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On coordinating document exchange in maritime containerized transport: the STM project

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Abstract

Maritime transport involves many stakeholders, whose decisions and actions affect the whole logistic chain of containerized transport. In this context, ports play a crucial role, since their operation performance determines the quality of containerized transport. Port call processes should be coordinated, and optimized, not only during planning, but also in realizing and evaluating conducted port calls. In fact, nowadays the document exchange in maritime transport is definitely too fragmented. A major reason why is that involved port actors usually try to get access to, and retain control of, information that is valuable with respect to their own goals. As a result, seaport approaches are often uncoordinated. Such a lack of coordination in information exchange among all the involved actors provokes at least a significant waste of time, and an avoidable decrease of maritime transport efficiency. Then, the challenge of designing and implementing an effective coordination in document exchange in maritime transportation should be taken and won, as also European Commission fosters.

Keywords: maritime data sharing; containerized transport; Sea Traffic Management.

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1. Introduction

Increases in world trade brought about advances in handling facilities and developed the shipping business proportionally to commercial and industrial progress. In particular, the world fleet for containers cargo has tripled in capacity in the last decade in both numbers and volume. Cellular vessels are also currently being built with even 13,000-15,000 TEUs with new ship designs reaching capacities of up to 22,000 TEUs. Such initiatives allow for wholly new economies of scale to be reaped in shipping. The size of the vessels and the related costs require optimal commercial management, expressed in fast routes between distant countries (Ocean Services) and a limited number of port calls (Malchow, 2014). The size of vessels and their management costs influence obviously container terminals which answer is looking for automation (Martín-Soberón et al., 2014). In fact, they continuously have to upgrade their systems to guarantee specialised handling and storage of containers. Managing terminals requires great organisation with a sophisticated IT system for tracking containers movements: for example, from discharging to delivery, recording the days of storage in the terminal. Container handling operations are performed by special cranes that, favoured by standardisation of dimensions and lifting systems, can achieve high operative speeds of lifting and moving. The increase in the capacity and size of container ships has made it necessary for land-based cranes to adapt in both height and especially outreach, which can extend as far as 65 metres out of from the wharf (International Transport Forum Report, 2015). This allows latest-generation ships to operate with 23 rows of containers on deck. Terminals currently use information technology (IT) systems to fully manage the containers' data and movements. Most of the information is processed according to EDIFACT (Electronic Data Interchange for Administration Commerce and Transport), which allows data to be exchanged with the ships (Bay Plan), and the optimisation of yard position, loading/discharge sequences (Stowage Plan), and real time container tracking. The EDI IT system is also available to external bodies (Customs, Port Authorities etc.), logistics operators, agencies and customers for their own information and documentation requirements.

EDIFACT standard provides a set of syntax rules to structure an interactive exchange protocol and provides a set of standard messages which allow multi-country and multi-industry exchange of electronic business documents. EDIFACT is widely used across Europe and has seen some adoption in the ASPAC (Asian-Pacific) Region, however, there are currently more XML-based standards being used in this particular region today. These messages are now in use worldwide and allow multi-country and multi-industry exchange. The aim of this work is to define an approach to assess the impacts of a coordinated document exchange in a phase of containerized maritime transport chain. Such coordination arises from the development of the Sea Traffic Management system. STM is an ongoing project intended to create a common standardized information sharing environment for actors in maritime sector. STM puts an emphasis on interoperable and harmonized systems allowing a ship to operate in a safe and efficient way from seaport to seaport with a minimal impact on the environment. STM involves multiple actors on multiple levels, which requires new procedures for information sharing in a distributed manner within each stakeholders' action scope (Lind et al., 2014; Watson et al., 2017).

