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OPEN-SOURCE SOFTWARE FOR OPTIMIZING MED PORT TERMINAL LOGISTICS PROCESSES

Buiza Camacho, Gracia [1]; Tsertou, Athanasia [2]; Martín Encinas, Enrique [1]; Amditis, Angelos [2]; Latsa, Evangelia [3]

[1] Instituto Andaluz de Tecnología, [2] Institute of Communication and Computer Systems, [3] SEAbility

Mediterranean (MED) port terminals are major logistics hubs for the circulation of goods, not only within the MED basin but also connecting European countries with key Asian ports. The efficiency of operations inside the port terminal as well as the connection of the terminal to its attached logistics areas are a constant challenge for the port operations personnel. New technologies are a vital instrument in this process. In the framework of INTE-TRANSIT project, two different open-source based software were developed: the first one which is pilot-demonstrated in the ports of Piraeus (Greece), Valencia (Spain) and Luka (Slovenia) aims to automate and improve container and yard equipment monitoring and visualization; the second one which is pilot-demonstrated in the Algeciras Bay logistics area (Spain) as well as the port of Naples (Italy) targets an increased cohesion between the port terminal and its regional and local networks and calculates a range of Key Performance Indicators (KPIs) affecting the corresponding operations. Both tools are based on an open and modular architecture, have different mapping capabilities in order to fit different port requirements and, finally, offer flexible configuration options to the user.

Keywords: *ports; dashboard; container; yard; monitoring; management*

SOFTWARE DE CÓDIGO ABIERTO PARA LA OPTIMIZACIÓN DE LOS PROCESOS LOGÍSTICOS EN LAS TERMINALES PORTUARIAS DEL MEDITERRÁNEO

Las terminales portuarias del Mediterráneo son grandes centros logísticos para la circulación de mercancías, tanto en el Mediterráneo, como conectando países europeos con puertos asiáticos claves. La eficiencia de las operaciones en la terminal portuaria, así como la conexión de ésta con sus áreas logísticas son un reto constante. Las nuevas tecnologías son un instrumento vital en este proceso. En el marco del proyecto INTE-TRANSIT, se desarrollaron dos paneles de control basados en código abierto diferentes: el primero, implementado en los puertos de El Pireo (Grecia), Valencia (España) y Koper (Eslovenia) tiene como objetivo automatizar y mejorar la monitorización y visualización de los contenedores y los equipos de patio; el segundo, que se ha implementado en el área logística del Puerto Bahía de Algeciras (España) y en el Puerto de Nápoles (Italia), está orientado a conseguir una mayor cohesión entre la terminal portuaria y sus redes regionales y locales y calcula una serie de indicadores clave de rendimiento (KPIs) relacionados con dichas operaciones. Ambas herramientas se basan en una arquitectura abierta y modular, tienen diferentes capacidades de mapeo con el fin de adaptarse a diferentes requisitos de puertos y ofrecen opciones de configuración flexibles al usuario.

Palabras clave: *puertos; panel de control; contenedor; patio; equipo*

Correspondencia: Gracia Buiza Camacho gbuiza@iat.es

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1. Introduction

Mediterranean (MED) port terminals are major logistics hubs for the circulation of goods, not only within the MED Basin but also connecting European countries with key Asian ports (Fageda, 2000).

At the heart of these supply chains, maritime ports play a key role as an interface between European markets and the rest of the world. The major European Seaports are now landlord ports. They increasingly invest directly or indirectly in better inland connections to their hinterlands, encouraging a more sustainable and secure transport. For them it is essential to be more efficient by automating processes and operations using new technologies. The integration of maritime and hinterland transport chains through ports requires a smoothening of the corresponding information flows via electronic platforms (Cassandra, 2011).

IO the other hand, the majority of container terminals face so many difficulties in measuring performance appraisal and also environmental evaluation, resulting from management attempts to match organizational performance and strategic goals. For this reason, the port authorities and maritime organizations realized that an acceptable development can be carried out by using Balanced ScoreCard (BSC) for measuring competitive advantage of a port and its container terminal (Divandri et al., 2011).

