Los Angeles-Gateway Freight Advanced Traveler Information System

Final System Design and Architecture for FRATIS Prototype

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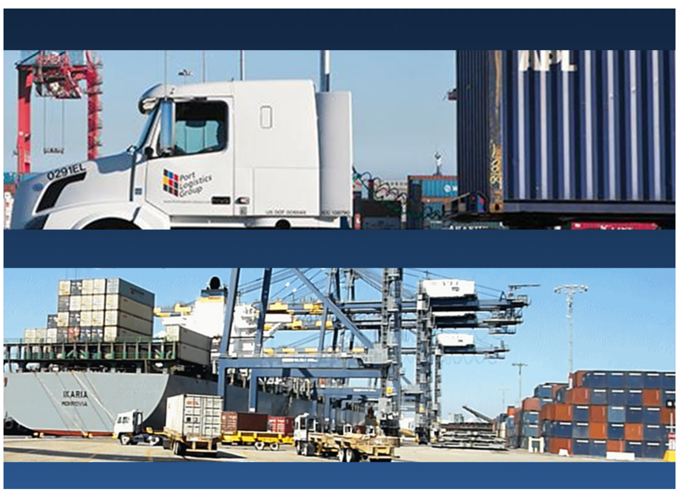

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16. Abstract

This Final Architecture and Design report has been prepared to describe the structure and design of all the system components for the LA-Gateway FRATIS Demonstration Project. More specifically, this document provides:

- Detailed descriptions of the selected architecture implemented in the LA-Gateway Region;
- A summary of the Agile development process; and
- Software development testing procedures, technologies selected for system development, and open-source development protocols for the LA-Gateway FRATIS prototype.

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1.0 Overview

1.1 Purpose of this Document

This Final Architecture and Design report has been prepared to describe the structure and design of all the system components for the Los Angeles-Gateway FRATIS Demonstration Project. More specifically, this document provides:

- Detailed descriptions of the selected architecture implemented in the Los Angeles-Gateway Region;
- A summary of the Agile development process; and
- Software development testing procedures, technologies selected for system development, and open-source development protocols for the Los Angeles-Gateway FRATIS prototype.

1.2 Background on the Los Angeles-Gateway FRATIS Demonstration Project

The Los Angeles-Gateway FRATIS demonstration project is focused on:

- Improving communications and sharing intermodal logistics information between the truck drayage industry and port terminals such that terminals are less congested during peak hours;
- Improving traveler information available to intermodal truck drayage fleets so that they can more effectively plan around traffic and port congestion; and
- Employment of an optimization algorithm, which will allow for the technologies to work together in a way that optimizes the drayage fleet deliveries and movements based on several key constraints (e.g., time of day, PierPass restrictions, terminal queue status, etc.).

Together, these three areas of focus can result in significant improvements in intermodal efficiency, including reductions in truck trips, reductions in travel times, and improved terminal gate and processing efficiency. These benefits, in turn, will directly result in the public-sector benefits of congestion reduction an improved air quality.

The two primary private-sector participants in the FRATIS Los Angeles demonstration project are Yusen Terminals, Inc. (Port of Los Angeles Terminal) and PLG Logistics (regional drayage fleets of 50 trucks). The primary regional public-sector agencies that are supporting the test are LA Metro, the Gateway Cities Council of Governments, and the Port of Los Angeles.

Technologies that will be utilized during the demonstration test include: advanced traveler information (from new Nokia applications); port terminal truck queue-time measurement (including detailed internal terminal queues); automated ETA messaging to the terminals one day in advance of truck arrivals; direct messaging of trucks by terminals; and employment of an optimization algorithm, which will allow for the technologies to work together in a way that optimizes the PLG truck deliveries and movements based on several key constraints (e.g., time of day, PierPass restrictions, terminal queue status, etc.).

The primary user interfaces for these technologies will be a web application for drayage truck dispatchers, a mobile application for drayage truck drivers, and messaging/alerts functionality for terminal operators.

This demonstration project currently is in the operational testing phase. Six months of operational testing began on March 1, 2014. The project will conclude on September 30, 2014.

