



Analysis of Impact of ICT Solutions in International Freight Management

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Abstract

The paper analyses a crucial problem in the international freight management and assesses the application of an innovative solution based on Information and Communication Technology (ICT) tools. In order to improve the customs clearance procedures, the paper analyses the main anomalies and bottlenecks related to international freight management of a case study by modelling the customs clearance activities in the Unified Modelling Language framework. Moreover, some novel ICT based solutions are proposed in order to optimize suited performance indices. The flow of goods and information involved in the case study is simulated in different scenarios in order to highlight the improvements reached by using ICT solutions. The simulation results point out the huge impact of ICT on customs clearance operations.

Keywords: Freight Management, Discrete Event Simulation, UML, Information and Communication Technology.

1. Introduction

The emerging requirements for freight transportation lead the logistic sector to focus on the implementation of integrated information systems to improve the provided services (Caris et al., 2008). Therefore, it is imperative to develop and integrate new security solutions related to customs operations. It is widely recognized that the application of Information and Communication Technology (ICT) in logistics has been promoted as a means to enhance logistics competitiveness (Feng and Yuan, 2006), (Giannopoulos, 2004) and ICT is considered a primary “enabling tool” for the safe and efficient freight transportation systems (Giannopoulos, 2004).

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Recently, practitioners and researchers are attracted by the key problem of using effectively and efficiently the latest developments of ICT tools for freight transportation management (Giannopoulos 2004, Ramstedt and Woxenius 2006, Verbraeck and Versteeg 2001, Xu and Hancock 2004). In particular, the modern ICT tools help to produce, manipulate, store, communicate, and disseminate information. Moreover, ICT makes possible to know the state of the system in real time and therefore to manage and change on-line paths, vehicle flows, orders and deliveries. In order to operate such choices, there is a need of suitable decision modules based on detailed models that can track the state changes of the various system components and determine performance indices typical of the tactical and real time management, such as utilization, traffic indices and delivery delays.

This paper addresses the problem of improving the efficiency of an intermodal logistic system that involves maritime and road transportation from the point of view of the processes, and, in particular, the customs clearance operations.

In the related literature several studies addressed the topic of the improvement of efficiency in intermodal logistic systems but they are mainly focused on the configuration of the different components of the systems (Crainic and Kim, 2007). As stated in (De Wulf and Sokol, 2004), ICT is not just an enabler, but it is fundamental to the future of customs administrations (European Parliament, 2008). Moreover, it is important to underline that some actions have been started for introducing technological tools in the customs procedure, such as the CARGO project and the Italian AIDA initiative (Agenzia delle Dogane). The objectives of these projects consist in integrating the customs agency in the logistic chain to overcome the fragmentation of the current processes. Such actions aim to define a procedural, logistics, organizational and technological model which can be implemented to re-launch the national port system. Therefore, the results are focused on local improvements that do not eliminate the human support and the paper based procedures.

In recognition of the pivotal role that ICT plays in modern customs administration, the contribution of this paper consists in proposing an innovative ICT based solution that takes into account the high priority on the selection and implementation of appropriate and effective technological solutions for customs and security operations (De Wulf and Sokol, 2004). Nonetheless, the fundamental and distinctive assumption of this work is that the introduction of new technology without a paradigm change does not completely solve the system anomalies and bottlenecks of the current situation.

In a previous work (Boschian *et al.*, 2011), the authors specify an integrated system devoted to manage Intermodal Transportation Networks (ITNs) at the operational and tactical levels. The integrated system performs a closed loop management procedure and evaluates the decision strategies to be applied to such complex and large systems. In particular, the integrated system helps the decision makers in identifying the benefits of ICT integrated solutions to the ITN and in tuning the strategies in the real applications.

Among the multiple decision problems concerning the ITN management, this paper focuses on a crucial issue: the problems and criticalities related to the Customs Clearance (CC) operations. To this aim, the paper describes and analyses the CC activities by the Unified Modelling Language (UML) (Booch et al, 1998): a graphic and textual modelling language intended to understand and describe systems from different viewpoints. In order to overcome the detected anomalies and bottlenecks, some innovative solutions are proposed on the basis of the application of ICT to perform CC operations. Indeed, the procedures related to customs activities have a strong impact on

the overall logistic chain because they affect the performance of the whole systems in terms of efficiency and time-spending. Currently, ICT is a critical strategic measure for modern customs organizations to manage the complexities that are implicit in today's global trading environment (Lewis, 2009). Moreover, customs automation is one of the most powerful tools to increase customs efficiency (Zografos and Regan, 2004).

