing Vesco to schedule these orders. An automatic geocode lookup could be developed to resolve this, although resources did not permit this to occur as part of the FRATIS DFW prototype.
- As described above, the integration to Trinium dispatch software was not completed, although plans were provided to Trinium via file transfer protocol (FTP), and this could be completed in the future.

From the perspective of the key user (dispatcher) at Associated, with respect to the three objectives for the program:

- He felt the program did save time and provided helpful suggestions when creating daily plans across their fleet.
- Although not quantified, he noticed matches at origin-destinations and felt that bobtail and empty miles were reduced when following the plans created by Vesco.
- Despite the automation of Vesco, he did not feel the human interface and input into the dispatching assignment and execution processes could be reduced. There are many orders received throughout the day, which would require near-constant re-optimization. Also,

[9] These constraints were identified in the As-Built FRATIS DFW System Architecture and Design Document.

Associated performs many live loads and unloads on site, and the time these moves takes is often unpredictable, requiring constant tweaking to the plans generated by Vesco, which assumed a specific amount of time for each freight action.

- Associated staff did feel that long-term use of Vesco could result in even more productivity gains; if enough confidence could be raised, the plans could be integrated into the Trinium dispatch screen, eliminating the need for the dispatcher to completely create a new dispatch plan in their user interface (although the dispatcher still may need to slightly alter the plans created by Vesco).

4.1.3 AOP

Unlike the optimization algorithm used by Vesco, the AOP program's objective was more narrowly focused. Instead of maxmimizing efficiency through miles traveled, the AOP sought to minimize empty moves/bobtails. In addition, to account for Southwest Freight requirements, the program limited the number of orders that can be assigned to a single driver (route) to four (although this was a flexible criteria in the code) and offered the user a field to enter the number of drivers/routes that should be included in the daily plan. [10]

As described earlier, the development team worked collaboratively with Southwest and PAI to customize Vesco and eliminate the issues noted by Southwest:

- Too many bobtails and high miles between bobtailed stops
- Overloaded certain drivers while not assigning any orders to other drivers
    - Unrealistic number of orders assigned to each driver
- Program assigned empty orders ahead of loads and as the first order of the day, when Southwest has all drivers complete a load first.
- The program initially would schedule a live load/unload but not assign the final freight action to the driver:
    - For example, a live unload would require three freight actions: 1) Picking up the loaded container on a chassis; 2) Delivering the loaded container on chassis to the destination and waiting while it was unloaded; 3) Returning the empty container on a chassis to a depot or other freight facility.
    - This issue was ultimately resolved by changing the Trinium query to group these actions together.
- Overall, the perception by Southwest was that Vesco required too much tweaking to make it work for their operation

Because of these issues, in September 2014 Southwest indicated that they were not willing to continue using Vesco for the duration of the prototype. In noting the issues identified with Vesco by the Southwest users, the development team felt that a program which focused solely on reducing bobtails may meet the majority of the requirements for Southwest.

The primary point of contact at Southwest was overall very pleased with the AOP. He was especially pleased with the matching capability and the ability to adjust the number of drivers. The primary user was extremely experienced; his feedback was that the program created plans much like the ones he

[10] A complete description of the optimization algorithm used by Vesco is contained in the FRATIS DFW As-Built System Architecture and Design Document.

would manually create. To that end, though, the program will be useful in training new or inexperienced staff.

Southwest, as with Associated, received many orders throughout the day and so the plans became less effective as the day went on. Near-constant re-optimization would be needed to account for these orders, in conjunction with in-vehicle devices, which their drivers may resist. Despite these criticisms, Southwest did elect to receive the program at the end of the prototype, which is reflective of their level of satisfaction.

Overall, the program met the three objectives of the optimization program. Because the program prioritized loaded moves ahead of empty moves (each driver was assigned a load before an empty), the program maximized value-added moves while minimizing non-value added moves. Also, because the AOP strictly focused on matching orders by street address or zip code, load matching was maximized and back hauls reduced.

There are some areas where the AOP could be expanded to provide Southwest additional functionality. First, the program could be expanded to include a re-optimization capability. This would allow the program to incorporate the multiple orders that are received during each business day, and select the driver that is the best positioned for assignment of that order based on the location of his prior orders. Second, the program could be automated in the same means as Vesco. This would eliminate the time of the dispatcher to create optimized plans. Finally, if there was a high level of confidence in the plans, these could also be integrated into Trinium, allowing automatic assignment of the plan to the drivers.

4.2 TERMINAL QUEUE TIME

The hypothesis for the terminal queue time application at the start of the prototype was that drayage company dispatchers would have current terminal wait time information to avoid sending a driver to a terminal when there is a long wait time and they do not have an immediate time commitment at the terminal. Since carriers would be spreading their arrivals over a longer period the average, wait time should be reduced. The total number of daily arrivals and departures will remain the same; however, the trucks will be distributed more evenly throughout the day.

