A Flexible Platform for Intermodal Transportation and Integrated Logistics

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***Abstract*— This paper proposes an application of Information and Communications Technology (ICT) tools and Internet of Things to support intermodal transport and integrated logistics. In particular, the design and development of a new ICT platform is presented in order to facilitate the connectivity of the logistics systems, applications or objects from stakeholders to any logistics collaborative environment. The proposed platform aims to *i*) provide technological solutions to enhance and simplify collaboration among actors along the supply chain; *ii*) adopt and provide core functionalities to improve, optimise and automate transport and logistics operations within supply collaborations; *iii*) simplify information exchange within an integrated security framework. Finally, we show a case study in order to enlighten the effectiveness of the proposed ICT platform.**

Keywords—Intermodal Transportation System, ICT tool, Logistic Platform.

I. Introduction

Intermodal transportation and integrated logistics are characterized by the use of different transportation modes carrying goods in the same loading unit or vehicle.

In the past, expensive efforts are performed to enable data sharing in Intermodal Transport Network (ITN) [1]. Today, new technological solutions are creating a new business reality: the actors create, use, and interact with multiple types of content, data, and digital resources via Web. This digital disruption reduces the complexity of integration efforts: *i*) enabling new services; *ii*) accelerating and extending existing services; *iii*) interacting both with private companies and SMEs [2], [3]. Indeed, Liu *et al.* [4] demonstrate how to use Information and Communications Technology (ICT) tools can get more profit than the independent operation. In [5], [6] the authors propose a discrete event system model in a Petri net framework for study the ferry terminal of Trieste (Italy) that is described and simulated in different operative conditions characterized by different types of ICT solutions and information and chronicity and highway congestion near the Inland terminal of the Trieste port. Another ICT application is presented by [7] that proposes a wireless vehicular network to support road haulage and port operations in a multimodal logistics environment.

In the industrial world, the diffusion of ICT allows radically re-organizing the supply chain production in an integrated way: design, job organization, product control, marketing and sales, customer relationship and the next maintenance can be managed and monitored in real time through clusters for Internet of Things (IoT).

Recently, practitioners and researchers are attracted by the key problem of using effectively and efficiently the latest developments of ICT and IoT tools for the ITN tactical and operational management [8], [9], [10], [11].

The study on Decision Support Systems (DSSs) for the ITN and integrated logistics has been particularly important and developed in [12], [13], [14] and [15].

In particular, in [12] and [13] the authors specify a cloud-based cooperative DSS that aims at integrating logistics management and decision support strategies for intermodal transportation systems. Mattei G. *et al.* [14] propose a GIS-based Decision Support System (IFDSS) to support policy makers in evaluating the impact of technological, infrastructural or legislative actions in the freight transportation framework. The IFDSS analyses different policy measures and intermodal scenarios configurations to optimize the choice of paths and transport modes. On the other hand, paper [15] is an example of DSS used to manage the truck transportation routing in different frameworks.

Moreover, the contribution [16] introduces a language, implemented by web service and usable in cooperative logistics, for specifying the possible truck routes and, subsequently, finding an order relation between the routes and their requirements.

In addition, the implementation of IoT in logistic services [17] is needed for increasing competitiveness leading to the establishment of the so-called “smart logistic transport”. The paradigm of IoT includes numerous technologies, characterized by several degrees of maturity: passive RFID, active RFID, Personal communication, Wireless Bus, Wi-fi, RMLP, PLC, Cellular network [18].

This paper focuses on the design of a new ICT platform, able to achieve a cloud based cooperative logistics ecosystem. More in detail, the platform is proposed as a user-configurable and secure intelligent dashboard, where information flows, which are provided by multiple sources, can be collected, organized, connected, manipulated and used depending on the role of the logistics and supply chain actors [19], [20]. Through the intelligent dashboard, each actor in the supply chain can easily deliver its information to existing and potential customers and obtain the needed information.

To this aim, the proposed platform aims to simplify the complexity of capturing fragmented information flows, aggregating and creating actionable information from multiple sources and actors in the logistics sector. Using this platform the actors, involved in the ITN, have not to modify their own software, but they can directly share and view the information in real time simply by connecting to the platform.