The approach followed in this paper is focused on the study of how improving the overall performance of an intermodal logistic system in relation to the fulfilment of customs procedures. Indeed the costs associated with inefficient procedures and systems for the customs operations can be enormous: for instance, the expense of supplying the required customs documents or the surcharges arising from procedural delays when importing goods could total as much as 15% of the value of the goods (OECD, 2003, OECD, 2005). Hence, the proposed innovative ICT solution applied to an intermodal logistic system will produce benefits that may radically affect the performances of transport systems (Zografos and Regan, 2004) from the regulatory point of view.

The paper is organized as follows. Section 2 describes the case study and the flow of goods and information in the current situation and points out the existing bottlenecks. Section 3 explains the ICT solution proposed to enhance the overall performance of the system. Moreover, Section 5 describes the application of the UML methodology to the proposed case study and Section 6 specifies on the basis of identified bottlenecks some Performance Indicators, describes the simulation and discusses the results. The last Section 6 summarizes the conclusions.

2. Description of the Case Study

This section describes the case study that is devoted to evaluate the proposed ICT solution in order to enhance the efficiency of the overall intermodal logistic system in relation to the customs operations. The case study considers the flow of trucks arriving from Turkey at the Port of Trieste (Italy) transporting hazelnuts and the related CC operations.

Currently, the traffic of ships arriving at the terminal is 14 ships/week and each ship contains about 240 trucks. The considered trucks transporting hazelnuts sacks are in average four or five for each ship. The total percentage of security check controls is about 4-5% considering the whole traffic that involves the terminal. Looking at the hazelnut traffic during a week, there is an average of 56-70 vehicles arriving at the Port of Trieste. Usually the percentage of the goods cleared in the port area depends on the market demand of the period, and we consider the average value of this percentage of 20% of the goods cleared in the port area and 80% cleared outside the port.

2.1 The Current Flow of Goods and the Customs Clearance Operations

In this section we describe the sequence of the operations in the current case that we call case as is. In order to explain the main parts of the flow of goods, the phases are listed in the following.

1. *Loading phase.* The hazelnuts sacks are ready to be loaded on trucks to be transported to Europe by ferry. There are not any means of traceability applied to the goods during the production and the loading phase.
2. *Shipping and data collection phase.* The trucks are loaded and the ship is coming to the Port of Trieste. The shipping agent, on behalf of the ship-owner, that is responsible for goods, collects and translates all the information to prepare the pre-arrival document and the “manifest” to authorize the arrival of the ship (so called MMA document). The freight forwarder inserts the information contained in the “manifest” document, such as the TARIC (Integrated Tariff of the European Communities) code, the weight of goods, etc. in the Customs Authority System. The Customs Authority System is centralized at European level and calculates the risk rate associated to the transported goods.
3. *Unloading phase.* The goods arrive at the Port of Trieste, the freight forwarder goes to the Customs Authority office in order to perform all the port unloading operations related to the foreseen documents. The freight forwarder presents a paper document to confirm that the goods are arrived at the Port of Trieste and obtains the MRN (Movement Reference Number) code.
4. *Security notification phase.* The Customs Authority Central System, called NCTS (New Computerized Transit System), decides by an elaboration of data about goods if the freight needs a security check control. The freight forwarder is informed of such a decision by verbal communication and there are two possibilities:
 - a. the freight has to be checked and the freight forwarder communicates to the truck driver the necessity to move the truck into a special area for the security check operations;
 - b. the freight is allowed to exit the port area without any security checks.
5. *Payment phase.* Before exiting the terminal area, the shipping tariffs have to be paid by the freight forwarder in order to perform the unloading operations. When the freight is authorized to leave the port area, it is stopped by an officer of the Port Authority in order to register the date and time of its passage. Moreover, the Port Authority checks whether the freight has been security checked or if it has the transport document to authorize its exit.
6. *Customs clearance phase.* The freight forwarder decides where the goods have to be cleared. The decisions can be of two types:
 - i. goods cleared in port area. The document to perform the customs clearing operations have to be prepared and the tariffs to be paid are calculated;
 - ii. goods cleared outside the port area. The documents to authorize the transportation of the goods, that are not yet cleared, have to be prepared. There are two types of transportation documents: the T1 transportation document or the Carnet TIR document. The document prepared for this business case is called “Carnet TIR”.

In the two cases, the CC procedures deal with the payments of the Value Added Tax (VAT) and the customs duties by the freight forwarder to the Customs Authority.

7. *Delivery phase.* The goods, not already cleared, arrive to the warehouse area and, when it exits the warehouse, it is ready to be delivered to the consignee.