4.2.1 Bluetooth/Wi-Fi

The goal sample size for the queue time technology was 20% of all trucks entering the facility; Bluetooth provided 5% of the sample size, whereas Wi-Fi provided 20% of the sample size, satisfying the prototype team's target size. The FRATIS DFW deployment included four readers, at the approach, in-gate, IMCG-gate (the gate for IMCG company trucks to use) and the out gate. Figure 4 illustrates the location of the readers at the IMCG-Wilmer facility.

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Figure 4. Bluetooth/Wi-Fi Reader Location at IMCG-Wilmer

This wait time information was forwarded to the FRATIS server every 15 minutes, which made it available to authorized users via the FRATIS portal. The information was also stored and used to predict expected times. The process by which this was done is described in the As-Built FRATIS DFW System Architecture and Design document for the prototype. The data latency of the Acyclica equipment was 35 seconds; per Acyclica specifications, the technology and traffic analytics provided by their software have an accuracy of 98%, and the software maintains an up time of 99.9%.

For the FRATIS DFW prototype, the readers were operational and data being shared between the Acyclica back-end server and the FRATIS server between May 10, 2013 and September 30, 2014. The biggest issue with respect to the readers was the human and environmental interference with the readers. Although the readers were installed in January 2013, the development team consistently noted gaps in the data; when investigated by on-site IMCG staff, the readers were found to have been disconnected from their power source. To mitigate this, in April 2013, Acyclica installed protective enclosures to reduce the interference of IMCG personnel with the readers and their connection to power and network interfaces. While this resolved some of the issues, volatile weather which caused power outages at the site could still trigger the reader to lose power or network connection. There were numerous instances of this, and the time to troubleshoot and resolve varied between a few hours to a few days. Therefore, while the software which received and processed the reads maintains a 99.9% uptime, the hardware at the site can be impacted by numerous factors, causing temporary outages that range in duration.

With respect to the data collected at the site, the most problematic of readers was the one at the approach to the facility, likely due to its distance from the primary site infrastructure. This reader was mounted to a power pole and wired to the power supply and network on the pole. This reader provided data for approximately 151 days, whereas the other three readers provided data for 349

days, between May 10, 2013 and September 30, 2014. The Acyclica algorithm processes the MAC addresses and calculates the current wait time for each route segment and as stated earlier, these times were provided to the FRATIS server via web service every 15 minutes; a total of 579,143 records were collected and stored on the FRATIS server from May 2013 to September 2014.[11]

With respect to the data collected by the readers, the development team was most interested in the points where it could be compared to the data collected by the DSRC equipment that was deployed, and is described in the following section. The main data points where the team was able to compare the Bluetooth/Wi-Fi solution was with respect to the average wait time by time of day and day of week at two of the route segments: from the approach to the in gate, and from the in gate to out gate (time in yard). For these two metrics, the Bluetooth/Wi-Fi showed:

- Average wait time at approach = 25 minutes
- Average time in yard = 29 minutes

The average times for these segments by time of day and day of week are captured in Table 4.

Table 4. Average Time at Approach and Yard (Bluetooth/Wi-Fi)