2.0 System Architecture

The Los Angeles Freight Advanced Traveler Information System (FRATIS) Integrated Tool consists of three main components, one for each of the stakeholders. The three stakeholders are Dispatchers, Drivers, and the YTI Marine Terminal, where each stakeholder has specific tools designed to aid and improve their operations. The system is composed mainly of a web interface accessed by the carrier staff (customer representatives, dispatchers, availability clerks, etc.) and a third-party tool – a navigation on-board device from TomTom Business Solutions for the drivers. A more detailed description of the system is presented next. Figure 1 shows the detailed system architecture.

2.1 Dispatcher Web Site

The Dispatcher web site is designed in a way that once users are logged in, they have the capability of selecting different features, from entering and editing orders, to running the optimization algorithm. Still, the interface itself consist of two main elements, the Drayage Optimization that takes the entered orders and generates driver itineraries based on given constraints, and a Real-Time Traveler Information section where users can get access to information regarding current traffic conditions, weather, and Marine Terminal waiting times.

The **Drayage Optimization Tool** is divided into three main parts or modules. These modules provide the capability for order collection and data processing, and offer optimized daily itineraries for truck fleet operations. The orders, constraints, and business rules are populated manually with order data by the company's dispatcher. This order data is assembled by the company's customer service representatives, based on all orders received and ready for scheduling.

This data includes parameters like shipper and consignee locations, freight actions, stop time, time windows, due date, equipment details, and driver data, such as driving availability based on driver's hours of service. These orders are then processed by the Customized Optimization Algorithm. The Customized Optimization Algorithm Module uses distances and travel-time information, including real-time traffic information, traffic incidents, and historical traffic information from Navteq.

Additionally, the optimization algorithm uses the estimated waiting times collected by Acyclica hardware at the Yusen Marine Terminal (YTI). The Acyclica system uses special equipment that reads signals from any truck with active Bluetooth and WiFi cellphones. The system consists of eight installed WiFi MAC address readers that have been deployed at the YTI terminal approach, key choke points within the terminal, and at the terminal exit. For the terminal queue measurement process, the Acyclica system uses the readers to match MAC addresses from WiFi or Bluetooth-enabled devices at different points approaching and inside the terminal.[1] The waiting times and turn times inside the terminal were collected and analyzed in order to estimate and forecast waiting times to be used by the algorithm when running orders for a given day and time.

The information delivered from these providers is utilized by the Customized Optimization Algorithm; order stops and their location are used to develop the most efficient feasible routes for the fleet, taking into account the different operational constraints. Furthermore, the system considers traffic conditions, based on historical data, to determine the best time of day to execute the orders.

The tool provides the best feasible itinerary for each truck in the Fleet Itinerary Assignment and Review Module, factoring in all the previously stated parameters. Dispatchers are able to edit the algorithm assignments based on business needs. These itineraries can then be shared with drivers through TomTom WebFleet services, which provides a distraction-free messaging capability with order execution status.

The algorithm also considers orders that require yard pulls, which consist of picking up containers from the marine terminals during the evening and storing them in the company yard for early morning delivery or for orders not using PierPass. The system handles these orders by breaking them down into at least two parts (legs), one for the evening move during the marine terminal off-peak hours (yard pull) and one for the morning move (customer delivery). Customer service representatives are responsible for entering this order leg information in the system.

In this demonstration the optimization algorithm is run at least twice daily. The first run is done during the early afternoon hours to generate the night shift plan once all orders, including yard pulls, are collected and entered into the system. Then, after next-day orders are received and entered into the system, a second run is done later in the afternoon for the next day’s morning shift plan.

Additionally, the algorithm could be run several times a day to update and recalculate the itinerary based on the orders that were completed, stop delays, and the new locations of certain drivers; however, this is an additional task for dispatchers given that they need to keep track of an order’s status and the position of each truck in order to update the algorithm with these changes, and then update the driver with the new modifications in the itinerary.

[1] See the FRATIS Los Angeles-Gateway Demonstration Plan dated June 28, 2013 for more information on the Acyclica technology.

