Proceedings of the 2009 IEEE International Conference on Systems, Man, and Cybernetics
San Antonio, TX, USA - October 2009

Using Information and Communication Technologies in Intermodal Freight Transportation: a Case Study

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***Abstract*— The paper focuses on the application of Information and Communication Technology (ICT) tools to the real-time transport monitoring in order to trace and automate specific procedures as payments and customs clearance operations. In particular, a case study, that represents an example of Intermodal Freight Transportation (IFT) system, is analyzed and simulated. The flow of goods and information involved in this case study is described in order to highlight the improvements reached by using ICT solutions. A simulation model for this system is proposed by the UML formalism and the discrete event simulation results point out the huge impact of ICT on real-time management and operations of IFT systems.**

***Keywords*—Intermodal Freight Transportation, Discrete Event Simulation, UML, Information and Communication Technology.**

I. INTRODUCTION

Emerging freight transportation trends demonstrate the importance and the necessity of Intermodal Freight Transportation (IFT) systems [3] so that intermodal transportation will continue to increase in importance [12].

The IFT recently received large interest in the related literature [3, 11] in which several definitions are presented. The European Conference of Ministers of Transport (2001) defines intermodal transportation as “movements of goods in one and in the same loading unit or more modes of transport without handling the goods themselves in changing modes”. This definition is too restrictive, thus in a more comprehensive way intermodal transportation may be defined as the transportation of a load from its origin to its destination by a sequence of at least two transportation modes, the transfer from one mode to the next being performed at an intermodal terminal [5].

Intermodal transportation, particularly container-based, is growing and will continue to increase in the foreseeable future. Enhanced planning and management procedures and decision technologies are thus required, offering both great opportunities and great challenges in the logistic sector [5].

The automation of container operations also opens up research opportunities in real-time decision and control of operations. Research is required to build up new models concerning the various planning and management problems under intelligent transportation systems and real-time information and to develop appropriate solution methods.

In order to be efficient, an IFT system needs to synchronize the logistics operations and the information exchange among stakeholders. Hence, solutions based on the modern Information and Communication Technologies (ICT) are the key tools to achieve the efficiency. As mentioned in [8], it is necessary to analyze the application of ICT solutions in a multi-modal chain. Actually ICT has been promoted as a mean to enhance logistics competitiveness. The application of ICT in logistics management is relatively recent, it lets real-time/on-line information communication and data exchange through the entire operation chains become realistic [7].

This paper presents an application of the ICT tools to the real-time transport monitoring in order to trace and safely handle moving goods. In particular, a real case study involving an IFT system is analyzed and simulated. More precisely, the case study deals with the transport of glass sheets coming from China and arriving to the Port of Trieste (Italy) and the intermodal terminal SDAG in Gorizia (Italy). The case study is analyzed in the frame of the EURIDICE Integrated Project, sponsored by the European Commission under the 7th Framework Program. The project aims to establish the most advanced information services for freight transportation in Europe, realizing the Intelligent Cargo (IC) concept. Intelligent cargo connects itself to logistics service providers, industrial users and authorities to exchange transport-related information and to perform specific functions whenever required along the transport chain.

The full realization of the IC approach will have a significant impact in terms of diffusion and effectiveness of ICT support to freight transportation, producing relevant benefits for businesses and the society (consider f.e. the European Conference of Ministers of Transport 2001, http://www.cmrt.org/online/glossaries/index.htm, the European Commissions, COM 2001 and COM, 2006). The mentioned benefits can be mentioned as follows: (i) enhanced and widespread capability to monitor, trace and safely handle moving goods at the required level of detail, from full shipments to individual packages or items; (ii) increased efficiency of transportation networks, by improving synchronization between logistic users, operators and control authorities; (iii) improved sustainability of logistic systems, by reducing their impact on local communities in terms of traffic congestion and pollution.