	Approach	*Yard*	*Approach*	*Yard*	*Approach*	*Yard*	*Approach*	*Yard*	*Approach*	*Yard*	*Approach*	*Yard*	*Approach*	*Yard*
Hour	SUNDAY		MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		SATURDAY	
0	17.31	30.8	30.68	10.57	23.9	23	16.44	17.88	23.88	27.49	24.33	33.28	24.62	24.12
1	14.33	37.26	12.69	1.16	44.09	38.42	17.24	19.93	26.73	19.54	39.51	27.68	16.11	16.39
2	0	20.84	19.7	24.11	17.41	24.07	22.76	24.86	16.08	23.69	14.33	26.62	18.14	25.41
3	41.99	42.75	24.11	39.85	28.42	35.14	25.62	33.96	21.91	34.06	25.29	37.46	28.53	37.02
4	56.61	40.38	24.36	35.69	27.34	33.43	21.7	25.61	29.54	32.66	22.91	34.31	17.33	35.2
5	0	45.88	27.01	24.79	25.27	28.66	23.8	27.22	24.55	28.91	26.01	31.43	35.09	38.85
6	16.59	35.58	28.44	26.05	31.16	28.4	30.16	26.65	27	23.5	22.75	22.05	23.74	30.24
7	35.06	36.59	27.49	31.2	21.71	26.66	23.95	29.08	29.4	30.25	28.51	28.25	24.02	32.41
8	23.37	36.23	24.73	24.1	19.71	23.96	24.48	25.76	24.54	24.28	27.91	23.57	32.02	31.46
9	25.44	30.65	26.83	27.23	27.67	27.05	27	26.35	26.28	25.15	26.34	26.95	36.5	30.66
10	35.8	31.91	24.85	32.08	23.83	31.41	23.65	30.24	26.64	29.67	25.05	31.08	29.59	37.06
11	35.71	34.31	23.24	30.05	22.39	30.18	26.94	29.56	24.22	29.89	21.86	29.08	24.18	32.2
12	20.98	38.17	25.76	29.48	23.75	25.72	22.33	26.11	23.08	27.69	23.15	27.96	32.04	34.07
13	17.89	29.45	24.61	29.34	24.9	26.51	26.16	27.59	24.92	28.24	23.8	28.21	34.88	34.98
14	42.06	39.09	23.01	27.31	25.19	26.21	25.43	27.43	25.51	26.58	25.02	28.14	35.65	37.22
15	48.83	28.02	23.92	27.09	25.55	25.55	24.01	25.03	22.84	24.49	24.06	26.21	30.75	34.32
16	15.05	44.67	22.33	24.9	27.98	26.49	26.68	27.82	23.97	25.53	24.68	23.34	35.16	30.95
17	45.25	33.03	30.11	26.9	28.84	26.52	22.72	27.24	24.03	26.05	26.07	26.78	30.6	26.52
18	36.36	36.93	27.94	29.33	30.37	29.03	20.85	29.76	31.66	27.05	25.97	27.34	32.04	40.91
19	22.06	17.45	14.28	24.94	31.48	25.6	24.22	26.19	18.24	26.05	34.04	31.12	31.33	36.79
20	38.69	20.12	29.48	28.5	12.96	26.77	14.55	29.04	22.56	27.17	20.06	34.73	32.04	27.54
21	0	22.04	24.37	26.65	18.41	26.83	14.07	24.88	11.96	16.86	20.23	24.97	35.26	27.27
22	4.68	49.78	23.46	28.63	5.39	22.99	26.29	25.24	28.83	29.47	29.58	23.52	58.48	12.02
23	0	0	41.31	34.49	28.62	22.45	24.58	27.19	35.49	33.26	34.21	31.05	22.5	33.14
Average	24.75	32.58	25.20	26.85	24.85	27.54	23.15	26.69	24.74	26.98	25.65	28.55	30.03	31.11

Source: Leidos/Acyclica

Both drayage companies were provided log-in credentials for the FRATIS DFW portal, although due to the focus on the optimization program, the development team had to provide frequent reminders of this information and their access to it. The use of the site was not significant during the test, as described by the participants (site analytics were not used for this site, as the development team knew

[11] This data was shared with the FRATIS Impact Assessment team via DropBox and will be posted to the USDOT Research Data Exchange upon conclusion of the FRATIS DFW Prototype Task Order.

the number of users were limited to the small group of test participants). Although the site highlighted when a wait time was significant, it still required the user to log on to the site to view the information. A more dynamic interface that facilitated alerts regarding current wait times and equipment availability possibly holds more potential for users. Even if a more dynamic notification could be employed, both drays reported that the information can help decide when to call the facility although many other factors are also considered including the location of the driver and the deadline for the equipment. If the equipment has to be picked up or returned that day, and if a driver is in the area, he will head to the facility due to his proximity regardless of the wait time.

4.2.2 DSRC Data Analysis

The specifics regarding the technical implementation of the DSRC wait time solution, in terms of equipment and installation, are captured in the As-Built FRATIS DFW System Architecture and Design document. There were five radios installed on IMCG-Wilmer drayage trucks; these were company trucks that the drivers typically left in a lot near the approach overnight. In addition, a single roadside unit (RSU) was installed at the out gate.

Although there were five radios installed, these devices change their identifier (an eight digit, alpha numeric identifier) periodically; this protects any personally identifiable information (PII), keeping the BSMs sent by the radio anonymous. From the data management system (DMS), the team obtained all of these identifiers – there were seventeen (17) identifiers generated from the five radios over the 30-day pilot period. The basic safety messages (BSMs) were broken out by these identifiers.

The DSRC equipment was installed at IMCG-Wilmer the second week in December, 2013. The devices were removed on January 29, 2014. Although the intent was to collect data for a continuous 30-day period, multiple issues impacted the collection of the BSMs; these issues were similar to ones that affected the continuous collection of the Bluetooth/Wi-Fi queue time data:

- The devices did not transmit any data from 12/22/13 to 12/25/13 and the week of 12/29/13 due to a system outage. The cause of the outage was a power outage to the RSU that was not caught due to a decrease in staff presence surrounding the Christmas and New Year's holidays.
- In addition, four of the radios were unplugged by drivers during this time; again, due to the Christmas holiday, these disconnected units were not discovered and rectified until January 3, 2014.
- Lastly, due to inclement weather in Dallas, a power outage again impacted the RSU; a power cycle restored the RSU's power and modem connection on January 6, 2014.