2.2 Main Anomalies and Bottlenecks of the Customs Clearance Procedure

By analysing the current situation described in Section 2.1, it is possible to point out the following critical issues that affect the efficiency of the considered intermodal logistic system:

- the lack of synchronization between the physical and information flow, e.g., the documents such as the “manifest” are sent by plane to the Port of Trieste;
- the redundancy in the information exchanges;
- the increase of unnecessary works for the shipping agent and the freight forwarder.

Going deeply in the details, there are many activities still manually done, such as the operations to obtain the MRN code and the data collection. In this context the main existing problems are related to the following points:

- the errors in the registered data can be very serious and in the worst case can stop definitively the flow of goods;
- the current means of communications are not suitable, i.e., some data are reported by voice communication by the freight forwarder operator;
- the paper based documents are all the documents concerning the payments of the Customs duties and the fulfilment of the clearing and transport authorization procedures are paper based;
- communication of the fulfilment of the operations are not present, i.e., the payment of the shipping duties are performed also after the exit of the terminal area and there is not a notification in relation to the payments.

3. The Proposed Solution

This section describes the proposed ICT based solution to solve the main drawbacks of the phases described in the Sections 2. The new automated solution is called to be.

The proposed ICT based solution aims to eliminate the current criticalities and the lack of synchronization by electronically associating the information and data about goods with the freight itself. This ICT application addresses the topic concerning the automation of the CC procedures and of the payment of shipping and customs duties. The proposed solution speeds up payments and authorization procedures, such as CC and security control checks. Moreover, it limits delays and errors thanks to the provision of electronic information, updated in real-time on the goods status. Finally, the ICT application progresses the port operations: the arriving at the port, the exiting the terminal area, the exiting the port, the entering and the exiting the warehouse area.

In particular, the utilization of Radio Frequency Identification (RFID) based technology foresees important changes in the processes of the flow of goods and in the workflow organization. Indeed, RFID tags introduce a univocal code of identification

that allows avoiding duplication of data travelling with goods. From the ICT infrastructure point of view, the freight communicates with the ICT system through smart devices, such as gates, located along the wharf, at the exiting point of the terminal area, at the exiting point of the port area and at the entrance of the warehouse. In these points the freight is able to communicate with the ICT infrastructure, updates in real-time its status, in terms of presence, identity and data of the goods. Moreover, the freight can detect its context, i.e., the involved actors, goods position and status.

In the following, we describe the sequence of the operations under the proposed ICT solution that we call *case to be*. To this aim the phases listed in Section 2.1 are revisited in the following new steps.

1. *Loading phase*. The hazelnuts sacks are ready to be loaded on trucks to be transported to Europe by ferry. The goods loaded on a truck are identified as single freight with an identifier based on the RFID technology in order to trace them throughout the whole flow.
2. *Shipping and data collection phase*. The Turkish shipper, once the trucks are loaded and the ship is coming to the Port of Trieste, links the tags to the data about goods and uploads the data about goods that are related to the Customs clearing procedures. The data are registered in the so called pre-arrival and MMA document. Such documents are automatically communicated to the Customs Authority System that sends back to the freight forwarder the risk rate associated to the freight.
3. *Unloading phase*. The goods arrive at the Port of Trieste and update their status about date, place and time arrival. The freight exchanges information with the Customs Authority. It notifies its arrival and receives back the MRN code and the necessity of security check controls.
4. *Automated security notification phase*. The freight automatically recognizes if it is authorized to exit the port area or if it has to be checked. In the second case, the necessity to stop is communicated to the freight by a traffic light that is positioned at the terminal exit.
5. *Automated payment phase*. The freight arrives to the Port of Trieste and communicates with the bank in order to fulfil the payment of the shipping duties.
6. *Automated customs clearance phase*. The freight forwarder decides when goods have to be cleared and the status of the freight is uploaded on the basis of this decision. There are two possibilities:
 - a. goods cleared in port area. While the goods are exiting the terminal area, it updates its status and recognizes that it has to fulfil customs clearance procedures. The customs duties (e.g., the VAT) are automatically calculated by the ICT infrastructure on the basis of the information communicated by the freight itself. Once all the customs clearance procedures are performed, the status of the freight is updated thanks to a direct communication with the Customs Authority system;

- b. goods cleared outside the port area. To exit the port area, authorization documents are needed in relation to the MRN code. The Carnet TIR document and its number are automatically registered. Then the goods are transported to the warehouse where the hazelnuts are stored. In such a case, CC operations are automatically performed in the warehouse area.
7. *Delivery phase.* Finally, the goods exit the warehouse to be delivered to the consignee.