The purpose of this paper is to present an approach to evaluate the benefits of STM, considered as a coordinated group of systems ready to work, in containerized maritime transport. The aim is to focus on a single phase of the port call process, analysing it and improving it through a tool, managed by STM, concerning how to improve the ship planning phase time loss in a real case study. In doing so, an ad-hoc model based on Discrete Event Systems has been developed to reproduce the information exchange process among the actors involved in this phase and a Genoa container terminal is considered as case study. A comparison between the same system without and with the application of the STM implementation tool will be described. The complete paper is structured as follows. After a related scientific literature review, the main problem of the process will be proposed and the model will be explained and shown. Then it will be validated through a case of study. The application of the model to the present scenario and to some possible future scenarios and developments will be described. The analysis and the discussion of the simulation results will conclude the paper.

2. Literature Review

Sea Traffic Management is a concept for maritime services based on standards and open interfaces. It was thoroughly analysed and defined by the MONALISA 2.0-project (2013-2015), inspired by the Air Traffic Management work conducted under the SESAR umbrella. To simplify the presentation of the STM possibilities, the services are grouped into four areas:

- Voyage Management is a concept for maritime services based on standards and open interfaces. It was inspired by the Air Traffic Management work conducted under the SESAR umbrella.
- Flow Management services will support both onshore organisations and ships in optimising overall traffic flow through areas of dense traffic and areas with particular navigational challenges.
- Port Collaborative Decision Making services will increase the efficiency of port calls for all stakeholders through improved information sharing, situational awareness, optimised processes, and collaborative decision making during port calls.
- System Wide Information Management will facilitate data sharing using a common information environment and structure (e.g., the Maritime Cloud). This ensures the interoperability of STM and other services.