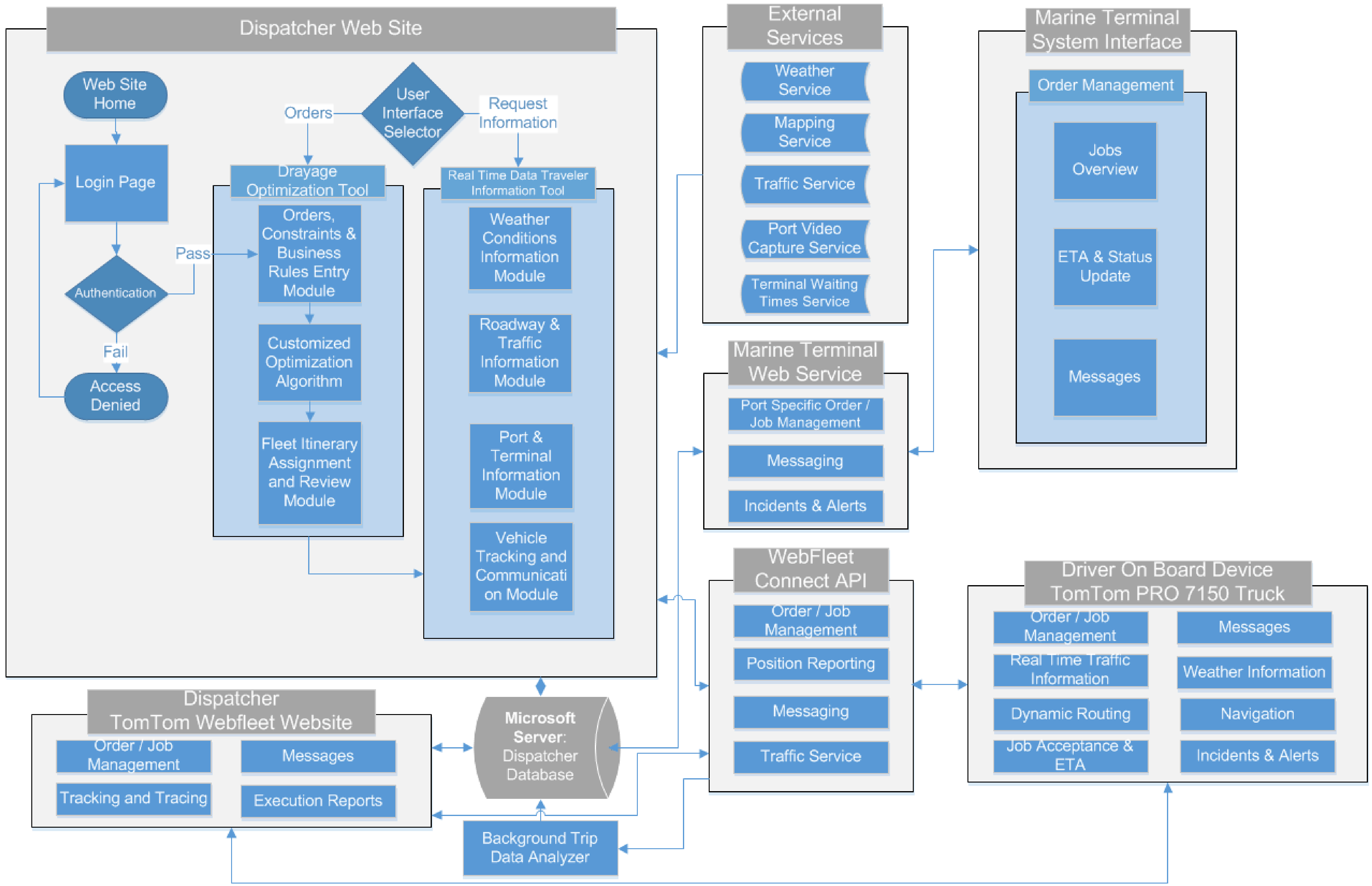

Figure 1. Los Angeles-Gateway FRATIS Architecture Diagram
(Source: Productivity Apex Inc.)

The Dispatcher web site also has a section or module for **Real-Time Data Traveler Information** that provides users with real-time information specific for freight operations, allowing stakeholders in the freight industry – particularly the Dispatcher – to better plan for their operations. This tool also is integrated by a Weather Condition Information Module that displays current weather condition information, warnings, and alerts on user-selected areas for freight operations. The Weather Condition Information Module draws this relevant information from the Yahoo Weather API.[2] A Roadway and Traffic Module uses data from Navteq web services to provide real-time traffic and accident information, allowing dispatchers to better plan routes and redirect drivers in case of incidents. The Port and Terminal Information Module displays terminal queue time from a third-party system (provided by Acyclica) deployed at Yusen terminal. This queue time shows the latest 30-minute gate queue waiting time average, providing both dispatchers and drivers the ability to schedule and plan around both expected and unexpected terminal queue times at the gate. Where available, camera feeds are provided for other terminals at the Ports of Los Angeles and Long Beach. The Real-Time Data Traveler Information Tool provides all of this information for each stakeholder to access, drawing together all of the data for easy accessibility through one central web site.