The new platform is configurable in an intelligent dashboard with a proper user interface, populated with the information that is required for specified missions or logistics business processes. Each information flow can come from any sources, including carriers, customs, rail, ocean and road authorities, and in general local logistics platforms and systems. However, the information flow has to meet minimum technical requirements (such as quality and reliability) to be managed by the platform.

In order to use the platform, the ITN actors have to be either publisher or listener: the publisher shares own set of information while the listener can monitor the published information flow for its own scopes (improvement of the good flows, optimize internal schedule operations, security checks, etc.). The published information flow can be local as well as related to pan-European applications.

The platform is realized in the framework of the H2020 project AEOLIX -Architecture for EurOpean Logistics Information Exchange (Programme available at https://aeolix.eu/).

The paper is organized as follows. Section II describes the AEOLIX platform and Section III shows the platform use cases. Finally, Section IV draws the conclusion and future works.

II. The Flexible Platform Design

A. *The platform architecture*

The ambition of the proposed platform is to address the information challenges in logistics, and to develop new solutions and business models by exploiting visibility and sharing of data among all actors involved in the process and technology to create more sustainable ITNs and logistics operations. The AEOLIX ecosystem proposes a novel common communication and navigation environment for logistics information sharing and enhancing the actors' collaboration across the AEOLIX community.

The AEOLIX architecture is based on the use of the IoT paradigms (RFID 4G, Wi-fi, cellular network, etc.) to facilitate the data transmissions from sensors and devices to the platform as Fig. 1 shows. Any actor (publisher or listener) involved in the ITN can be connected to the platform by a low-cost Application Programming Interfaces (API). The use of API allows the actors to employ their own software and obtain sensitive information from the platform.

The data manager converts the information standards used by different actors in an internal XML information object then the core service send these information to all actors interested in on the basis of the public and subscribe approach. The service core is a message dispatcher. Moreover, the platform also includes many toolkits, i.e., sets of software components useful to make tactical and operational optimal decisions in the ITN processes. Fig. 2 shows the main toolkits used in the platform. The toolkit outputs can be monitored by the ITN actors: drivers, rail, ocean and other companies.

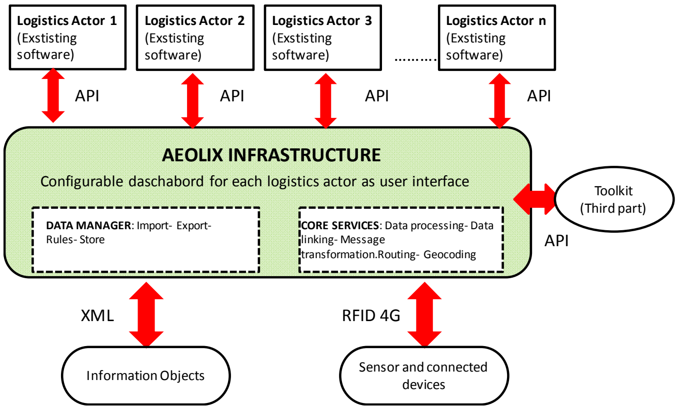

Fig. 1 AEOLIX infrastructure concept

Main function	Advantages								Operational measures and tactics
	Optimum fleet management	Product Warranties	Safety/Security	Preventive maintenance. Optimization cost	Organization, emergency travel management	Traveling time optimization, unforeseen management	Unexpected management	Driver's responsibility	
Fleet Trucking	X				X				Real-time communications during the trip
Monitoring Box Temperature and Alert		X			X				Adopting technical solutions restore ideal conditions
Fuel Consumption			X						Real time cumunication stations closer
Fleet Maintenance Schedule				X					Preventive maintenance or failure planning
Geofencing					X		X		Communications travel variations to traveling staff
Out of Route Notification					X	X			Communications changes and / or delays to staff
Over Speed Control			X				X		Reduction of cruising speed
Delivery Delay Alert					X		X		Early communication and / or delays and useful times
CCTV/MDVR(Mobile Digital Video Recorder)			X					X	
Driver Management			X					X	Training/ information personal

Fig. 2 Toolkit description.