Information sharing is the key to increase the efficiency of operations inside the port terminal. It provides the basis for the controlling of logistics-related operations and for seamless supply chain integration (Tapaninen et al., 2010). Information in the supply chains is used to prevent uncertainty that is related to lead times, capacity availability and product quality (Ketzenberg et al., 2006). Information sharing improves supply chain coordination, reduces a bullwhip effect, decreases supply chain costs, and makes it possible to respond to changing customer needs more quickly (Ketzenberg et al., 2006). Information shared in the supply chain has to be of good quality. This contains aspects such as accuracy, adequacy, completeness, credibility, accessibility, compatibility between users and timeliness (Monczka et al. 1998). The highest gain from information sharing is achieved when every actor in the supply chain contributes to information exchange and a full transparency in the chain can be implemented attained (Posti et al., 2011; Pulli et al., 2007).

The importance of information sharing is emphasized in the ports where multiple transport modes, shipments and actors are present. The information exchange between different port-related actors is often cumbersome and it still involves a lot of manual work and paper. Generally at each port call, the same data has to be entered several times and often manually, which may cause errors and delays and waste resources. Some studies have also shown that port-related actors do not get all the information they need in their activities (Pulli et al., 2007).

For this reason, innovative ICT technologies (including interoperable web platforms and emerging technologies such as RFID, OCR or GPS) are essential to share accurate and timely information in real time and have proven of great assistance to tackle MED/EU port challenges regarding logistics and communication systems.

This article describes the open source software designed in the INTE-TRANSIT project, co-funded by the Regional European Development Fund under the MED program. The basic objective is to improve the information management systems that are currently used in the ports and their logistical activities zones, through open source software and an integrated management model. Specifically, this article will make reference to the work carried out in Algeciras Bay, Naples, Valencia, Piraeus and Luka Koper.

Two different main management systems have been designed in the INTE-TRANSIT project and implemented in port and logistics facilities (INTE-TRANSIT, 2015):

- A) The INTE-TRANSIT management system (ITMS) that it is a low-cost, yet high accuracy client-server system, suitable for improving the efficiency of port terminals, through an enhanced monitoring of the containers as well as of the yard equipment (trucks, straddle carriers, reach stackers, etc).
- B) The INTE-TRANSIT Manipulation Detection System of the trucks' flow between ports and their logistic area. Additionally, a dashboard to show the values and evolution of the key performance indicators (KPI) linked to this flow has been designed to collect and integrate the information generated by this detection system.

2. Objectives

To improve the management in port terminals on the base of the information management, this study considers two complementary groups of activities (A and B) with the following specific objectives:

- Group A: To get an efficient and accurate management of the storage procedure of containers inside a port terminal area at a minimal cost and an always up-to-date inventory of the stored containers.
- Group B: To get an efficient and accurate monitoring of goods between port and the inland terminals. This specific objective responds to the needs of allowing containers/vehicles to clear procedures in the customs facilities inside a Logistic Area located at a certain distance from the port and ensure the control of the flow of goods in the route between these two localizations.

3. Methodology

To get the objectives set in the study, two different systems were developed. The methodology and tools used in each case are described below:

3.1 Group A Management Server

In order to meet the objectives of the study, the ITMS server consists of several well defined layers of operation. Each of these layers of operation operates independently, while also having the ability to robustly communicate with its neighboring layers, designed to ensure efficiency and reliability under heavy workloads. The architecture layers are described in what follows:

- A Middleware gateway is designed to maintain all information exchange activities between the web based user interface and the core software of the ITMS through the utilization of secure web service calls. The middleware gateway is actually in its most part a web application server written in Java, implementing SOAP (SOAP, 2015)-based web service calls. The motivation between using web service calls in the gateway is that any part of the application outside the port authority's ITMS closed network and wishing to access it, will need to invoke (after passing through OpenSSL (OpenSSL, 2015) based authorisation) web service calls in order to complete the transactions. Moreover, the gateway also serves in this application server in order to do so. Data conversion module: Responsible for data formatting and conformance. This module is responsible for the necessary conversions between different data formats to avoid misinterpretation of data. This module will provide the required functions to convert data when necessary to the end user or the system itself.