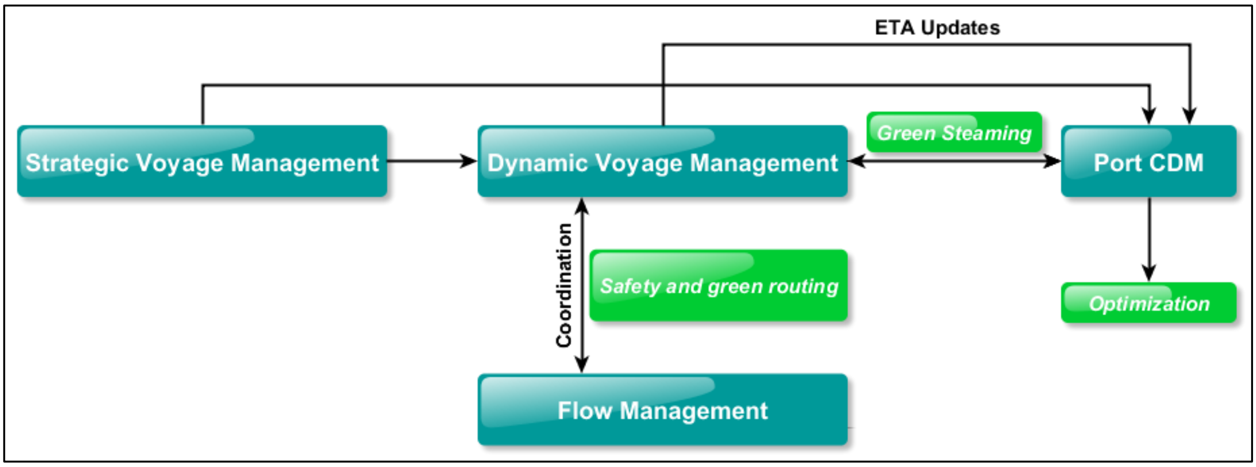

Fig. 1 The four concepts of Sea Traffic management and the expected contribution

So the idea is built on information sharing and collaborating to optimise the maritime transport chain while increasing safety and sustainability. The digital information on-board and on shore is several; however, the interconnection today is point-to-point and proprietary and stops the industry becoming more efficient. Sea Traffic Management will help the industry achieve improved predictability by introducing standards for key information and supplying an infrastructure for information exchange. This enables all actors involved in the transport to plan better and utilise their resources more efficiently. Shorter routes, just-in-time arrivals, shorter port calls are factors that will strengthen the competitiveness of the maritime sector (Lind et al., 2016)**.** Thus, ports started to be oriented towards supply chains to meet the nowadays changing needs of their users and customers (Shaw et al., 2016). For this reason, the idea of our study is to analyse how the STM technology could improve the maritime freight transportation showing a real case of time loss in a specific small phase for containers' ships in port terminal. This small phase is a step of the stowage planning problem. In literature the stowage planning problem is analysed in terms of slot planning optimization algorithm (Pacino et al., 2015), and in general port operations are analysed as a whole system where trying to optimize resources and performance indicators (Kourounioti et al., 2016) also through to discrete event simulation (Kotachia et al., 2013) while the idea of our study is to coordinate the data sharing information needed among the actors involved in a critical sub phase before the stowage operations. Data sharing could be managed in the STM system also through standard messages EDI which application is well described in literature (Bahija et al., 2016; Stefansson, 2002) and customary in freight maritime shipping.
The new contribution of our analysis is focusing on a real problem that some terminals ports have to face out during their operations and try to understand how the STM system could manage this kind of problems. To do this, our model first shows a time loss problem in a phase before the stowage planning operations and its consequences' impacts and then a solution to solve this problem is described.

3. The Stowage plan: operational problems and resulting impacts

The stowage plan was originally decided by the ship's master who decided it on arrival in a port. Today these operations must be planned in advance so as to optimize the ship's capacity and the productivity of the ports. On-land planning centres have been thus created to centralise the collection of ship data and booking data from port agencies across the relevant commercial area (for example Mediterranean Sea). The work is carried out by terminal planners. The bookings sent in the agencies must bear different kinds of information. Depending on the ship's condition when it docks, the planner makes the discharge plan and then the loading plan, using the booking data, and taking account of the containers remaining on board. The stowage plan is simulated by computer cell-by-cell using dedicated planning software for each individual vessel (see Fig. 2) so that once loading is complete, the required technical conditions for the ship are achieved in terms of stability, displacements, drafts, shearing forces, bending and torsional moments. If the plan meets commercial and technical requirements of the ship, the planner sends it in EDI format to the port terminal and the ship's master. The terminal uses the same stowage plan to develop the port sequences for moving the exported containers from the storage area to the ship to shore crane for loading, matching them to the cells provided for by the planner. When the operation has been completed, the Terminal recalculates and completes the export stowage plan, sending it again in EDI format (BAPLIE: Bay Plan occupied and empty Location message) to the master and planner for the checking and updating of the ship's status in view of the operation in the next port. Depending on the loading/discharge instructions received by the planning office, the terminal organises the work by calling the gangs required on board and ashore, making available the quay cranes and the means of handling that are needed to operate in shortest time. After unlashing the containers, the container discharge operations are performed by cranes. The terminal's operational efficiency is expressed by the number of movements per hour, these being on average 25 per portainer in Europe with a maximum of 35 in the Far East ports. The speed of operations depends on both the terminal's level of organization and the personal. Crane drivers perform operations according to the EDI plan received from the planners and this is recalculated using terminal's data for transferring the containers from the ship to the terminal yard. Loading follows the same procedures; once identified, the outgoing containers are transferred alongside the ship and then are lifted on board directly into the locations provided for by the planner. As the loading operations are completed on deck, the containers are lashed/secured. The terminal supplies ship command with the final cargo plan so that it can check the technical conditions before the ship's departure.