The static and dynamic IFT system model is described by the Unified Modeling Language (UML) formalism [1]. Indeed UML enables to unify the notions necessary to describe various activities of complex and large systems in an object oriented development process. In order to show the applicability and benefits of ICT in typical interactions of cargo with authorities

978-1-4244-2794-9/09/$25.00 ©2009 IEEE

and infrastructure operators, the UML model is implemented by a discrete-event simulation in Arena environment [10].

In particular, the simulation study allows us to analyze by quantitative performance indicators the benefits of the ICT implementations. More precisely, the presented simulations compare the interactions among cargo, authorities and infrastructure operators in two cases. The first case reproduces the current organization in which the flows of material and information are completely disconnected. The second case describes a new proposed solution aiming to guarantee for the regularity of cargo movements, in terms of customs authorizations, transit rights, security regulations. The task is to provide services for the efficient utilization of infrastructures, both singularly and across territorial networks (e.g., port terminals synchronization with rail and road connections) and to contain the impact of logistic infrastructures on the local communities, reducing congestion and pollution caused by the associated freight movements.

The paper is organized as follows. Section II describes the case study and the flow of goods and information in the two examined cases. Section III proposes the simulation model by the UML formalism. Moreover, Section IV specifies the simulation and discusses the results. The last Section summarizes the conclusions.

II. Description of the Case Study

The aim of this section consists in describing the considered real case study that involves freights of glass sheets coming from China and covers a share of the logistic flow sufficiently wide to demonstrate impact on a critical joint (admission point to Europe) and the link between road transportation and sea shipping. Figure 1 shows the schematic flow of goods and information starting from the China port up to the Trieste port and the Terminal of Gorizia.

We present two different ways of managing the typical interactions of cargo with authority and infrastructure operators: a) the current situation, called case "as is", b) the new solution, called case "to be".

The current situation is described in order to highlight the existing problems mainly regarding the facts that the flows of goods and information do not have the same timing and that the accompanying information are often not the same. To improve the whole intermodal system, a new solution is presented. It is based on the application of ICT that will allow the creation of a "green line" to speed-up transit through the regional logistic system (port and land infrastructures).

Next sections describe the phases of the flow of goods and information in the two cases by labeling with *a* the phases of case "as is" and with *b* the phases of case "to be".

A. The Current Flow of Goods and Information

The selected flow of goods and the related information regards sheets of glass used to produce solar panels and it is described by the following phases:

1*a*) Production phase: the producer company, Ilva, assigns the production of the goods to Chinese companies. Then the sheets, collected in loading units, are sent with the C&F (cost and freight) procedure to a Chinese loading port.

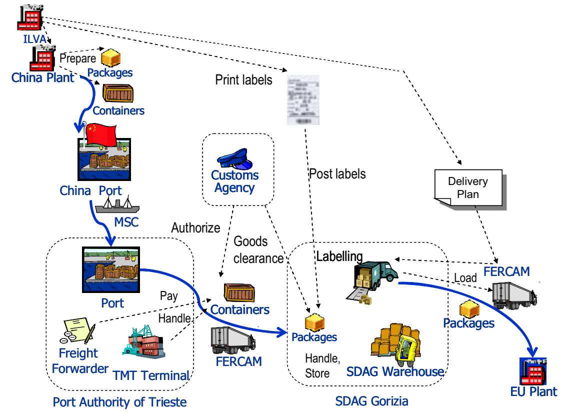


Figure 1. The flow of goods and information – "as is"

Before loading the goods at the Chinese port, there is the phase of booking a place in the hold of the ship. In order to load the container, the shipping company prepares a bill called "clean on board" regarding the status of the goods.

2*a*) Shipping phase: the load is shipped by the shipping company MSC. During this phase, a set of documents are prepared, e.g., packing list for loading, called "manifest". This document is transferred to Customs and contains information about all the goods in the ship.

3*a*) Unloading phase in the port: after having been shipped, the load arrives at the Port of Trieste where it is unloaded by the terminal operator, TMT.

4*a*) Payment phase: the freight forwarder receives the information regarding units and packages inside them. When the container is released by the terminal operator, shipping tariffs are paid in relation to the quality (glass) and quantity (tonnage) of the goods.