- A core software agent implements the "business" logic of the ITMS, maintains a connection to a Data Base Management Server (DBMS) in order to store and manage container and yard equipment positioning and identification information. It also implements all the required communication interfaces for the exchange and translation of data between all data sources (RFID, DGPS, DBMS, and Graphical User Interface (GUI)). The core software agent which is the 'brain' behind the ITMS server encompasses different functionalities. In particular, it maintains, through threads, a set of socket network interfaces responsible of connecting with local and remote data sources. This module maintains permanent socket connections with the terminal clients as well as socket connections that expire after a certain time. Moreover, it includes truck positioning module, which is responsible for assisting the positioning of trucks and reach stackers inside the port terminal yard. In particular, it coordinates (by correlating the retrieved location and identification data to actual coordinates and equipment IDs) the terminal client devices inside trucks and reach stackers during their operation of assisting the proper storage of containers inside the designated areas of the port. The positioning data received by DGPS modules and the container identification information received by the RFID readers is cross-referenced with block/bay/row grid data and equipment ID information stored in the database.
- The hardware management endpoints include all the client software required to maintain the interconnection between the hardware elements that retrieve information (DGPS receivers, RFID readers) and the core software of the ITMS.
- The ITMS server GUI has been developed in such a way so as to provide the end-user with useful information and at the same time to be user-friendly in its usage. For that reason, the GUI has been organized into five sections (Figure 1):

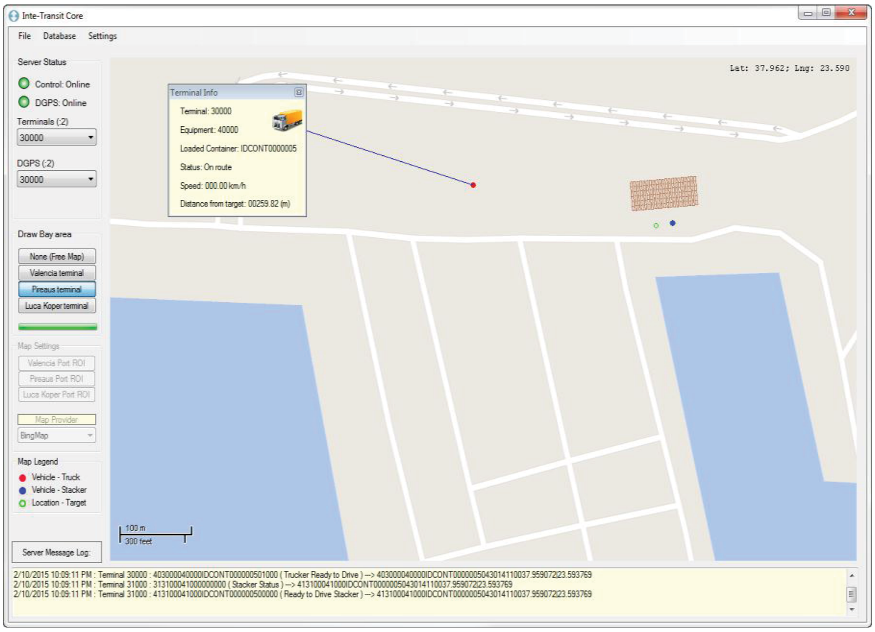


Figure 1: The INTE-TRANSIT Management Server GUI in Piraeus pilot.