The dispatcher also is able to exchange messages with the marine terminal, informing them about future pick-ups. This will be covered in greater detail in the Marine Terminal section.

2.1.1 Driver On-Board Device

The Driver On-Board Device consists of the WebFleet TomTom Telematics System integrated by the TomTom WebFleet web site, the TomTom Pro 7150 Truck Navigation Device, and TomTom Link 510 GPS Tracking Device. This system creates a seamless way to manage orders, communicate with dispatch, report positions, and provide dynamic routing all through the TomTom WebFleet Tracking and Navigation System.

The TomTom Pro 7150 Truck navigation device was placed inside 50 PLG trucks. In collaboration with the Link 510 tracking device, the Pro 7150 receives messages from the dispatcher, through the WebFleet web service (WebFleet Connect API). These messages provide drivers with their scheduled order itineraries, which they can accept and update as they are executed through the touch screen on the Pro 7150 Truck navigation device. These updates will let the Dispatcher know whether or not the Driver has started a job, if the job is in progress, and when the job is completed. Dispatchers also can send and receive unique messages and notifications to and from the drivers through the WebFleet services.

When drivers accept job orders, the Pro 7150 guides them to their destination using GPS technology. The device also offers the capability of dynamic routing, rerouting the drivers in case there is an incident or traffic delay on the road where rerouting would be necessary, always taking into consideration the most efficient truck route to get to the final destination. The device also provides drivers with weather information, delivered through the TomTom web service. The TomTom Link 510 tracking device is installed in every truck and, along with the TomTom Pro 7150 truck navigation device, is used to collect data regarding vehicle position, speed, and idling time, which may allow for stop-time data collection at specific locations to be used for algorithm input.

[2] https://developer.yahoo.com/weather/.

2.1.2 Marine Terminal Notification

Marine terminals play a vital role in the drayage industry. Specifically, terminals in the Port of Los Angeles and Long Beach area are among the ones with the most freight traffic in the nation. Because of this, there is an increasing need to improve their operations in order to ensure the best service possible. The drayage industry has frequently complained about turn times and queues to enter the terminals, even though solutions have been offered in the past like the implementation of PierPass and night and weekend shifts.[3] Because of this, the proposed solution implemented during this project allows marine terminals and drayage companies to interact by exchanging predetermined notifications.

As stated earlier, terminal waiting times (at YTI only) are captured through a service provided by Acyclica. This provides information regarding current and historical queue wait times and terminal turn times, which can be used by the Customized Optimization Algorithm to determine a solution for daily itineraries considering the most appropriate time of the day to go to the terminal. The drayage company can then notify the terminal when trucks would be going to perform a transaction.[4]

As previously stated in the dispatcher web site, a notification system was established with Yusen Marine Terminal. These notifications are shared with Yusen Terminal through a web service linked to the dispatcher web site and the driver on-board device. The notifications are specific for the type of transaction to execute at the terminal, whether it is an import or an export.

There are three primary messages that are sent between the Dispatcher, the Driver, and the Marine Terminal for Import Transactions. They consist of the following:

1. As soon as the customer service representative enters a new order in the system, the system will recognize the location as Yusen Marine Terminal and send a notification message.
2. Once the dispatcher runs the optimization algorithm and the order has been scheduled and assigned to a driver for pick-up, the system will automatically update the notification with a scheduled pick-up date and time, and the name of the driver to execute the order. This will give the marine terminal at least 6 to 12 hours of advanced notice for pending truck arrivals from PLG.
3. The day of pick-up, once the driver starts the order and navigates to the Terminal using the on-board device, an automated message will be sent to Yusen Terminal notifying that the driver is on his way, providing an estimated time of arrival (ETA) calculated based on his current location. This ETA will be determined using the TomTom traffic information provided through the TomTom Pro 7150 Navigation device, considering factors like distance and real-time traffic.