5*a*) Authorization phase: the freight forwarder and the customs authority prepare the transportation documents to authorize the exit of the containers from the port area.

6*a*) Transportation phase: after executing the payment and authorizing phases, the goods are loaded on trucks and transported by the carrier to the truck terminal of Gorizia.

7*a*) Unloading phase in SDAG: the containers arrive to Gorizia where they are unloaded to wait for the authorization to enter in SDAG.

8*a*) Customs clearance phase: depending on the quality and quantity of the goods, customs tariffs are paid. Customs clearance operations are quite slow to execute and they are carried out by the freight forwarder that prepares the customs duties bill containing a customs code, the origin of the goods, its value and profit after the phases in the port of Trieste.

9*a*) Warehousing phase: goods are managed by SDAG. Its operations regard opening containers, warehousing and labeling packages. Current information flow requires that SDAG personnel stick labels on packages. Now labels are produced by Ilva and then posted from Verona before the goods arrival.

10*a*) Loading phase in SDAG: FERCAM communicates to SDAG the delivery plan and SDAG loads the goods on trucks depending on the packing list. Currently this happens by phone or by e-mail. When the load is ready SDAG communicates it to FERCAM which has the responsibility to deliver the goods to the final destination. It has been estimated a flow of 20 containers/month. Each container has 36 packages inside and each pallet contains in their turn about 120 sheets of glass.

Currently an electronic link between goods and information does not exist at the beginning and labels containing all the identification data are produced in Italy and posted to the warehouse, then stuck after the container has been checked by customs and opened. This organization causes significant delays and frequent errors on the administrative procedures at the port, that eventually add up to the total transit time and users' administrative costs.

B. The New ICT Solution

The new solution is based on the specification of a *Cargo Identity Module* including technology components and basic services that give the possibility to memorize and access the identity, the context, the location of goods and the related up-to-date information and to extend it with useful information-based services. This information should include a univocal code of identification that allows to avoid duplication of information, information about weight, quality, quantity and origin of goods. These data can be accessed anywhere along the flow of goods to support automated certification and to fulfill payments of fixed and variable costs as customs, shipping tariffs and terminal services.

The main features of this solution are that cargo interaction is supported by a smart device integrating identification, connectivity and computational capabilities, based on mobile and Service Oriented Architecture (SOA) technologies. The smart device communicates directly with an hosted service that performs several operations, like univocal identification of the cargo item, the cargo owner and position (context detection), activation of the corresponding web services published by the cargo owner to perform the required operations (user services) and activation of further services, from different stakeholders, based on rules defined by the cargo owner. These include vertical application services made available by specialized providers.

This system based on ICT solutions will allow the creation of a "green line" to speed-up transit through the regional logistic system (port and land infrastructures) by: (i) expediting customs clearance including payment of duties and other fees; (ii) providing real-time information to infrastructure users for monitoring the whole flow and the exact moment in which goods arrive and leave the port and to infrastructure managers for a more punctual scheduling of terminal operations in order to use empty containers in a more efficient way.

In this context, there are involved two different types of units: load unit (container) and package. At the first level information regards status, means of transport and passing gates, while at the other level it regards payment of duties and services too.

In this way, even if packages are managed one by one, there is the possibility to trace all information about their former load units too. So, in case of any problems, the receiver knows from where goods are coming.

Prepaid billing, booking in advance services, automated clearance are functionalities that need an elevate level of security. This system should be implemented using codes based on public- private keys cryptography that allow transactions and operations at the right moment in the logistic flow and by the subjects in charge.

The above described functionalities are implemented by cargo itself because status data are available in real time through the service infrastructure, cargo is able to invoke services and start processes autonomously in response to predefined events, has decisions making capabilities and is able to choose services to invoke according to circumstances.

The following description aims at highlighting the changes obtained with the "to be" solutions in the phases summarized in Section IIA. The differences only regard the information flow while the flow of goods is unchanged.

1*b*) Production phase: goods are produced in China and the hosted service platform is prepared to follow the cargo during the whole flow. Smart tags are created for containers and packages and they are directly linked to objects in the platform. In this way the hierarchy among IC items is automatically created.