- **The “Connectivity Status” area:** In this area the user is being provided with information about the current network connection status of the server. Both the Control and DGPS modules are referenced in this area. Also, in this section the server provides the user with information about the connected client terminals as well as the connected DGPS modules. The user has the option to select between the connected client terminals and view specific information about a particular vehicle.
- **The “Drawing Bay” and the “Map Settings” area:** In this area the Server provides the user with the options of drawing the Bay Areas of the selected Container Terminal as well as moving the GIS Map’s view to that particular Terminal. The drawing procedure of Bay Areas is based on the actual coordinates of every Bay, giving maximum viewing and calculating accuracy.
- **The “GIS Mapping” area:** In this area the server displays the GIS Map where the current activity of the ITMS is displayed. Every connected vehicle is spotted on the GIS Map in real-time and the user is provided with information about a vehicle’s current job status, location, assigned container etc.
- **The “Message Log” area:** In this area, the server keeps a log file with information about the exchanged communication protocol frames between the server and all connected clients. The operator of the ITMS server may hide this area or make it visible depending on whether they want to operate it in debugging mode or in a normal operations mode.
- **The “Container Search” area:** This feature gives the ability to an administrator user to collect information about a specific container through the ITMS Server’s GUI and can be used for container planning, tracing and monitoring purposes. The Container Search engine is implemented through an interactive form where the user has the following options:

Apply Search Filters: The user is given the option to apply search filters based on their needs. Depending on the applied filters the search engine will make queries from different points of the database (i.e. stored or pending containers). Furthermore, the search engine can make queries for currently assigned / on-going containers.

Enter a keyword: The search engine asks the user for a specific keyword to look for (i.e. a container ID).

Search by Container or Location ID: The user is also given the option to search either by Container ID or by Location ID. In this way the search engine is more flexible and the user can retrieve information like which container is stored (or is to be stored) at a specific location of the Bay Area.

3.2 Group B Manipulation Detection System of the truck's flow between ports and their Logistic Area

The Manipulation Detection System is an open-source platform which aims to monitor the cargo flow from the exit gate of the logistics area (ZAL) to the arrival at the port terminal. During the movement of the truck, the system controls if it:

- Goes out of the predefined route.
- Drives with a low speed.
- Stops along the route unexpectedly.
- Has not GPS Data in one or more points along the route.

The system uses signals emitted by a GPS system located on the truck during its trip and checks if there is any strange or suspicious behavior that makes a manipulation of the goods transported possible. The final output linked to each trip is: “route with incidents” (so the user cannot trust on the goods transported, they have been able to be manipulated) or “route without incident” (the user can trust on the goods transported).

The system is formed by a server where all data and the basic configuration are stored. This server is connected to the Internet using a router to:

- Communicate with the GPS devices.
- Publish the User Interface Tool to the Network.

There is no need of desktop applications in the user´s computer.

It is relevant to highlight that the access control based on a plate license recognition system gives extra possibilities triggering the monitoring system when a truck leaves ZAL. Additionally, the system is prepared to control if a truck and its cargo, before leaving the ZAL, has all the documentation required by the port authority. If a truck tries to leave this area without this documentation, the control access system will stop it.

Finally, at the end of the trip, if the system certifies “route with incidents“, the control access system stops the truck before getting in the port area.
The other hardware element used in the system is the GPS device. The study has used mobile phones and has developed an Android Application that collects GPS data and sends them to the server.

All the software elements have been built with free and open source tools such as: Java as the programming language, PostgreSQL as the Data Base Server Engine, Tomcat as web server and servlet container, Foundation (a Java HTPP web server), Java Server Faces (a Java specification for building web applications), Prime Faces (a component library for Java Server Faces), JQuery (a JavaScript library designed to make friendly client-side web page, create animation, handle events and develop AJAX applications), OpenStreetMap (a collaborative project to create a free editable map of the world), Open Layers (an open source JavaScript library for displaying and managing maps in web browsers) and Java Topology Suite (an open source Java library which provides an API with geometric functions).