We summarize the advantages and innovations of the presented platform as follows:

- shared view of the complete logistics reality,
- simplified connectivity, realised by deploying flexible, adaptable and low-cost plug-in APIs;
- use of toolkits that are sets of software components accessible through the platform;
- re-use of existing assets, so that the ecosystem is not a replacement of functionality of current logistics information platforms and systems;
- employment of a security framework that is based on a trust model for cloud-oriented collaborative networks and security mechanisms, aligned with EU directives and recommendations (such as e-Identification, Digital Agenda, Digital Single Market).

III. The Case Study

A. *Description of the Port of Trieste Case Study*

In this section, we describe the ICT platform designed for the case study represented by the Trieste port and the connected inland terminal. Such case study is one of the living labs proposed in the AEOLIX project with the aim of validating and implementing the designed platform in the real world.

The platform has to improve customs procedure management by introducing secure, paperless, data sharing procedures, enabling submission of the required documentation in digital form before freight arrives. The Port of Trieste, schematized in Fig. 3, plays a decisive role, both in long-distance intercontinental maritime transportations and short-medium-distance intra-Mediterranean trades. In particular, the seaport of Trieste is the maritime entry point for the Europe: Trieste supports the main shipping lines from and to China, the Far East, Singapore and Malaysia, with stops in several other ports in the Mediterranean as Albania, Slovenia, Croatia, Greece, Turkey, Egypt, Lebanon, Israel. Moreover, the port of Trieste intercepts the Baltic-Adriatic and the Mediterranean corridors. More than 160 trains per month link Trieste to industrial and manufacturing areas of the Northeast Italian and Central Europe with different destinations (Germany, Austria, Czech Rep., Hungary, Switzerland and Luxembourg). Mainly, the port is connected with the international and national rail network and allows all areas to be served.

The port of Trieste takes advantage by the Fernetti inland terminal located to 12 km from it. The inland terminal consists of 24.000 m^2 of storage areas and 130.000 m^2 of open space for customs operations, parking and storage. It is directly connected to: *i*) the national railway station; *ii*) several motorways that connect Trieste to different European countries; iii) the airport.

Fig. 3: Port of Trieste

Thank to the proposed platform, new ICT procedures will reduce the time spent in queue at the port and terminal gates. Trough the new dashboard it is possible to monitor the movements of the trucks that have already performed the customs procedure at the Trieste inland terminal, but that have still to travel on the Italian territory in order to reach the port of Trieste. This will create a virtual tunnel between the port and the inland terminal area.

Moreover, in order to improve the end-to-end visibility of freight between the European hinterland and the port, novel IoT based procedures will facilitate document transfer, booking, status and incident and emergency management, across multiple logistics operators. The new procedure will enhance operational quality and efficiency of the intermodal operations.

Fig. 4 shows the actors that exchange data and information with the platform: motorways, carriers and railways. Moreover, other users are connected thought a DSS and the Port Community Systems: terminal operators, shipping forwarders, shippers and health authorities.

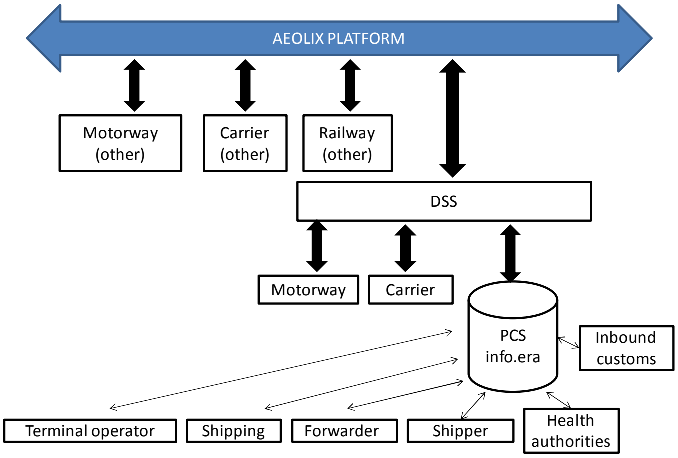

Fig 4 Data sharing and visibility in the platform.