Table 5 highlights the dates on which BSMs were collected at IMCG-Wilmer. The shaded dates indicate dates data was collected.

Table 5. DSRC Data Collection Dates

December 2013						
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

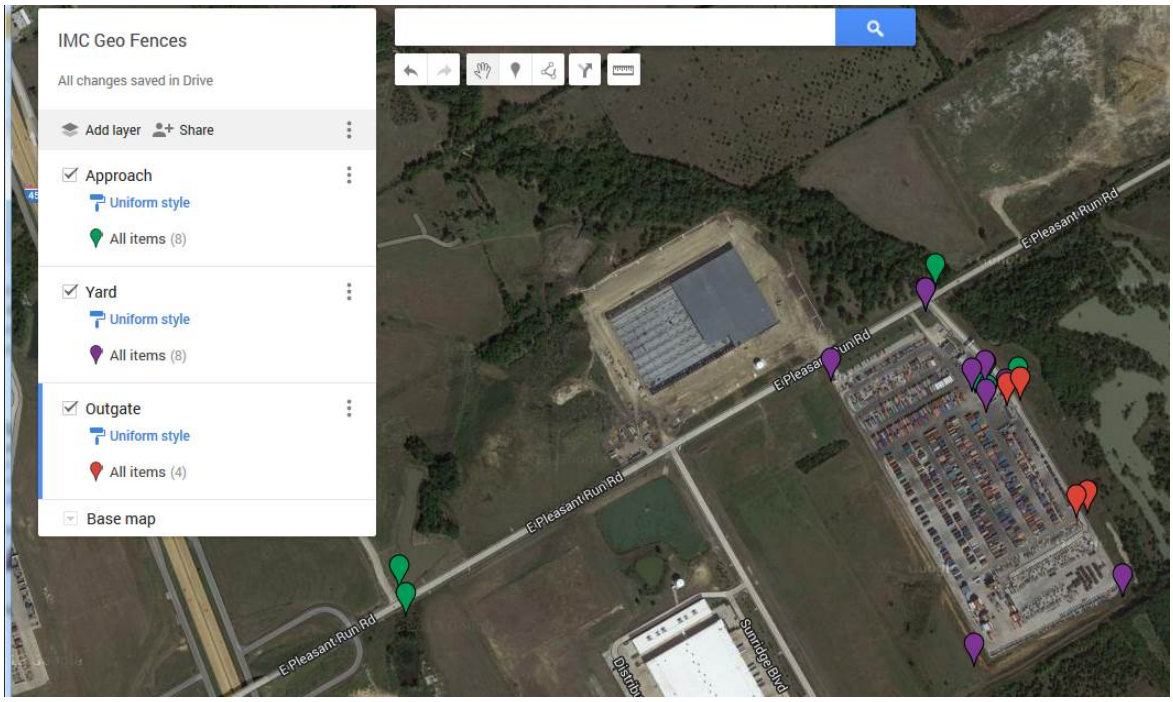
January 2014						
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Leidos

BSMs were collected for 19 days during this period, for a total of just over two million BSMs. [12] Once collected, the team had to retrieve and analyze the BSMs in comma separated value (.csv) formatin order to calculate the wait time. The process by which this was done is articulated below:

1. Data was retrieved from the existing connected vehicle DMS
2. Java code was used to process and parse the BSMs.
3. The code used the geofences to identify where in the facility the message was transmitted. These geofences were necessary to identify which of the operational areas the truck was in when the BSM was sent (approach, yard, or out-gate). These geofences defined the boundaries, i.e., latitude and longitude for each of these areas (each BSM contains a latitude and longitude position); these boundaries are identified in Figure 5. When processing the BSMs, a 'true' or 'false' entry would be created in the relevant field for that point of interest (approach, yard, or out gate).

[12] This data was shared with the FRATIS Impact Assessment team via DropBox and will be posted to the USDOT Research Data Exchange upon conclusion of the FRATIS DFW Prototype Task Order.



Leidos

Figure 5. Geofences for Container Yard Operational Areas

4. The code that retrieved the BSMs from the DMS created a unique comma separated value (CSV) file for each identifier and date; for the 30-pilot period, 42 individual comma separated files were generated. Within each file, each BSM was a row.
5. Each file contained the following data elements for each BSM:
    - Identifier
    - Latitude
    - Longitude
    - Speed (miles per hour)
    - Heading (degrees)
    - Time Stamp (MO/DA/YEAR HH:MM)
    - In Approach (TRUE/FALSE)
    - Yard (TRUE/FALSE)
    - Out gate (TRUE/FALSE)
    - Event Time (Date and Time stamp when a wait time was identified)
    - Wait time in minutes; this field was calculated by the Java code based on the length of the time the vehicle/radio was within a particular geofence.