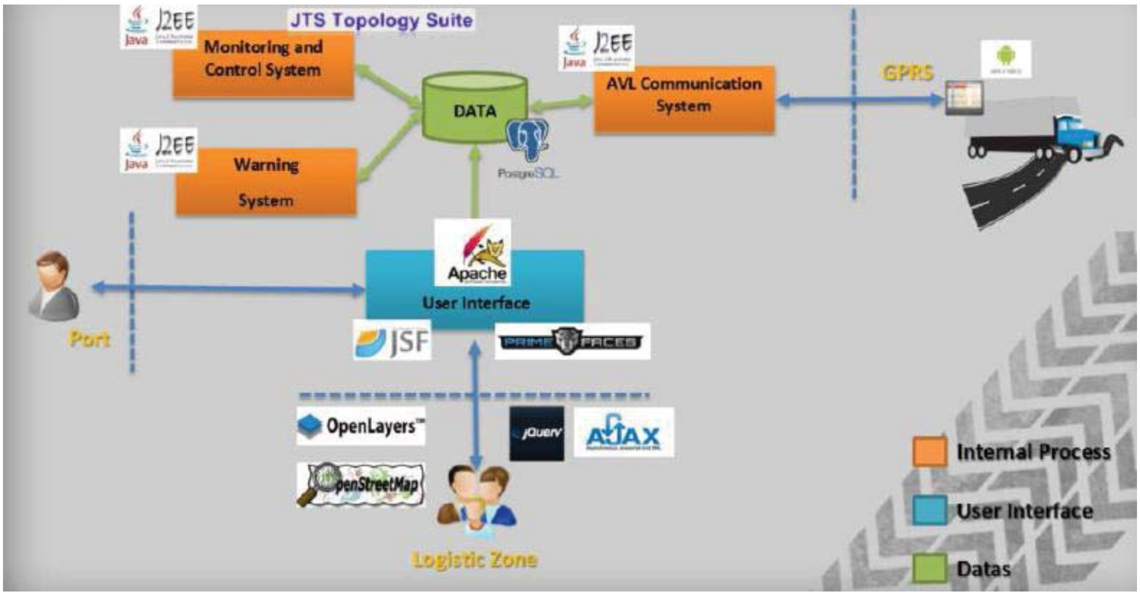


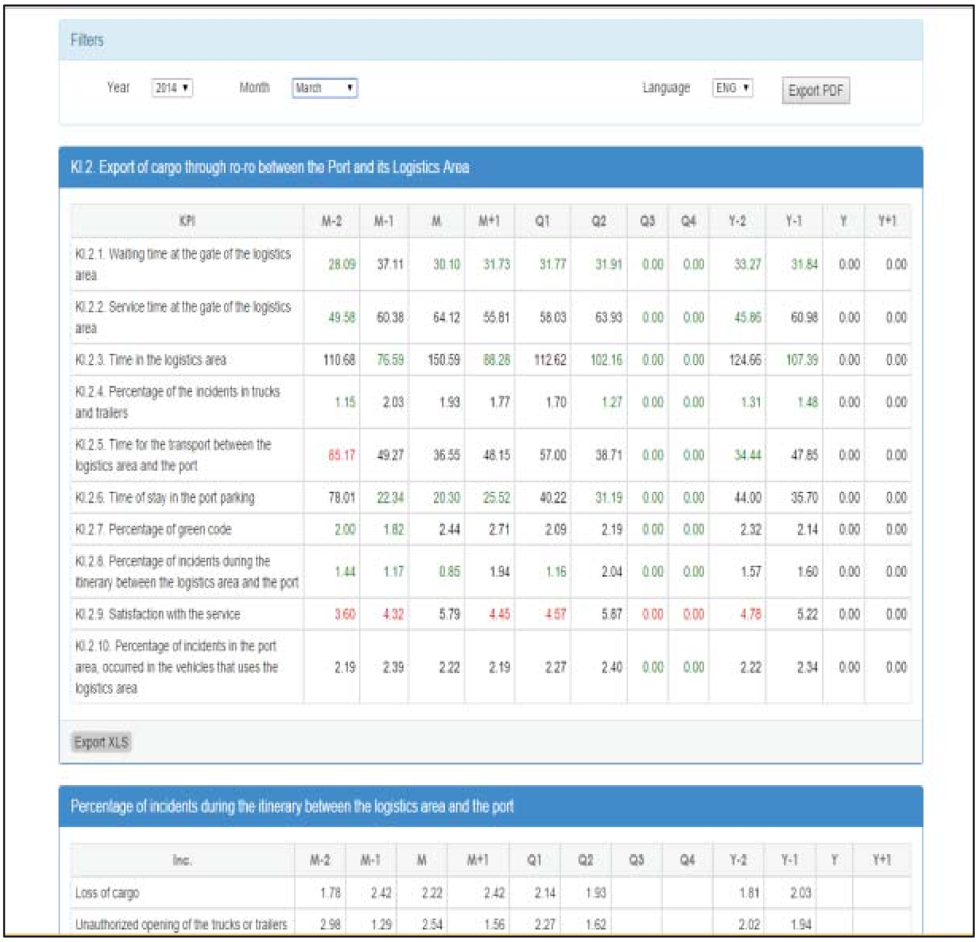
Figure 2.System components: Hardware and Software. Group B Manipulation Detection System.