2*b*) Shipping phase: information that are collected in the picking list for loading, the "manifest", is requested in order to allow the unloading of goods in the Port of Trieste. This document is generated directly via cargo-ship interaction, possibly using satellite communications.

3*b*) Unloading phase in the port: after the unloading the cargo enters in the area where it is able to communicate with the infrastructure implementing SOA technologies in order to recognize the context and its current conditions to invoke services and start processes.

4*b*) Payment phase: shipping tariffs are automatically paid by the direct interaction on the hosted service platform with the bank system.

5*b*) Authorization phase: thanks to the cargo intelligence and the hosted services all the data for creating the authorization documents are in the platform and the process is automatically done.

6*b*) Transportation phase: after the execution of port procedures, the cargo communicates with SOA technologies in order to update its status of leaving the port of Trieste.

7*b*) Unloading phase in SDAG: once arrived in SDAG, containers do not wait for the authorization to enter in SDAG because their status is already known and updated.

8*b*) Customs clearance phase: goods are automatically cleared communicating with the platform and with the custom authority system.

9*b*) Warehousing phase: containers are opened by SDAG personnel and packages are managed in the warehouse. Packages are already labeled and a hierarchy between packages has been created, so it is possible to trace all the information about goods from the beginning of the flow.

10*b*) Loading phase in SDAG: the delivery plan is present in the platform and so it is available to all the involved actors in this phase and finally goods are transported to destination.

III. THE SYSTEM MODEL

This section describes the model of the considered case study including the system physical structure and the activities of the involved actors. In particular, the system is modeled as a Discrete Event System [4] whose dynamics depends on the interaction of discrete events, such as demands, departures and arrivals of transporters at facilities, acquisitions and releases of resources by vehicles, blockages of operations [6]. Since the task of the model is a simulation study, the UML formalism is used to describe the various viewpoints of the system: static (describing the different type of objects in the considered system), functional and dynamic (describing the activities of each object with the relative relation of precedence, synchronization, cooperation, timing) [9]. Indeed, UML is defined as a graphic and textual modeling formalism intended to understand the needs and to specify and document systems. For more details on the UML, the interested reader is referred to [1].

A. The Static Model

The structure of the system is described by two class diagrams shown in Figures 2 and 3, that show the main elements necessary to characterize the port of Trieste and the truck terminal of Gorizia, respectively. In UML classes describe the different type of objects that are need within the considered system to meet those concerns. Moreover, class diagrams show these classes and their relationships.

In particular, the classes of the diagram in Figure 2 are the resources present in the port, the queues that involve the flows of material, the generators of arrivals and the authorities. The resources are distinguished in two types: the ones belonging to the port area (i.e., the parking, quay, discharge and warehouse areas) and transport and moving means (i.e. ships, cranes, trucks). Other basic classes are the queues associated with trucks, ships and gates. Likewise, the diagram of Figure 3 depicts the resources of the truck terminal that includes the warehouse and different areas such as enter, delivering, unloading, parking, exit, preparing, labeling and customs areas.

Moreover, the transportation resources are represented by the trucks that are associated with containers and packages. Other relevant classes are the queues of trucks in input and in output of the terminal. Furthermore, the two diagrams in Figures 2 and 3 show the associations, the aggregations and the multiplicities among the classes [1]. For simplicity reason, the figures do not depict the attributes and the operations of each class. A more detailed description of a node belonging to a logistics network can be found in [2].

B. The Dynamic Model

In order to describe the management processes relative to the flow of goods and of information, we use here the UML activity diagrams. All the nodes of an activity diagram are actions, that are drawn as rounded rectangles. Moreover, forks represent actions that begin execution at the same time and the join means that all incoming actions must finish before the flow can proceed past the join. Forks and joins are both identically drawn by thick bars.