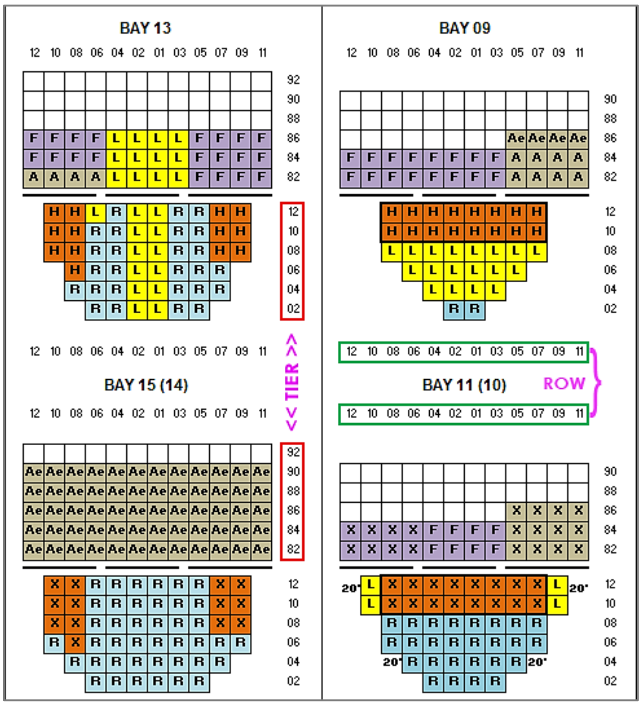

Fig. 2 Stowage plan example

Nevertheless, there is an intermediate phase when the ship arrives in the seaport. In fact, ship's master is responsible for the ship during navigation and he aims that the ship and navigation are safe. So he's the actor who has to decide how the final loading plan will be. In many cases, when the ship arrives in the port, the terminal planner has to go on board the ship to show the loading plan to the ship's master. The planner goes on board with a paper printed version of the loading plan or a digital one, and shows it to the ship's master. The terminal planner spends time analysing the plan face by face with the ship's master who, sometimes, can modify the position of containers depending on weight stability constraints of the ship in order to improve the ship safety during navigation. This takes time (hours): this additional phase creates more than one step in the port call process and inside the entire chain. The time needed obviously could change time by time, depending on the ship, on the changes in the plan, on the resources and so on. First the terminal planner has to go on board the ship to discuss the plan, then, if there are some changes by the ship's master, he has to plan again the new final loading list for the ship stowage and for the cranes' working queues. So the discharging and loading phases for the terminal in these cases are not optimized. If the ship has to discharge a good enough number of containers, the terminal ship planner probably gets enough time to recalculate the final loading plan with the new changes. But if there are not containers to unload or if the discharging phase ends before the terminal ship planner recalculation, there will be waiting time for cranes and all the process will be interrupted until the final loading plan will be ready. Moreover, to guarantee more efficiency usually cranes work on discharging and loading phase at the same time by following an optimized list of moves which meets all the ship's constraints.
The model presented below shows the loss of time due to this real phase. It's built to be adaptable to each terminal thanks to the possibility to change the cranes' movements per hour, the number of containers to discharge and the number of containers to load. A real case of study is presented in the following section and the results will show the time loss trends in function of the number of containers to unload. Then a solution for this kind of problem and a comparison model between the nowadays process and the one with the effect of STM implementation are presented.

4. Methodological approach

A discrete-event simulation of a system is an imitation of the occurrences of events in a system. Time is represented in a discrete-event simulation and it is also called the current time. There are two types of discrete-event simulation: event-based simulation and time-based simulation. In an event-based simulation, the current time is set to the time when the event occurs. In a time-based simulation, the current time advances regularly; in other words, a time event occurs at regular intervals and each time event updates the current time. Any event that must occur in the current time occurs before the next time event occurs.
A discrete-event simulation may be used to study a system. In this case the occurrence of every event may include the creation of other information. For example, if a study includes an analysis of the average amount of time entities spend

in the system, then the amount of time spent in the system for every entity is the difference between the time when the entity entered the system and the time when the entity exited the system; the difference in time and the average amount of time are the other information. ExtendSim tool is used to develop the simulation models for containers handling within the new terminal.

The aim of simulations is to define a support system for managers in strategic decisions. As mentioned, the simulation model is used to simulate time loss in the phase of setting the final loading list that has to be defined and sent to cranes to load ships. The simulation model is built as a discrete event system, whose state does not continuously varying with time, but switches from a state to another when a particular event occurs. An event set and a state set are defined and it may not be possible for some events to occur at some state or, in other words, any state x in the state space allows a peculiar feasible event set, which is a subset of the whole event set.