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[3] PierPass is a nonprofit formed in 2005 by a coalition of terminal operators at the Ports of Los Angeles and Long Beach to address ongoing issues such as congestion, security, and air quality. All container terminals at the ports have established five new shifts per week under the program during off-peak hours. As an incentive to use the new shifts and cover their cost, a Traffic Mitigation Fee is assessed on most cargo that is moved during peak hours (Monday through Friday from 3:00 a.m. to 6:00 p.m.).

[4] See Section 2.4.3 for more information about the hardware installed for the test.

Note here that originally the Architecture and Implementation Options report (dated July 31, 2013) stated that the communication with Yusen Marine Terminal was going to be through a web service. However, before the start of development and due to concerns related to the use of web services by Yusen Terminals, it was determined to use FTP as the communication protocol with the Terminal. The FTP service was initially developed, but before the implementation of Marine Terminal Notification via FTP, issues and concerns with the use of web services were clarified and resolved internally by Yusen Terminals. It was therefore decided a web service would be used as the final alternative for the Marine Terminal Notification module. Consequently, Yusen Marine Terminals handed an API to the development team, in order to seamlessly communicate with their systems. As a result, there have been no departures from the system architecture originally proposed in the Architecture and Implementation Options report.

2.2 Level of Effort and Costing Information

2.2.1 Level of Effort

As developed for this test, the FRATIS prototype required 1,600 man-hours for software development, testing, and debugging. Development occurred from July through December 2013. Staff used for development included:

- Two Developers (811 hours);
- Two Testers (491 hours);
- One Project Manager (175 hours); and
- One Designer (123 hours).

2.2.2 Costing Information

Upfront Costs

Upfront costs include those for hardware and software that was purchased to facilitate the test. For the Los Angeles test, this included:

- Fifty TomTom Link 510 units – $14,997.50;
- Fifty TomTom Pro 7150 Truck units – $16,497.50;
- Installation/activation/shipping for above – $7,800;
- Eight Acyclica Bluetooth/WiFi readers and associated hardware for queue detection – $15,998;
- A $2,000 service agreement for Acyclica to ensure the readers function properly throughout the test with minimal downtime; and
- A service fee of $5,000 incurred by YTI to enable the drayage-to-MTO messaging capability; this fee covered integration engineering, including setup of a Lynx web service.

Recurring Costs

Recurring costs covered:

- **Subscription fees for the TomTom system.** A one-year subscription to TomTom WebFleet services was purchased for this test at a cost of $20,592 – this subscription would need to be renewed by participants if they wish to continue using the TomTom services beyond the end of the demonstration test; and
- **YTI web service subscription fee.** YTI has incurred a monthly cost of $750 to run the web service for drayage-to-MTO messaging.

The Los Angeles test utilized a Navteq real-time traffic feed to calculate travel times for the algorithm. Navteq provided this service free of charge for the demonstration test; however, for a larger and/or longer test, a subscription fee may be required.

2.3 Open-Source Publication

All software developed within this task order will be released as open source through the OSADP, excluding proprietary code or COTS software used in the task order. All personally identifiable information (PII) will be removed prior to publication to protect users, per the requirements of the OSADP.

2.4 Prototype System Elements and Detailed Design

This section describes the hardware, software, and external service requirements for the FRATIS development.

2.4.1 Hosted Infrastructure

The FRATIS Prototype is hosted in the Amazon Web Services (AWS) cloud, powered by a Microsoft Server virtual machine, leveraging Internet Information Services 7 and the Microsoft .NET Framework Version 4.5. A single-server instance is hosting all web and FTP sites/services developed for this project.

For the Marine Terminal Notification System, integration has been achieved through a Representational State Transfer (RESTful) web service developed and hosted by YTI. This service provides bidirectional data exchange between the marine terminal and dispatcher. Utilizing the methods provided by the YTI web service, the following operations are supported:

- Query import container availability;
- Job confirmation; and
- Driver dispatch notification.

The dispatcher web site persists the last successful synchronization time for orders that are being reported via the above-referenced web service. A background updates the status of relevant orders, periodically calling out to the marine terminal in order to update the availability status and report estimated arrival times.

The integration between the dispatcher web site, the optimization algorithm, and the marine terminal web service delivers key functionality in regards to order/container availability status checking, and planned execution time reporting, that should be of significant benefit to interested parties.

Figure 2 (taken from the *Architecture and Implementation Options* report) illustrates the web infrastructure architecture for the FRATIS Los Angeles tool.