B. Trieste Living Lab use cases

In order to show the effectiveness of the platform two different use cases are identified in the Trieste living lab.

The Use Case 1 (UC1) aims to point out the logistic chain improvement through smart customs procedures; in particular, secure and smart innovative customs procedures allowing pre-clearing and advanced operations for import RO-RO trades between Turkey and continental Europe.

The Use Case 2 (UC2) aims to point out the logistic chain improvement through smart customs procedures: secure and smart innovative customs procedures allowing pre-clearing and advanced operations for export RO-RO trades between Trieste port and Turkey. In particular, secure and paperless data sharing procedures will be introduced.

1) UC1-"As is scenario"

The "as is" customs procedures foreseen for the vessels bringing goods into the customs territory of the Community can be sketched as shown in Fig. 5.

Figure 5 reports the UML activity diagram [21] modelling the actions of all actors involved in the process (the as is scenario is represented by solid and dashed lines). In particular, the process starts when the Shipping Line (RO-RO Operator) sends to the Customs Office a document called Entry Summary Declaration (ENS) for each truck/trailer boarded on the ship: this document contains various information regarding the transported goods, including the EORI number (i.e., the number which identifies each commercial trader).

The Customs Office that has received the ENS generates the Movement Reference Number (MRN), an 18 digits' number codifying the essential information regarding the goods (one for each truck).

At Trieste port, the shipping line collects all the ENSs of the trucks/trailers boarded on the ship by his client and, when the vessel arrives at the destination port, it generates the Manifest of Arrival (MMA), i.e. a list of all goods transported by the ship. When the MMA is ready, the unloading operations can be performed by the terminal staff.

If the terminal staff completes the unloading operations, then the Customs Office performs the security and safety risk analysis examining the information included in the ENSs. In particular, the Customs Office decides whether a specific truck/trailer boarded on the ship needs an inspection by the port authorities.

If an inspection is needed, the Customs Office in collaboration with the Shipping Line perform it, otherwise a new code (Free Port Area – PF) is manually assigned by the Customs Office to each truck/trailer.

Finally, the truck/trailer can leave the port for the final client.

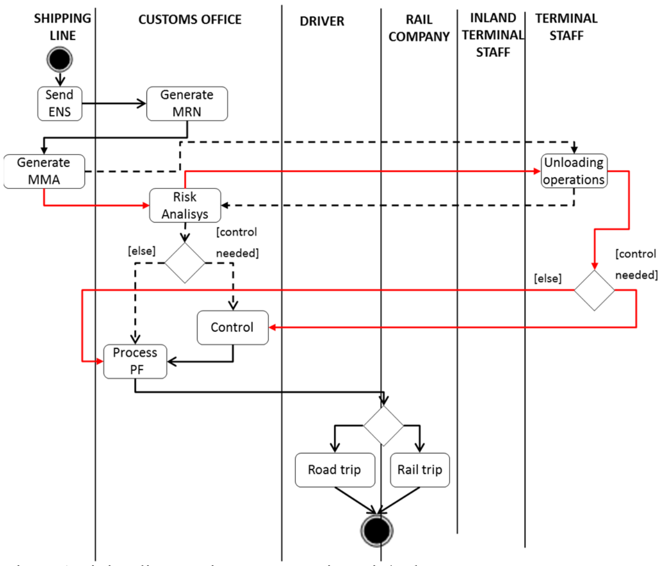

Fig. 5 Activity diagram import scenario as is/to be

2) UC1-"To be scenario"

The adoption of the AEOLIX platform can speed up the unloading operation of freight coming from Turkey. Indeed, in the "as is scenario" the unloading operations can be completed after the vessel arrival, while in the "to be scenario" (see Fig. 6, solid and red lines) the risk analysis and the PF codes can be generated during the vessel trip by the Customs Office. This procedure strictly relies on the ability:

i) to identify uniquely each transport unit boarded on the vessel (XML information);

ii) to share transport unit data between Shipping Line and Customs Office (API).