The main software elements of the system are (Figure 2):

- An application which communicates with the GPS device.
- The monitoring and control process. It collects the GPS data for applying the rules defined for the route and that allow deciding if a trip can be considered as "trusted" or not.
- The Warning System which is responsible for sending the information to the user via SMS or email.
- The WEB User Interface.
- The Data Base which is not only an information repository but an element that allows the communication between the processes, using SQL queries.

This system has been integrated in a dashboard designed with a Business Intelligence platform, Pentaho (Figure 3). It gives the user the KPIs values to contribute to the decisions making by managers. We used the Value Stream Mapping tool (VSM) and the standards such as: ISO 9001 (about Quality Management Systems), ISO 14001 (about Environment Management Systems) and ISO 28000 (about Security

Management Systems for the supply chain) to define the KPIs linked to the process of cargo transport from the port to the ZAL (González et al, 2014).



KPI	M-2	M-1	M	M+1	Q1	Q2	Q3	Q4	Y-2	Y-1	Y	Y+1
KI.2.1. Waiting time at the gate of the logistics area	28.09	37.11	30.10	31.73	31.77	31.91	0.00	0.00	33.27	31.84	0.00	0.00
KI.2.2. Service time at the gate of the logistics area	49.58	60.38	64.12	55.81	58.03	63.93	0.00	0.00	45.86	60.98	0.00	0.00
KI.2.3. Time in the logistics area	110.68	76.59	150.59	88.28	112.62	102.16	0.00	0.00	124.66	107.39	0.00	0.00
KI.2.4. Percentage of the incidents in trucks and trailers	1.15	2.03	1.93	1.77	1.70	1.27	0.00	0.00	1.31	1.48	0.00	0.00
KI.2.5. Time for the transport between the logistics area and the port	65.17	49.27	36.55	48.15	57.00	38.71	0.00	0.00	34.44	47.85	0.00	0.00
KI.2.6. Time of stay in the port parking	78.01	22.34	20.30	25.52	40.22	31.19	0.00	0.00	44.00	35.70	0.00	0.00
KI.2.7. Percentage of green code	2.00	1.82	2.44	2.71	2.09	2.19	0.00	0.00	2.32	2.14	0.00	0.00
KI.2.8. Percentage of incidents during the itinerary between the logistics area and the port	1.44	1.17	0.85	1.94	1.16	2.04	0.00	0.00	1.57	1.60	0.00	0.00
KI.2.9. Satisfaction with the service	3.60	4.32	5.79	4.45	4.57	5.87	0.00	0.00	4.78	5.22	0.00	0.00
KI.2.10. Percentage of incidents in the port area, occurred in the vehicles that uses the logistics area	2.19	2.39	2.22	2.19	2.27	2.40	0.00	0.00	2.22	2.34	0.00	0.00

Inc.	M-2	M-1	M	M+1	Q1	Q2	Q3	Q4	Y-2	Y-1	Y	Y+1
Loss of cargo	1.78	2.42	2.22	2.42	2.14	1.93			1.81	2.03		
Unauthorized opening of the trucks or trailers	2.98	1.29	2.54	1.56	2.27	1.62			2.02	1.94		

Figure 3. Example of a dashboard´s screen which provides the KPI´s values linked to the transport of cargo between the port and its ZAL.

4. Case study

The scenarios that have been implemented and tested in the Group A pilot activities and specifically in the Piraeus port, are the following:

- New Container insertion and registration to the Server's database.
- Container assignment to a truck vehicle and transport to Bay area.
- Container assignment to a reach stacker vehicle and storage.