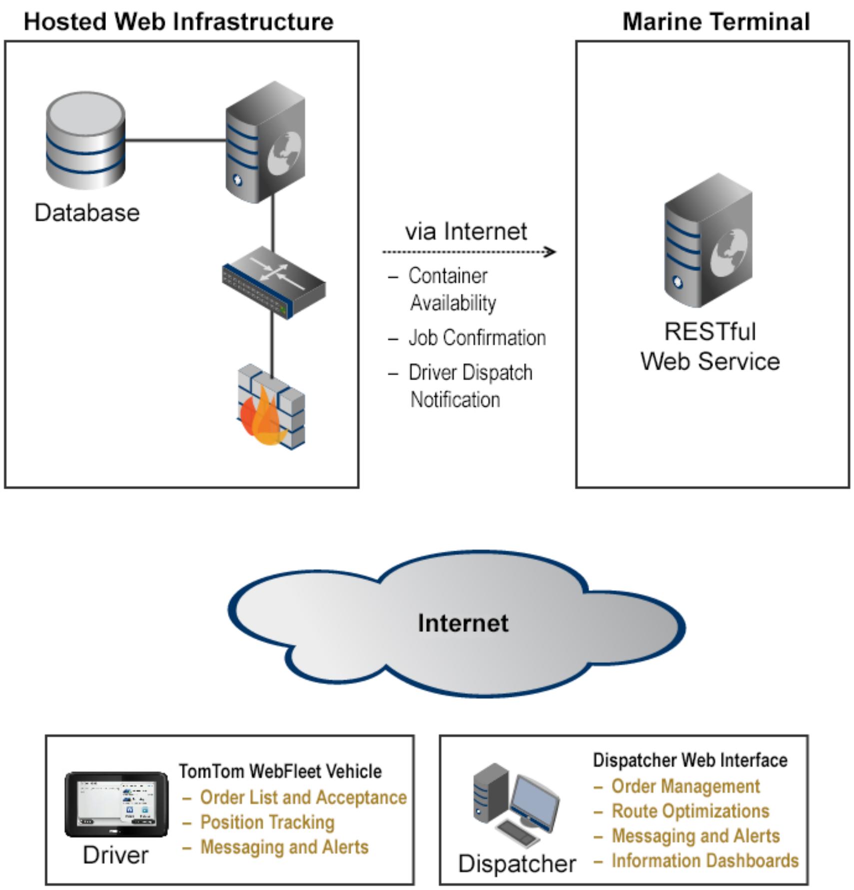

Figure 2. Los Angeles-Gateway FRATIS Web Infrastructure (Source: Productivity Apex Inc.)

2.4.2 Software Requirements

Table 1 details the software requirements per FRATIS system component.

Table 1. Software Requirements per Component/Subsystem

Core System Component	Technology
Web Site	Microsoft Server Operating System Microsoft IIS 7 Web Server (Internet Information Services) Microsoft .NET Framework Version 4.5 MVC Web Site (Model-View-Controller)
Object Persistence	Microsoft .NET Framework Version 4.5 Microsoft Entity Framework Version 5
Database/Repository	Microsoft SQL Server 2008 R2
Optimization Algorithm	Microsoft .NET Framework Version 4.5
Marine Terminal Data Exchange	RESTful Web Service – ASP.NET Powered

2.4.3 Hardware Requirements

The hardware used during this project consists of the following:

- **TomTom Link 510 GPS Tracking Devices –** 50 tracking devices were installed on PLG's truck fleet. Installation was completed on August 21, 2013. These devices go under the dashboard of each truck and are Bluetooth-enabled for communication with the TomTom navigation devices.
- **TomTom Pro 7150 Truck Navigation Devices –** 50 of these devices also were installed on PLG trucks, with installation completed on February 14, 2014. All units were successfully paired with the Link 510s.
- **Acyclica readers and associated hardware –** Seven readers were installed around the YTI terminal, one each at the overflow yard, the entrance booth, booth 2, booth 5, the bobtail entrance, the roadability check area, and the terminal exit. Ancillary hardware required for installation included mounting hardware, bidirectional antennae, antenna cable, reader enclosures, three WiFi network bridges, and a GSM modem. Installation was completed by July 9, 2013.

No problems were encountered during device installation.