In this way, when the vessel arrives to the Trieste port, the unloading operations and the PF code assignments can be immediately processed, while only the truck/trailer, needed an inspection, waits the check and the following PF code by the Customs Office.

Hence, the advantage to use AEOLIX platform is twofold: 1) the truck/trailer duration stay in to the port is significantly reduced; 2) the data security is guaranteed by the truck/trailer e-Identification.

Moreover, the platform toolkit can help the fleet and rail companies to monitor the truck/trailer activities.

3) UC2-"As is scenario"

The UC2 refers to the export operation that starts when the carrier has to embark an export truck/trailer directed to Turkey. The carrier files a notice of the truck arrival by filling in an electronic form in the Trieste Port Community System (PCS). This is done from the carrier's administrative office via any PC with manual data entry into a formatted screen with fields to be filled in. In particular, the following data are required:

- Shipment data: booking, arriving by road/train/ship, vehicle type, ILU (intermodal loading unit) code, truck/trailer license plate, port and terminal of destination.
- Driver data.
- Freight data: container ID, commodity, container type, number of packages, custom document, MRN code and item.

The PCS sends the notice by an e-mail to the customs office, carrier's office, the terminal staff and the driver. The port Authority finalizes the customs operations and the truck/trailer license plate is uploaded in a white list of trucks and/or trailers expected to reach the port.

Now, the truck/trailer can arrive to the port. Recently, the Trieste PCS can monitor the trucks that are travelling along the Autovie Venete motorway by the Dangerous Goods Monitoring System (DGMS). In particular, the DGMS detects the truck license plates by a set of several monitoring points, and communicates them to a Decision Support System DSS (the Trieste Pilot Site platform developed in the European CO-GISTICS Project). The DSS checks if the detected license plate is contained in the white list and, in case of positive response, it communicates to the PCS the vehicle position and the Estimated Time of Arrival (ETA). Such information is useful to the terminal staff in order to plan the export operations.

When the truck is at the Lisert tollbooth (motorway exit) the DSS, using the Geofencing toolkit, notifies to the driver by SMS or phone application one of the following options:

- a direct access to the Trieste port is allowed;
- a deviation through the Trieste port inland terminal to wait the port call is necessary.