The above scenarios involve extended testing of the ITMS Server as well as of the Client functionality in conjunction with the hardware equipment installed to the pilot vehicles and their corresponding assignments:

- The ITMS Server software and its modules is installed and running under a windows-based computer with access to the existing network infrastructure of Piraeus Container Terminal.

- The ITMS Client software is installed and running under a windows-based tablet or rugged portable personal computer which is placed inside the corresponding Pilot's vehicle.
- The DGPS Base Station serves as a reference point to a known geographical point. It is implemented through a GPS receiver connected to a windows-based computer at the Pilot site running the RTKLib (RTKLib, 2015) software. The data collected from the RTKLib are provided to every ITMS Client through the existing network infrastructure.
- The installation of client terminal hardware on the vehicles of the yard (1 truck and 1 reach stacker, RS).

The scenario execution at the Piraeus Pilot is according to the following map diagram: According to Figure 4, a truck vehicle (red line) is loaded with a container and requires assignment from the ITMS server. The server assigns the job to the truck and instructs to transport the container to the intermediate location pointed by the green circle.

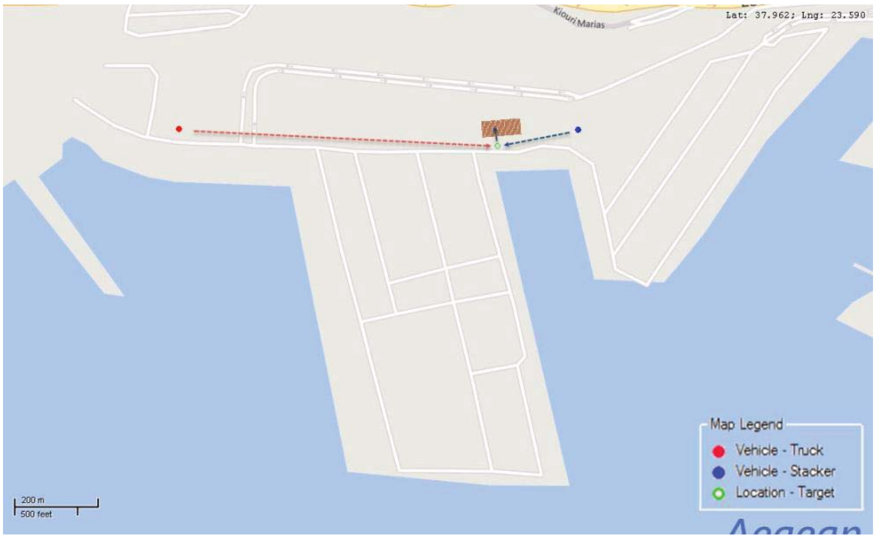


Figure 4: Schematic diagram of Piraeus pilot scenario.

At the same time a RS (blue line) requires assignment by the server, which on turn instructs it to move to the intermediate location (green circle).When the truck reaches the designated location the server will respond by informing the corresponding client that it reached its destination and wait for the RS to arrive. The RS client terminal will also be informed by the server when it arrives at the meeting location. At this point the RS will unload the container from the truck and the stacking procedure will be initiated by the server. When the container is positioned above the designated stacking location (brown-marked area) the server will inform the client and the vehicle's user will store the container at this bay. Both vehicles are released by the server when their corresponding job is successfully completed.

The above scenario has been executed with a successful bidirectional communication between the ITMS server and the vehicles client terminals.