An excerpt of a daily file from one device is shown in Table 6. In the example below, the third record indicates that a wait time of 1.98 minutes was identified in the Approach geofence on 1/25/14 at 8:32 a.m. At that time, the vehicle has a speed of 6.34 miles per hour and a heading of 251 degrees.

Table 6. Excerpt from Daily File of BSMs for One Truck Identifier

ID	Latitude	Longitude	Speed	Heading	Date/Time	In Approach	In Yard	In Outgate	Event Time	Wait Time
0DE42005	32.61415	-96.6738072	6.4	248.5	1/25/2014 8:32	TRUE	FALSE	FALSE		
0DE42005	32.61415	-96.6738137	6.38	249.8125	1/25/2014 8:32	TRUE	FALSE	FALSE		
0DE42005	32.61415	-96.67382	6.34	251	1/25/2014 8:32	TRUE	FALSE	FALSE		
									1/25/2014 8:32	1.983333333
0DE42005	32.61414	-96.6739393	5.7	287.45	1/25/2014 8:32	FALSE	TRUE	FALSE		
0DE42005	32.61414	-96.6739452	5.7	289.8	1/25/2014 8:32	FALSE	TRUE	FALSE		
0DE42005	32.61416	-96.6739823	5.56	305.725	1/25/2014 8:32	FALSE	TRUE	FALSE		
0DE42005	32.61417	-96.674	5.38	314.325	1/25/2014 8:32	FALSE	TRUE	FALSE		

Leidos

To analyze the wait times generated by the BSMs and Java code, each of the 42 CSV files was reviewed; records containing wait times were isolated. One identifier may generate countless BSMs, depending on how many times during that 24-hour period the truck was within line of sight to the RSU. For the 42 files generated from IMCG-Wilmer, there were anywhere from 1,000 BSMs to 100,000 BSMs within each one. Since the java code written for this project calculated the wait time within the CSV file, each file was sorted by wait time. Then, these wait times were sorted by the location where the wait time was identified. Pertinent statistics related to this analysis include:

- Of the 42 files for individual identifiers and days, 12 of these records did not contain any calculated wait times
- Some 549 event times were noted as having a wait time during the 19 days of data collected.
- The average wait time within the 'Approach' geofence was 13 minutes
- The average wait time within the 'Yard' geofence was 75 minutes; this was logical due to the extended time to complete the physical transaction within the yard. In addition, isolated, extended wait times of longer than 100 minutes were noted within this geofence; these were mainly observed in the early morning hours and likely because of the fact that IMCG drivers can leave their trucks at the facility overnight
- Of the wait times noted, none was calculated for the 'Out gate' geofence

The day and hour of each wait time observation were also noted to allow for calculation of average wait time by time of day/day of week, as presented in Table 7. These measures were also collected by the Bluetooth/Wi-Fi wait time system as presented in Section 4.3.1.

Table 7. Average Wait at Approach and Yard (DSRC)

	Approach	Yard	Approach	Yard	Approach	Yard	Approach	Yard	Approach	Yard	Approach	Yard	Approach	Yard
Hour	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
1	3.92				7.23			449.18			2.23	811.34		
2	9.57	15.33							6.90					58.78
3													18.68	
4														
5		317.62												
6		50.97											2.09	
7									6.79	19.75				
8	1.98						237.02	9.12						
9						2.88	1.61	19.75					7.83	4.96
10					4.28	43.58					10.59	11.92	1.45	22.90
11					3.25	14.32	6.38	4.08						
12					14.70		8.75	18.20			6.78			
13					5.65	13.53	3.13				2.28	2.22	15.30	
14					1.35		7.86		11.92	13.67				20.66
15											1.88		2.93	
16					2.17				10.12				1.43	
17									1.47	39.42	31.53		1.43	
18													2.13	
19													1.40	
20					7.97	3.30							4.18	4.77
21														
22					2.80		3.71	1.72						
23											3.68		3.53	

Leidos

4.2.3 Advance Notice to Terminals

This piece of the FRATIS DFW prototype did not have a hypothesis tied directly to it since this function was added once the development team began regular receipt and analysis of drayage company data. However, the intent of this information was to improve the planning process at terminals. By anticipating when loads will arrive, and what level of effort will be required to process them (whether loaded or empty), the terminals may be able to better plan the labor and resources to accommodate them. In addition, it provides the terminals with insight and visibility over expected daily volumes. Last, it will help the terminal to coordinate appointments among multiple drayage companies and customers.