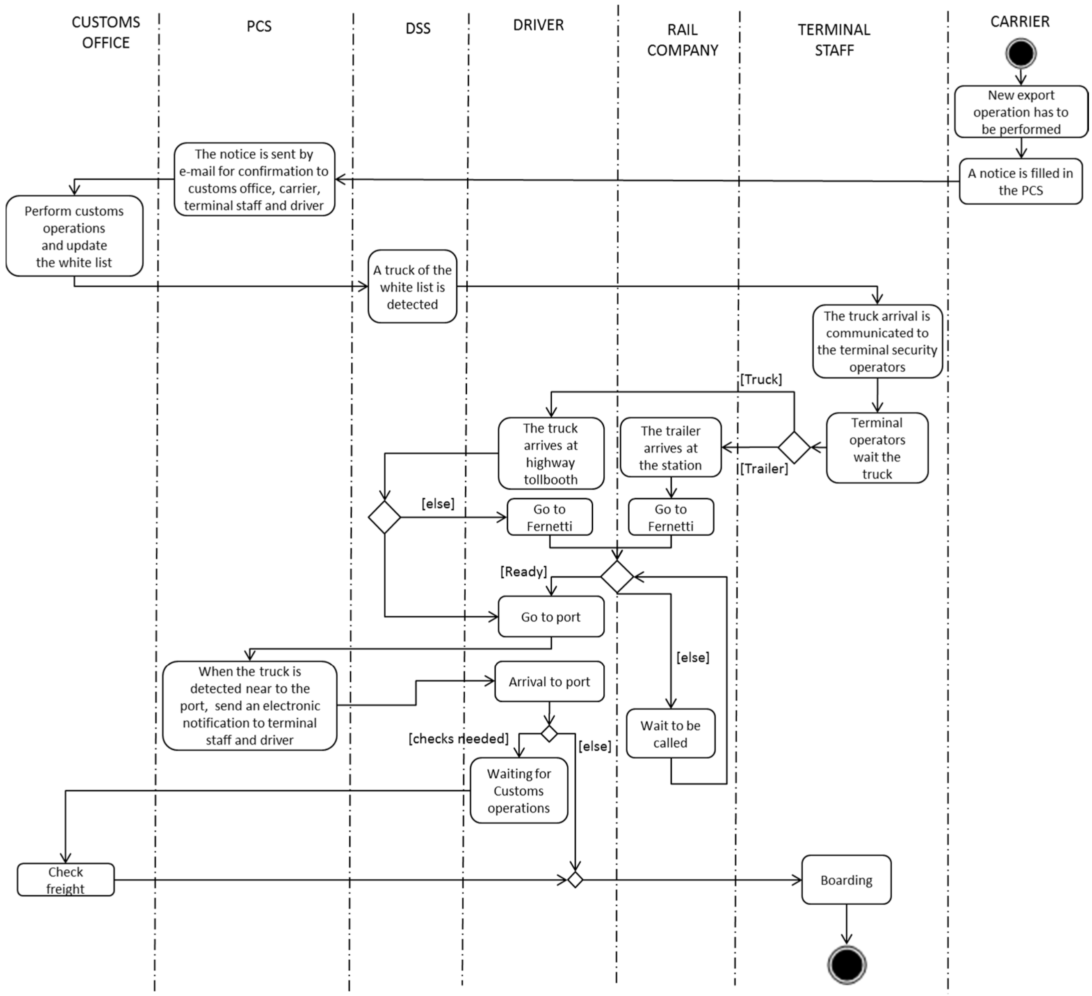

Fig. 6 Activity diagram export scenario as is/to be

Moreover, the DSS communicates to the PCS and to all interested stakeholders such information by emails. On the contrary, the trailers have to be transported by a truck necessarily (port authority rules) from the rail station to the inland terminal before to reach the port.

When the truck/trailer leaves the inland terminal and it is near to the Trieste port gate, the PCS updates the vehicle position data and sends a notification of the truck arrival (electronic document for mobile phone) to the security operators and to the driver. When the truck reaches the Trieste port, the driver shows the notice of arrival on his mobile phone to the security operators and the boarding operations can start. However, some trucks are checked in the port by the Customs Office before the boarding.

The activity diagram, sketched in Fig. 6, summarizes the operations performed by the different actors involved in the "as is" export process.

4) UC2-"To be scenario"

In order to speed up the loading and clearing operation of export freight, the AEOLIX platform can integrate the CO-GISTICS platform, monitoring and sharing by IoT applications the vehicle position data in the route that links the inland terminal and the Trieste port. This information flow allows to execute the check and security operations in the inland terminal area, because the trucks/trailers can be monitored from the inland terminal to the Trieste port. Only the trucks that will have an anomalous behaviour (out of route notification toolkit alarm) from the inland terminal to the Trieste port will be again checked.

Hence, the AEOLIX platform will reduce the time spent to check the freight in the Trieste port by exploiting the truck waiting in the inland terminal. Moreover, the platform will increase the road kilometres in which the trucks will be monitored, integrating the CO-GISTICS platform. Finally, the monitoring and sharing of the truck position data among the export process actors will improve the system security and reliability.

IV. Conclusions

In the paper a new concept of information and communication technology (ICT) is proposed. In particular, the new AEOLIX platform is described in detail enlightening the information exchanges and the benefits that it provides to the Intermodal Transportation Network (ITN) users. Indeed, the proposed platform concept improves the connectivity of the logistic systems without unnecessary additional costs.

Moreover, a case study concerning the port of Trieste is presented. We introduce the test site and identify two different use cases by UML diagrams: import and export scenarios. After, the advantages, derived by the use of AEOLIX platform, are pointed out.

Future works will regard the identification of evaluation criteria, the corresponding Key Performance Indices (KPIs) and the implementation of a simulation framework to estimate the performances of the ITN relating to use the proposed platform.

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