5. Model application to a real case study

In the following figure (Fig.3) the model developed in ExtendSim is presented. As mentioned before, this model can calculate the time loss in real cases depending on the cranes' movements per hour, the number of containers to unload, the number of containers to load. This data can be modified to characterize a specific terminal and its efficiency. In fact, the cranes' movements per hour represent a sensible parameter in terms of efficiency and time saving. Obviously each case could change in function of ship type, number of containers and also changes by ship's master as described in section 3.

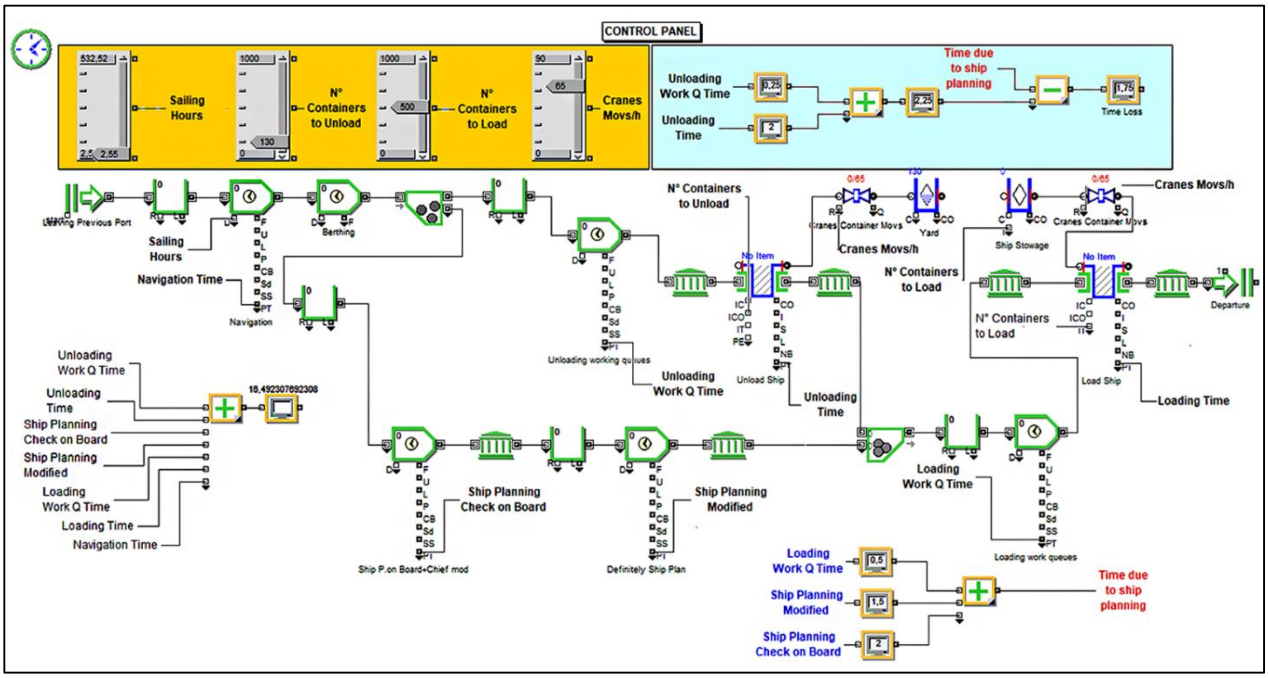

Fig. 3 Model to calculate time loss

Another input of the model that can be modified is the sailing duration. In fact, sometimes it happens that the previous port is less hours far than the time needed to end the stowage plan. To analyse the output of the model, a case of study based on real port terminals data in Genoa is presented. In this scenario the terminal ship planner spends two hours on board the ship with the ship's master to plan how to change the placement of some containers; to end the final loading plan with all the ship's master changes, the planner takes 1,5 hours and we can suppose a 30 minutes before the first crane can start the container handling from the final planning. This time takes into account also the ground resources time to pick the container in the specific yard zone and bring it in the crane operational zone. These data are resumed in Table 1.