From the perspective of IMCG-Wilmer, one of the recipients of the information, the utility of the information was noted:

- The email helps to prepare the facility for the day in terms of the number of staff to have on hand, planning for their hours in terms of when staff should start, end and when extra staff should be available and an additional lane opened.
- The notification is helpful in identifying what specific equipment will be dropped off or picked up; in the case of a pickup, it can provide IMCG with the information necessary to unbury the container in advance of the pickup.
- Dealing with the steamship lines and chassis pools, it provides IMCG with an edge regarding additional information they can offer these customers. It may enable them to bring in new customers, if they can show access/insight into this type of information.
- The bottom line noted by IMCG was that any information helps their staff prepare, adjust and manage the flow of operations. This could be enhanced if information from more drayage companies was made available. IMCG-Wilmer reported that at least 15 local drayage

companies in the DFW region call their facility regularly, and insight into all of these companies would provide a substantial benefit.

4.2.4 Routing, Navigation, Traffic, and Weather

The hypothesis for this component related to the identification and use of the fastest truck-appropriate route that avoids traffic and weather-related congestion. As traffic changes and incidents occur, the driver will be directed to alternative routes, saving driver time and reduced idling time. The key value will be reducing driver time and some savings in fuel usage.

The development team was in the midst of exploring the ALK Co-Pilot application for satisfaction of these requirements, when in related talks with Trinium Technologies, the dispatch software provider, it was revealed that they intended to enhance their web-based work order application MC2 to include routing, navigation, traffic and weather information via an interface with a similar ALK product. The development calendar and planned roll out coincided with the prototype schedule, which eliminated the need for the drivers to have multiple applications open on their smartphone. The MC2 web application integrated with the ALK Maps product as the back end tool for the routing, traffic, and weather information.

Both Associated and Southwest were able to deploy Trinium's enhanced MC2 application in March 2014. Unfortunately, Southwest was not able to see the weather overlay, and this was not noted with Trinium. In addition, both drays did not *require* the use of the MC2 application, and still allowed drivers to accept work orders by coming in to the office and picking a hard copy of the order. Unless the work order was accepted within the application, the routing, navigation, traffic and weather would not be dynamically provided to the driver. Although all drivers had the application on their phone, not mandating its use impacted the level of usage of the information. Despite the inconsistent use of the application, the feedback the drays received from the drivers that did use it was that it was useful to see the real-time traffic information, although routing was not as useful. This was mainly due to the fact that the drivers are intimately familiar with routes in the DFW region and are less in need of dynamic routing information. Associated noted that this information did provide more utility for their regional moves, more than 100-miles from the DFW metroplex.

From the perspective of the development team, the application could have been more dynamic in nature, especially compared to the ALK Co-Pilot application that the team evaluated. For example, the user had to refresh their interface in order to update the route after they accepted their work order. It should be noted, though that the route, traffic and weather did automatically refresh anytime the driver exited and re-entered the MC2 application. Trinium's perspective on this feature was that the routing application can be as dynamic as the driver chooses, similar to anytime a personal driver were to "update from here" within Google Maps. Finally, a key gap in the application from the development team's perspective was that the application did not include an audio component, which made the driver dependent on written or map-based information.

5 Conclusions and Recommendations

Identifying and documenting lessons learned and opportunities for expansion and improvement are a critical final step in the prototype process. This section provides documentation to the successes and challenges encountered during the test. Second, it helps understand opportunities that may be explored going forward. The conclusions in this section are from the perspective of the development team, and do not include either the qualitative or quantitative anlaysis or conclusions from the USDOT-funded independent impact assessment of all three FRATIS prototypes.
Test Conclusions

1. **The optimization program was the focus of the prototype, limiting the ability to broaden the other applications**.

The guidance from USDOT indicated that a major focus of the FRATIS prototypes was the drayage optimization program. Moreover, given the results of the prior test in Memphis with the PAI algorithm, the development team felt that time should be spent implementing this solution and customizing it for each drayage company. While the benefits of the algorithm had been documented in the Memphis test, the business environment of the participating drays in DFW varied from those in Memphis, resulting in many changes that had to be made to the algorithm. In this environment, trying to use a canned or pre-created algorithm was inefficient; a better approach would have been for USDOT and the prototype teams to evaluate the participating drayage company workflows prior to the start of the prototype and assess whether the PAI program was the best suited to optimizing their work.