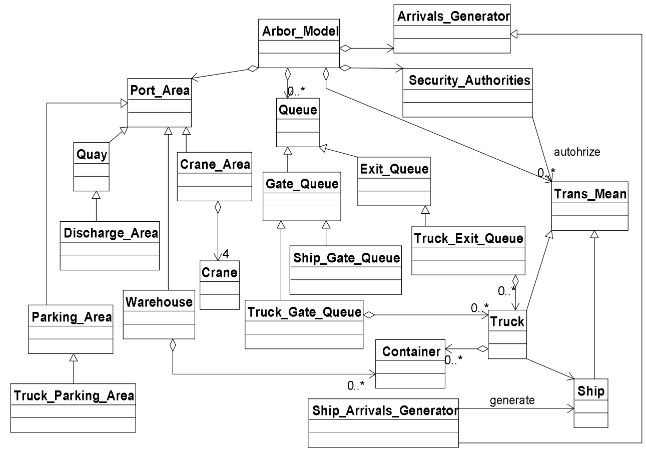


Figure 2. The UML class diagram of the Trieste port

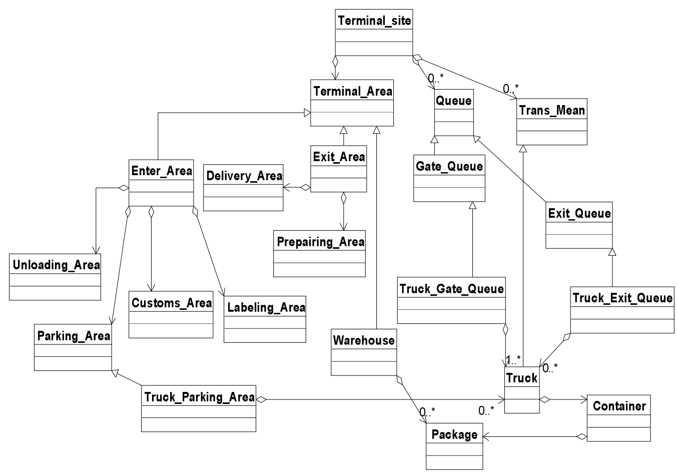


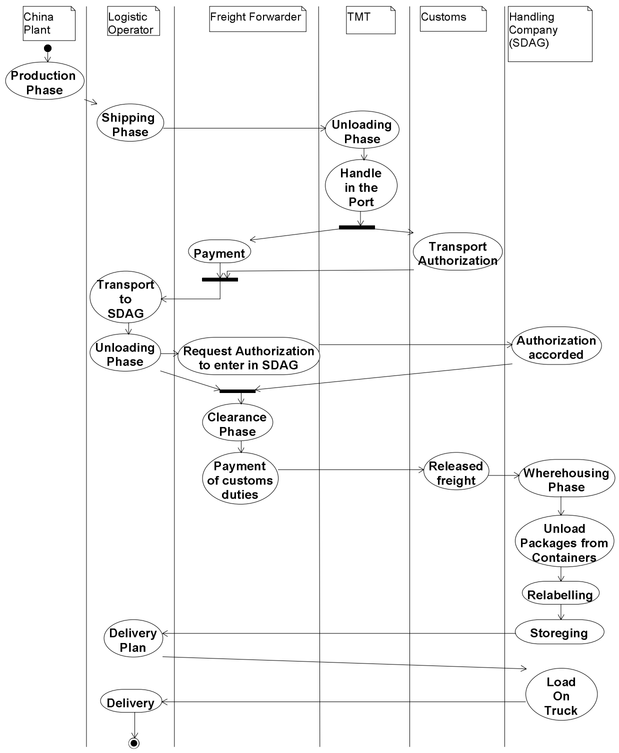
Figure 3. The UML class diagram of the intermodal terminal of Gorizia.

Figures 4 and 5 show the activity diagrams of the case "as is" and "to be", respectively, and specify the phases described in section II.

The columns of the activity diagrams are divided into swim lanes that show the actors responsible for each activity. The activities of the actors are the decisions and the operations that influence the flow of material and the management of the resources specified by the class diagram.