The details of the specifications of these devices can be found in the FRATIS Los Angeles-Gateway Demonstration Plan. The reason for the selection of this hardware is because they form part of a suite of products from TomTom Business Solutions, called TomTom Telematics, which offers an open API that allows integrating in a seamless way with their technology and using their tracking, navigation, dynamic routing, and messaging capabilities.

2.4.4 External Services

As described in the *Architecture and Implementation Options* report, a number of external services are required to enable key FRATIS functions. These are shown in Table 2.

Table 2. FRATIS Los Angeles-Gateway Prototype External Services

External Service	Description
Vehicle Reporting and Order Management	TomTom WebFleet Connect SOAP/REST External Service • Vehicle Reporting • Order Management • Messaging and Notifications • Driver/Route Reporting
Mapping and Traffic Reporting	SOAP/REST External Service • Estimated Time-of-Arrival Calculations • Distance Calculations • Incident Reporting
Marine Terminal Waiting Times	SOAP/REST External Service • Reporting of Predicted/Actual Waiting Time
Weather Conditions	SOAP/REST External Service • Live Conditions • Severe Weather Alerts • Weather Forecast
Marine Terminal Data Exchange	SOAP/REST YTI Web Service • Container Availability • Job Confirmation • Driver Dispatch Notification with ETA

2.5 Test Support and Procedures

A series of tests were performed over the different stages of the project: during development, predeployment, and postdeployment. This ensures the functionality of the system and demonstrates the effects associated with the system implementation.

A list of the core programming test procedures performed on the FRATIS System during the development stage is presented in Table 3. Unit tests were performed by developers through the entire development process, from the initial design and implementation of relevant services, through the final iteration, to assure functionality was never broken.

Table 3. FRATIS Los Angeles-Gateway Software Development Test Procedures

Test Type	Services Being Tested	Test Names
Unit Tests	Calculation Tests	• Numeric Conversions • Geoconversions: Latitude/Longitude, Z/X/Y, Quadkey • Distance/Euclidian Distance • Taxicab Tests
	Optimization Algorithm	• Pheromone Matrix Tests • Probability Matrix Tests • Node Connection and Timing Tests • Feasible Route Solution Tests • Statistic Service Tests
Integration Tests	Data and Database Integration	• Database Interactions • Entity Framework • Can Save to Backend • Can Update Records on Backend • Can Delete Record on Backend
	Optimization Algorithm	• Solution Testing • Sample Data • Test Solution Results • Test for Infeasible Solutions • Test Output with Traffic Logic • Test Output without Traffic Logic
External Service Tests	Weather	• Can Get Weather for City • Can Get Critical Advisories • Can Get Wind Conditions
	Traffic	• Can Get Incidents within Region • Can Get Traffic Image Overlay • Can Estimate Travel Time with Traffic • Can Fetch Historical Traffic Data • Can Predict Future Traffic Data
	Location and Distance	• Can Get Distance between Points • Can Get Travel Time between Points
	Video	• Can Access External Video Source • Valid Image Returned from Source
	Mapping	• Can Plot Multiple POI on Map Image
	Marine Terminal Web Services	• Can Connect to External Web Services • Can Query Container Availability • Can Confirm Job • Can Report Dispatch with ETA

2.6 Assessment of Scalability

The architecture of the FRATIS Los Angeles tool can be easily scaled up to handle a larger user base. The FRATIS prototype is hosted in the Amazon Web Services (AWS) cloud. Leveraging the power and benefits of Microsoft's IIS Web Server, Microsoft SQL Server and the .NET Framework, the application must be hosted on Microsoft Server operating systems. As a virtualized hosting environment, it is relatively simple to take a "snapshot," or disk image, of the existing servers and redeploy them to alternate geographic locations, or to scale both horizontally and vertically. For horizontal scalability, and to provide a fault-tolerant solution hosted in multiple availability zones, the Elastic Load Balancer (ELB) should be used. The use of a load balancer allows for incoming requests to be distributed among a cluster of IIS Web Servers, and for ongoing health checks to be performed against each server instance, removing unhealthy servers from the pool. Similarly, the MS SQL database server can be hosted using Amazon's Relational Database Service (RDS), which offers out-of-the-box master/slave database configurations across multiple geographic regions. Finally, a distributed caching system can be implemented using the ElastiCache service, which is powered by open-source Memcached, to further improve service performance.

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