In addition, utilizing the PAI algorithm required much modification, which had schedule and budgetary modifications for the prototype team. Once the development team began internal testing of the algorithm, it was found that manual order entry was required. Given that both of the participating drayage companies used off-the-shelf dispatch software, the team did not want to require the dispatchers to enter orders twice. This led to the team to develop the pre-optimization processor. Similarly, the format of the optimized plan was not usable to the participants and needed to 'speak their language' and include similar fields to what they found within their Trinium software. The development team then had to build the back-end, post-optimization processor. The development of these items was not anticipated and significantly impacted the budget and schedule.

The documentation that was available for the algorithm affected the development team's confidence in customizing the algorithm as received from PAI. As such, once the prototype began, the development team had to initiate a subcontract with PAI to create and implement the constraints requested by the drayage companies. The development team, however, had to remain engaged in this process especially with respect to testing the changes once they were incorporated because the development team was more familiar with the operations of the drays than PAI. In addition, PAI's work had to be added to their development calendar. These activities also contributed to development delays and unanticipated costs.

Finally, as the development team learned in the case of Southwest, the work and effort to make Vesco a success perhaps went on for too long before moving to an alternate solution. If the team had moved

on from the Vesco implementation at Southwest sooner, more resources may have been available to build out the AOP and add more functionality.

2. Automating certain functions of the prototype increased usage

Drayage companies are consistently trying to do more with less. While they may be willing participants in a pilot, operational priorities will always be ahead of their participation in a voluntary pilot. That does not necessarily indicate their lack of interest, but it is reflective of the time they have available to contribute to the agile development process and the testing/prototyping of the solution. Automating Vesco for Associated guaranteed consistent use of the program and helped overcome these types of challenges. In looking back, other functions could have improved usage of them as well. For example, if the real-time wait time had been provided to both dispatchers and drivers, there would have likely been a more positive reaction to this information. It may have been especially useful if it was provided in the form of an alert or notification. Likewise, providing the equipment status as an automatic email to dispatchers may have increased the value of this information and saved time – given that in baseline operations, these dispatchers have to call the facility to inquire about this information. Even traffic information, if automatically generated and sent to drivers and dispatchers, may be found to be more useful if the user did not have to seek or request this information from a system.

Perhaps most significantly, although integrating the optimization into the Trinium dispatch software was not possible for this pilot, establishing this connection would allow the optimized plans to be displayed via the dispatch sequencing screen in Trinium, where load assignments are made. If the optimized plan were largely what the dispatcher intended to assign, this could be a large time savings. However, confidence in the optimized plans needs to be well-established before this type of integration could occur.

3. Including vendors/providers had pros and cons.

The development team was fortunate to have encountered a software provider such as Trinium Technologies. Despite the fact that they were not an official subcontractor, they were instrumental in creating the proper dynamic queries to capture the correct baseline data and input data for the drayage optimization programs. In addition, they provided critical insight into troubleshooting issues with the input data, in particular they were able to identify that the initial queries were not capturing the second and third leg of live loads and unloads. The change to the query required the creation of a customized report, which Trinium created at no charge to the development team. The bottom line is that the optimization programs would not have been as successful without the involvement of Trinium.

The involvement of Trinium also ensured that Associated was able to purchase and quickly implement Trinium dispatch software. Similarly, both Associated and Southwest were able to receive system upgrades and the enhanced MC2 product much sooner than they would have had they not participated in the FRATIS DFW prototype. The working relationship among the development team, drayage companies, and Trinium Technologies was especially symbiotic and may be able to realize future benefits if Trinium seeks to continue exploring the utility of including a drayage optimization component within their software.

The flip side of this involvement was that the enhanced MC2 product was not as dynamic as the development team intended. Although the application technically met most of the requirements for the FRATIS freight-specific traveler information application, there is room for improvement. The integration between the ALK Maps tool and MC2 was the first step in Trinium's exploration of this functionality. If the limited test with this tool yielded positive results, Trinium was open to the use of more dynamic

tools such as ALK's Co-Pilot. ALK Co-Pilot was not initially selected due to the license and subscription requirement. However, since it was not a subcontracted relationship, the development team was limited in what could be required of Trinium. For the same reason, the team was also restricted by Trinium's development calendar, of which FRATIS-related items were few and of lower priority.

4. **The dynamic routing solution needs the right environment – a regional carrier may benefit more from this type of solution.**

Both drayage companies felt that the dynamic routing, traffic, navigation and weather information was somewhat helpful, but neither felt this was an application they would continue using beyond the pilot. Associated, who does both regional and local moves, thought that the information was better suited to the drivers who perform regional moves since the destination may be one that they have not been to before. Local drayage companies are intimately familiar with the routes – both primary and alternate – that exist between frequently visited facilities, especially primary rail hubs and long-term customers.