IV. THE SIMULATION SPECIFICATION AND RESULTS

This section describes the simulation of the considered IFT system under the two presented management processes, in order to study and compare the flow of goods and information during the relevant phases of the procedures. In particular, the simulations start from the beginning of phases 3*a* and 3*b* (unloading phase in the port) and end to phases 9*a* and 9*b* (warehousing phases). The discrete event model of the system is implemented in the Arena environment [10], that is a software particularly suitable to deal with large-scale and modular systems. The port of Trieste handles about 336.000 twenty-foot equivalent units (TEU) of containers per year. However, the case study simulation considers only the flow of containers that are managed by a specific freight forwarder.



The UML activity diagram of the case “as is”

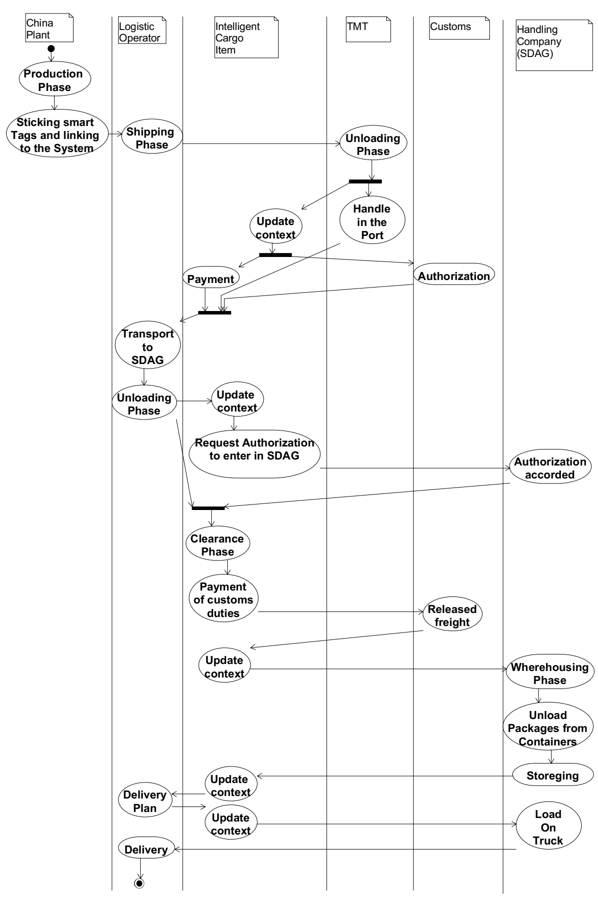


Figure 4. The UML activity diagram of the case “tobe”

TABLE I
TRIANGULAR DISTRIBUTION SPECIFICATION OF PROCESSING TIMES AND NUMBER OF NECESSARY OPERATORS

Operation	δ(t.u.) Case “as is”	D_δ Case “as is”	d_δ Case “as is”	δ(t.u.) Case “to be”	*Op*
Unloading phase 1	30	180	25		2
Handle in the port	20	22	18		1
Payment	15	30	12	0	1
Transport authorization	15	120	12	3	1
Transport to SDAG	120	144	96		1
Unloading phase 2	30	120	25		2
Request authorization	10	60	8	0	1
According	30	120	25	3	1
Clearance phase	15	30	12	0	1
Payment duties	15	30	12	0	1
Released freight	30	180	25	3	1
Unload packages	30	120	25		2
Re-labeling	30	40	24		1

Hence, we assume as input of the system 800 TEU/month. More precisely, the arrival time instants of containers are randomly generated by an exponential distribution of mean 72 time units (t.u.) where we consider as time unit the minute. In addition, the processing times of the phases described in session IIA for the case “to be” and “as is” have triangular distribution. Table I reports the processing time distributions of the case “as is “ and “to be”. In particular, the second column of Table I reports the modal values δ of the processing time distributions of the case “as is”, the third and forth columns show the maximum and minimum values of the range in which the firing delay varies, denoted respectively by D_δ and d_δ. Furthermore, the fifth column of Table I shows the modal values δ of the processing times that change in the case “to be”, assuming that in such cases $D_\delta=\delta+0,2\delta$ and $d_\delta=\delta-0,2\delta$. We remark that some operations either are not present in the “case to be” or are automatically performed (i.e., the associated processing time is zero).