Each client's job execution is logged by the server for further analysis according to the message format which has been defined as per the pilot requirements:

01/30/2015 2:03:37 PM: Terminal 10000: 100100000000000 (Trucker Error)

01/30/2015 2:03:38 PM: Terminal 10000: 301000010000IDCONT2XXXXXX01000 (Trucker Status)

01/30/2015 2:03:44 PM: Terminal 10000: 401000010000IDCONT2XXXXXX01000 (Trucker Ready to Drive)

01/30/2015 2:03:58 PM: Terminal 10000: 501000010000IDCONT2XXXXXX23H00220100 (Container Undocked)

01/30/2015 2:04:37 PM: Terminal 60000: 316000060000000000 (Stacker Status)

01/30/2015 2:05:00 PM: Terminal 60000: 416000060000IDCONT2XXXXXX00000 (Ready to Drive Stacker)

01/30/2015 2:05:36 PM: Terminal 60000: 516000060000IDCONT2XXXXXX23H00221100 (Stacker Reached Location)

01/30/2015 2:05:37 PM: Terminal 60000: 1116000060000IDCONT2XXXXXX23H00221000 (Stack Location Ack)

01/30/2015 2:07:03 PM: Terminal 60000: 716000060000IDCONT2XXXXXX23H00220120 (Container Stored)

5. Conclusions

The importance of having the appropriate data to support the decision making and to optimize the management in seaports is a fact accepted internationally. Ports play a key role connecting markets and need to be more efficient. Their efficiency is a key factor in the supply chains. The developments and implementations in this study are oriented to get useful information for the port terminal managers to achieve this objective.

On one hand we focus on the container yard of a port terminal (group A) and on the other hand on the route between a port and its ZAL located at a short-medium distance from it (group B).

Regarding the group A, the primary objectives of the container tracking are the physical localization and the terminal processes optimization. Nowadays, this activity is mainly performed by human operators. In this paper, the software architecture including all architectural elements of the ITMS was presented in detail, illustrating the open and modular system as well as the design principles followed.

The main purpose of the ITMS is to obtain-retrieve data (container identification, truck id information, positioning data, control actions status) from all communication endpoints such as DGPS receivers, RFID readers; managing the storage procedure of a container inside the storage areas of the port authorities and also keeping a detailed inventory of the stored containers while also providing the ability to a remote user having all this information properly displayed and visualized inside a GUI.

These functionalities were combined with a user-friendly visualization tool for yard equipment positioning and jobs, offering various and configurable mapping capabilities (a container research functionality and remote access for the system operator in almost real-time).

Regarding the group B, our project offers to managers the benefits of using a dashboard able to integrate to other software such as the Manipulation Detection System of the trucks flow that provides data to calculate the KPIs.

The results of the group B project could be very useful in some particular cases where an appropriate control and monitoring of the cargo in the route between the port and its ZAL is key to ensure that it has not been manipulated. Some of these cases could be:

- Live animals: This category is a very special cargo in ports because it needs very specific waiting areas: they must be provided with water, food, etc. and the waiting area for export cannot be close to the import one because the health regulations.
- Low value goods: They cannot stand the cost due to delays because they have a very low profit margin.
- Dangerous Goods: They require enabled enclosures for waiting. If there is no such an enclosure into the port area, this type of good has the paradox that it cannot be into the port, but at the same time it has to be into the port to send the documentation to Customs.
- Transit traffic to a Free Zone: These goods require a double control, out of the port and at the entry of the Free Zone, despite of being close in distance.

Bearing in mind these scenarios, it is easy to think that a controlled area outside the port could facilitate this kind of traffic and to have a cargo tracking and tracing system would be a requirement to avoid the manipulation of the goods while they are transported between the port and this ZAL. Additionally, this should be developed under conditions of low investment and easy implementation, use of mature and accessible technologies and high reliability. It is important to take in account that ports and their ZAL are used to be managed by public administrations and those requirements are applied by them usually. This system, giving responds to all these conditions, has been the result of the Group B.

Although other projects have been developed in this port environment, our project is unique in that it has a holistic and complete vision regarding the port terminal needs which are: to improve their competitiveness, adapting new technologies for a better and more secure cargo tracking, to pursue developments based on international standardization and interoperability mechanisms as well as on open source tools, to actively involve different agents participating in the processes and sharing information (terminal operators, logistics area manager, port authorities, etc.) and to contribute to a more sustainable port activity.

This way, we applied an innovative integrated approach to overcome the fragmentation of knowledge and vision, towards the promotion of a new information management system based on open sources software for the ports. Our approach allows improving the logistics operations on the base of cargo monitoring.

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