One positive aspect of the freight-specific routing and navigation component is the utility of the data that may be collected in its application. Although it may require much sanitizing, this data could provide valuable data for freight planning within state DOTs and metropolitan planning organizations (MPOs). The type of data that may be useful include route preferences, alternate routes, infrastructure requirements of freight facilities, and truck counts; pilots such as FRATIS can provide this information, even post-test, as short-term goals within the transportation planning community is 2-3 years.

5. **The "right" stakeholders are critical to test success**

The development team would define the "right" stakeholder as one who is open to the idea that the benefits technology can provide, yet has to have an opportunity to apply this technology within their organization to realize the highest level of benefits. Southwest, for example, noted that if they didn't use Trinium software, and hadn't used it for such a long time, the drayage optimization program may have been more beneficial. Both drays felt that the optimized plans would be especially useful in illustrating the type of assignments to less experienced staff.

The stakeholders also have to be open to changing operational preferences, as these can be difficult to change. Optimization, in particular, is most effective when the plans can be applied globally, accounting for all loads, and all drivers. Most constraints, however, were included to account for driver preference and routines that had been established within the drayage companies. For example, certain drivers prefer to handle orders for certain customers and these orders had to be excluded from the optimization. The more constraints that are added, the more limited the solution becomes. In addition, the users of the program have to be open-minded with respect to the results, as one driver's approximate miles traveled may increase, while the overall fleet miles traveled may decrease. These metrics should be easily derived and visible within the solution; to make it more effective, these types of measures should be collected and calculated using the baseline data so that small, incremental quantitative benefits can be shown to both dispatchers and drivers, increasing the likelihood of acceptance.

6. **The use of DSRC to calculate wait time is not yet as accurate as other methods, in this case Bluetooth/Wi-Fi, although the reliability of the equipment seems comparable.**

The average wait time at the approach using DSRC technology was 13 minutes, while the Bluetooth/Wi-Fi system was 25 minutes. Similarly, the time in the yard (from in gate to out gate) varied

significantly between the two technologies, with DSRC calculating an average of 75 minutes while Bluetooth/Wi-Fi calculating 29 minutes. While these seem like significant gaps, it is important to highlight that the DSRC prototype was extremely limited, with only 5 trucks being equipped with these devices. Moreover, these were company trucks belonging to IMCG; therefore, it was not unusual that they would remain parked at the facility overnight; this would cause a very long time in the yard to be noted by the technology. In addition, the IMCG-owned trucks are allowed to enter the facility through a dedicated lane, whereas other providers are restricted to a single lane that must be shared among the multiple drayage companies who call that facility. That said, the limited test illustrated important points, including:

- The BSM provides sufficient information needed to calculate wait time
- The development team wrote accurate code which calculated the time between two geo-fenced locations
- The existing connected vehicle test bed data management system did not require significant change in order to facilitate the collection of the messages and the calculation of wait time

5.1 RECOMMENDATIONS

From these lessons learned, recommendations for moving forward can be suggested and archived, as these may be incorporated into future pilots and/or prototypes. Some of these recommendations relate to opportunities to capitalize on the momentum gained by the FRATIS DFW prototype while others may be more appropriate for future tests.

- More exploration of the application of DSRC to freight transportation is warranted. In particular, there may be opportunities to explore the feasibility of using DSRC technology to track the location of freight trucks in the distribution center and port terminal domain for the purpose of creating communication links with the distribution center operation and port terminal operation. In addition, this technology may provide the ability to send and receive data between the freight truck and the distribution center operation/port terminal operation, resulting in improved movement of freight trucks in and out of a distribution center and port/intermodal terminals, reducing queues and thereby reducing emissions from idling trucks and providing seamless communication to back-office operations the asset departure-arrival times to improve customer service. Although there will be challenges related to unlocking and demonstrating the DSRC technology for use in a new, interesting and useful ways, the demonstration of this technology in DFW was positive and should contribute to the need for expanded application and testing. This may be possible through the upcoming connected vehicle pilots or other opportunities.
- Vesco and the AOP have the opportunity to provide expanded benefits if enhancements were made. Vesco could be built out to include frequent re-optimizations, as Associated indicated that near-constant re-optimization would help create the best possible plans. Likewise, given the fact that the operations are ever changing, with new orders and new locations constantly being added, the more automated the program, the more usable it becomes to the dispatchers. Regardless of whether the programs are deployed in their entirety, certain components – such as the automation of the optimization process and the automatic geocode lookup – hold potential value to applications beyond the drayage optimization program and FRATIS DFW.

- The application of technology, as demonstrated by the FRATIS DFW prototype, is worth exploring with the current network of stakeholders and new locations. DFW stakeholders all articulated that increasing the number of participants could increase the level of benefits. This would occur as a result of increasing the information sharing among the freight community within DFW. In addition, the benefits of the three prototypes may assist in the recruiting of new stakeholders in different cities.

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