4. The UML Model

In this section we describe the model of the considered case study including the system physical structure and the activities of the involved actors. In particular, we model the system as a Discrete Event System (Cassandras, 2008) 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. Since the task of the model is a simulation study, we use the UML formalism 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) (Gomaa, 2008). Indeed, UML is defined as a graphic and textual modelling formalism intended to understand the needs and to specify and document systems. For more details on the UML, the interested reader is referred to (Booch *et al.*, 1998, Miles and Hamilton, 2006).

Referring to the metamodel proposed by (Boschian *et al.*, 2011), the first step consists in identifying the main subsystems that compose the logistic network. In particular, this paper addresses the structural subsystem related to the so called “Logistic Operator and Custom Authority” UML package, see Figure 1.

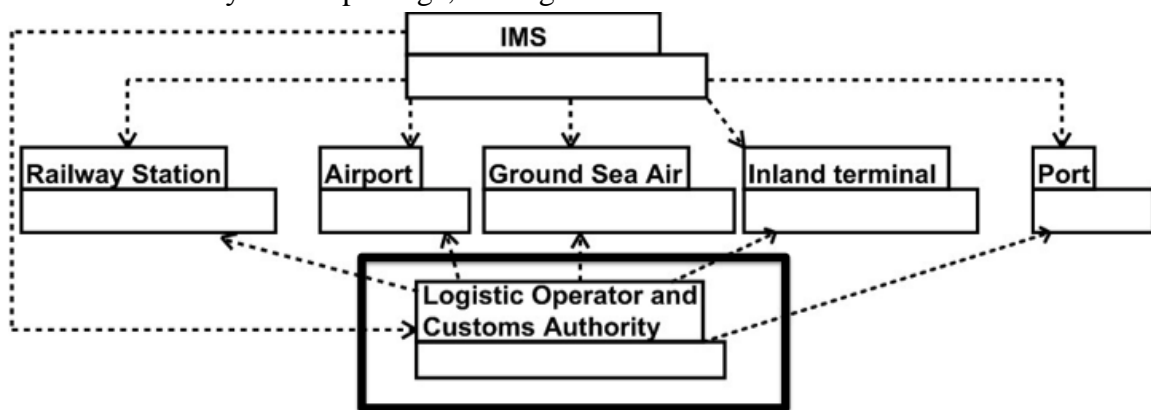


Fig. 1. The package diagram of the Intermodal Logistic Network.

In order to achieve an overall improvement of the logistic system, it is necessary to focus not only on the configuration of the different structural components but also on the management and administrative operations. For this reason, this paper focuses on a specific part of the logistic network, analysing how the utilization of ICT tools impacts on the overall logistic performances. Looking at the effect of ICT on customs administration and security operations, we particularly address the dynamic part related to the information exchanges related to the resources present in the port and involving, in particular, the authorities. Therefore, the focus of this analysis is not on the static component of the system, but above all on the dynamic description of the different operations, as described in the following Section 5.1. Indeed, the considered package has several dependencies with other packages, because of its crucial role.

4.1 The Operation Description by the Activity Diagrams

In order to describe the management processes relative to the flow of goods and of information, we use here the UML activity diagrams. In particular, UML activity diagrams unify the notions necessary to describe various activities of complex and large systems in an object oriented development process. 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 drawn by thick bars. In addition, the columns of the activity diagrams show the actors responsible for each activity. The actions 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. Figure 2 shows the activity diagram of the current flow of good for the considered case study.