The simulation results focus on the management of the interactions among cargo, authorities and infrastructure operators of the containers of glass sheets coming from China. Hence, the “as is” and “to be” procedures are applied to only one container per day and each container contains 36 packages of glass sheets. In this context, we consider the following operators devoted to the performances of the activities specified in Figure 4: 6 freight forwarders (3 in the port and 3 in SDAG), 2 TMT operators, 2 customs officers (1 in the port and 1 in SDAG), 6 workmen in SDAG. Moreover, the last column of Table I reports the number of infrastructure operators, denoted by *Op*, that are necessary to perform the corresponding operation.

In order to analyze the system behavior, the following basic performance indices are selected:

- the average system throughput *T*, i.e., the average number of packages delivered per t.u. by the SDAG;
- the average lead time *LT1*, i.e., that average time interval elapsed from the unloading phases in the port (3*a* and 3*b*) till the authorization phases (5*a* and 5*b*);

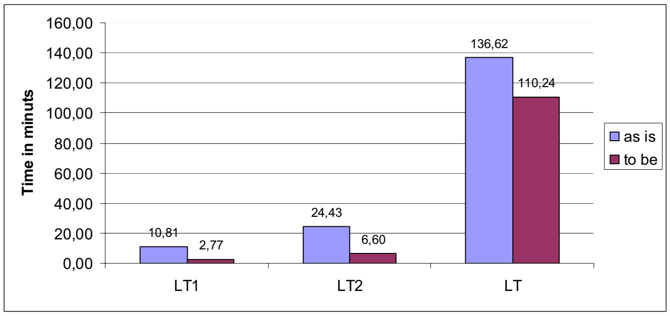


Figure 5. The average lead times in the two cases: "as is" and "to be"

- the average lead time *LT2,* i.e., that average time interval elapsed from the unloading phases in SDAG (7*a* and 7*b*) till the warehousing phases (9*a* and 9*b*);
- the total average lead time *LT* that is a measure of the time spent by the goods from the unloading phases in the port (3*a* and 3*b*) till the warehousing phases (9*a* and 9*b*).

All the indices are evaluated by a long simulation run of 15.768.800 t.u. (3 years if we associate a minute to a t.u.) with a transient period of 43.200 t.u.. In particular. the estimates of the lead time *LT* are deduced by 50 independent replications with a 95% confidence interval. Besides, we evaluate the percentage value 1.5% of the confidence interval width to assess the accuracy of the total lead time estimation.

The simulation results are depicted in Figure 5 that reports the average lead times previously defined. The results show that the change from the "as is" to the "to be" management leads to a noteworthy decrease (equal to -74.3%) of the *LT1*, i.e, the lead time referring to the unloading phases in the port. Moreover, the *LT2* decreases of about -73%. Nevertheless, it is interesting to note that the average throughput is almost unchanged: it is about 34.560 packages per t.u. in the two cases. This is due to the fact that only a subset of the containers are managed by the new ICT solution, consequently the benefit of the ICT solution is limited.

Summing up, the simulation results show that ICT has a huge potential for efficient real time management and operation of ITS, drastically reducing the lead times in the port and in the SDAG terminal.

V. CONCLUSIONS

The paper proposes an application of Information and Communication Technology (ICT) tools to the Intermodal Freight Transportation (IFT) in order to trace and automate specific procedures as payments and customs clearance operations. A case study is presented in order to improve the flow of goods and information involved in the transport of sheets coming from China and arriving to the Port of Trieste (Italy) and the intermodal terminal of Gorizia (Italy). The IFT system and two different management procedures are described by the Unified Modeling Language formalism.

A discrete event simulation study shows that the application of the ICT tools allows us to locate goods and the related up-to-date information and to extend it with useful information-based services. Summing up, the simulation results show that integrating ICT into the system leads to a more efficient system management and drastically reduces the system lead times.

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