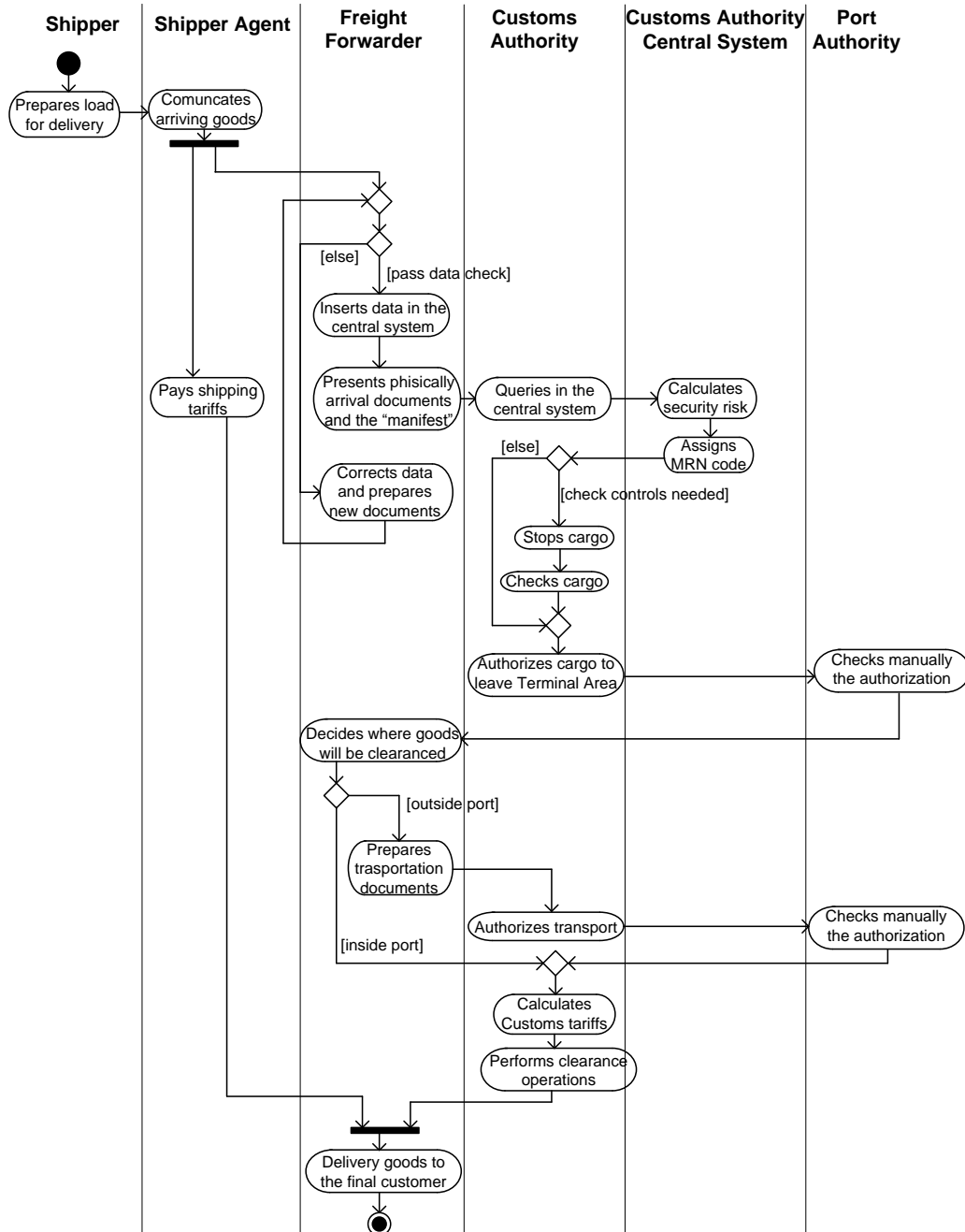


Figure 2. The current flow of goods and the CC operations

The sequence of the different phases of the case to be is formally described by the UML activity diagram depicted in Figure 3.

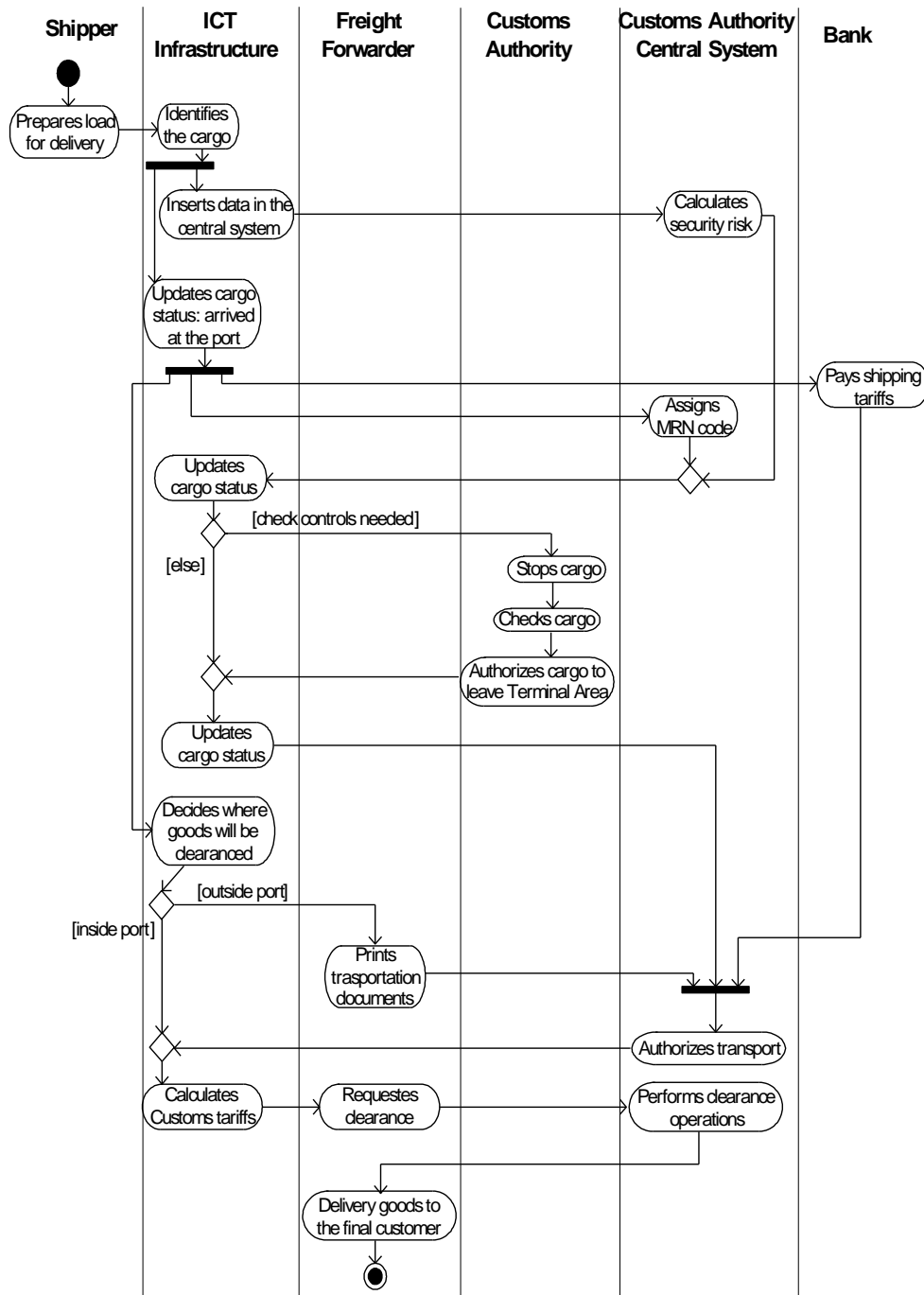


Figure 3. The flow of goods and the CC operations under the proposed ICT solution

5. The Simulation Specification and Results

This section describes the simulation of the considered intermodal logistic 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.

5.1 Definition of the Performance Measures

In order to compare the two CC procedures, some performance indicators are defined that are employed to evaluate the current system and to tune the proposed ICT solutions. The task is enhancing the efficiency of the overall logistic system in relation to the security and customs clearance operations. To this aim we consider as a basic indicator the time spent to perform some crucial phases of the customs clearance. More precisely, the performance measures are defined in the following.

Lead Time 1 (LT1): it is the average time necessary to unloading goods and to register the arrival of the goods in the Port of Trieste. Such a delay is the time (some hours) requested for the docking and unloading operations of the trucks and for the customs office procedures. It is important to measure this time because in the current scenario it causes a delay in recording the needed data about the goods.

Lead Time 2 (LT2): it is defined as the average time spent for the notification of the security check request. More precisely, it is the time necessary to communicate the security procedures coming from the Central Customs European System.

Total average Lead Time (LT): it is a measure of the time spent during the total flow of goods.

Moreover, in order to evaluate the labour cost in the security and customs operation phases, we define the following indices:

- **average labour time 1 (LB1):** it is evaluated as the average time spent by an employee (man-hour) per month to fulfil the security operations;
- **average labour time 2 (LB2):** it is defined as the average time spent by an employee (man-hour) per month to fulfil the CC operations;
- **average total labour time (LB):** it is defined as the total average time spent by an employee (man-hour) per month to fulfil all the described phases.

5.2 Simulation specification

The simulations start from the unloading of trucks in the terminal area of the port of Trieste and end when goods finish their clearance activity before leaving the port. The discrete event model of the intermodal system is implemented in the Arena environment (Kelton et al., 2008), (Teilans, 2008), that is a software particularly suitable to deal with large-scale systems.

The simulations compare three different scenarios. The first scenario represents the current system behaviour (case as is) that is described in Section 2.1. Moreover, the second scenario (named case to be1) simulates the system behaviour after the introduction of the ICT infrastructure previously proposed. Finally, the last scenario is the case to be2 that reproduces the to be1 scenario with a doubled flow of trucks.

In addition, the processing times of the phases described for the three scenarios have triangular distribution. Table I reports the processing time distributions: the second

column depicts the modal values δ of the processing time distributions of the case as is, the third and fourth columns show respectively the minimum (d_{δ}) and the maximum (D_{δ}) values of the range in which the firing delay varies. All times are expressed in minutes.

Moreover, in the cases as is and to be the trucks enter the system with an exponentially distributed rate of 10 trucks/day.

All the indices are evaluated by a long simulation run of 12 months with a transient period of 15 days. In particular, since the total average lead time is the most meaningful index of the simulation, the estimates of LT are deduced by 50 independent replications with a 95% confidence interval. Besides, we evaluate the percentage value of the confidence interval width to assess the accuracy of the LT estimation.

Triangular distribution values of the operation times (in minutes)			
<i>Activity</i>	d_{δ}	δ	D_{δ}
Communicate	4	5	6
Pay Tariffs	24	30	36
Present Manifest	24	30	36
Correct Data	60	720	1080
Insert Data	24	30	36
Calculate Risk	4	5	6
Assign MRN	4	5	6
Check Good	30	60	360
Prepare Transportation Documents	48	60	72
Calculate Customs Duties	4	5	6
Clearance	48	60	72
Terminal Check	4	5	6
Port Check	4	5	6

Table 1. Triangular Distribution Specification of Processing Times

5.3 Simulation Results

The results of the simulation experiments are summarized in Figs. 4, 5 and 6 that report the values of the average lead times, the average labour times and the

throughputs, respectively. We remark that the width of the confidence interval, being less than 0.98% in any simulation, confirms the sufficient accuracy of the total average lead time estimation. In particular, the results show that the management change from the case as is to the case to be1 leads to a noteworthy decrease (about -97%) of LT1 and (about -73%) of LT2. Analogously, the results in Fig. 5 point out the huge decrease of the labour costs, since $LB1=0$ for the case to be1.

Nevertheless, it is interesting to note that the average system throughput for the first two scenarios is almost unchanged: it is about 304 trucks per month in the two cases (see Fig. 6).

In order to verify the potentialities of the new ICT solution, the case to be1 is modified in the scenario to be2 that is characterized by an input rate exponentially distributed with an average of 20 trucks/day. Figure 4 shows that the scenario to be2 exhibits an increment of LT2: it is obvious because the input flow of trucks is greater than in the case to be1. On the contrary, the throughput in case to be2 is much higher than in case to be1: this means that the system managed by the ICT solution is able to tolerate a higher workflow by exploiting the same resources.

Indeed, considering the average labour costs shown in Fig.5, it is apparent that the amount of hours spent for the customs activities decreases in case to be1 with respect to the case as is. However, with a rational reorganization of the workflow, in case to be2 it is possible to increase the service rate of the system. Indeed, it is possible to move the underutilized resources to fulfil the security operations to satisfy the customs clearance operations.

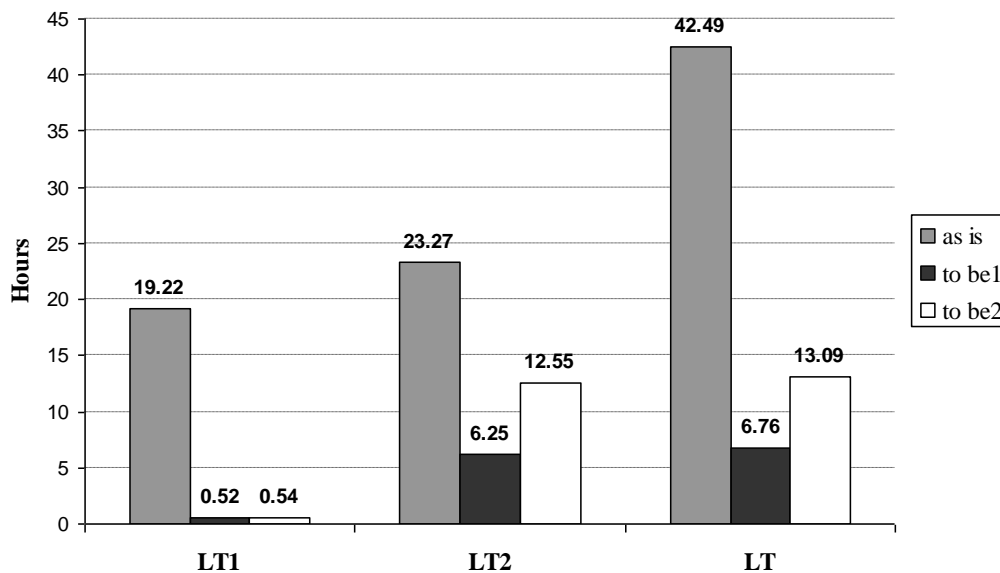


Figure 4. Average Lead Times

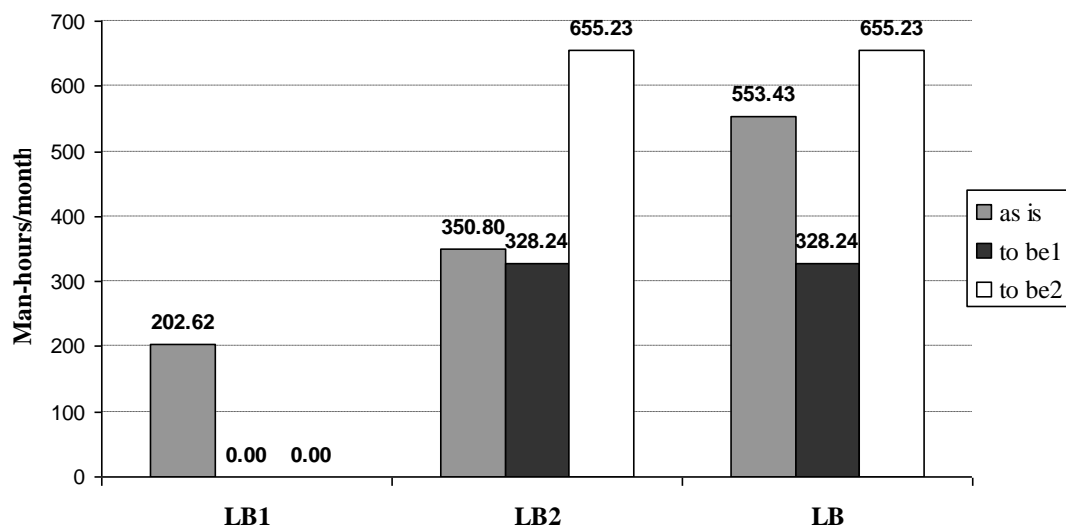


Figure 5. Average Labour Costs

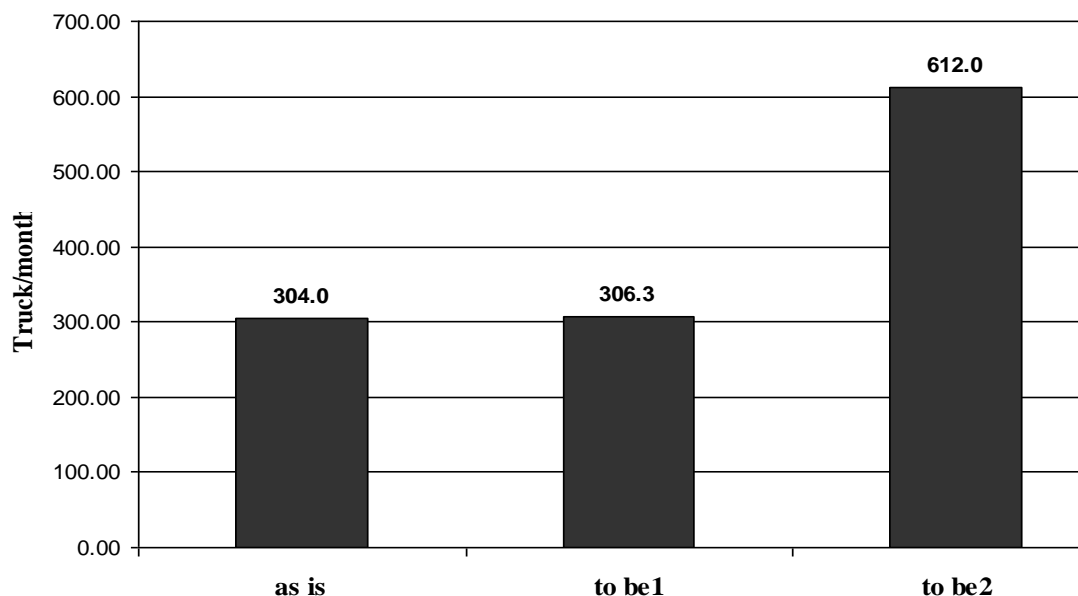


Figure 6. The average throughput

6. Conclusions

The paper proposes ICT based solutions to speed up the transit of goods at international borders and to increase security levels. The objective can be reached by security information self-generated by the freight, the automation of clearance and authorization procedures and the automated billing system. The security information is generated automatically interacting with carrier, agent and customs authority. Moreover, the customs clearance procedures are activated by the freight communicating with the involved authorities thank to the applied ICT solutions.

A discrete event simulation study shows that the suitable application of the modern ICT based solutions has a huge potential for efficient real time management of customs operations, drastically reducing the lead times in the port. Moreover, the simulation results allow proposing a reorganization of the workflow in order to suitably utilize human resources in the context of the new proposed ICT management.

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