Table 1. Real case of study: time data input

Data Input for the final ship planning	Time (hours)
On board the ship	2
Final ship loading plan	1.5
Container listed in the final plan handling	0.5

With this input data the model gives out the time loss linked to the number of containers to unload with an average overall movement rate of the cranes. It's supposed the use of three cranes at the same time. Results are presented in the figure below. The figure shows three example of cranes' movements per hour in the same chart.

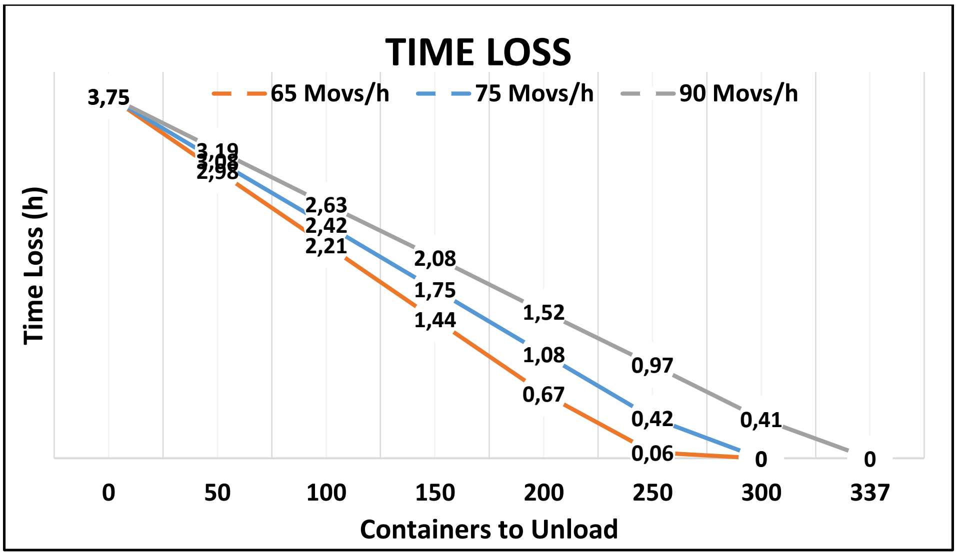

Fig. 4 Time loss due to containers discharging, depending on cranes' movements per hour

This is an example of how the model works. The idea of this model is to allow to choose the parameters for different kinds of terminal and analyse a specific case each time.
This study shows how real operations could be affected by time loss, like the example presented, and it's well know that loosing time, for sure, means losing money, efficiency, reliability, also for the involved actors of the whole logistic chain. The following Tables (2,3,4) show the output values of the model used to create the chart of Figure 4.

Table 2. Time loss results for 65 movs/h cranes' rate

Cranes' movs/h	N° containers to unload	Time loss (h)
65	0	3.75
65	50	2.98
65	100	2.21
65	150	1.44
65	200	0.67
65	240	0.06
65	244	0

Table 3. Time loss results for 75 movs/h cranes' rate

Cranes' movs/h	N° containers to unload	Time loss (h)
75	0	3.75
75	50	3.08
75	100	2.42
75	150	1.75
75	200	1.08
75	250	0.42
75	282	0

Table 4. Time loss results for 90 movs/h cranes' rate

Cranes' movs/h	N° containers to unload	Time loss (h)
90	0	3.75
90	50	3.19
90	100	2.63
90	150	2.08
90	200	1.52
90	250	0.97
90	300	0.41
90	337	0

Real cases like that cause inefficiency in the entire chain of the process because just in time operations are not guaranteed. This means worse performance for all the actors involved in the port call process. In fact, there could be delays in operations, negative impact in terms of costs and consumes, and the possibility to miss the booking windows in the successive ports of the logistic chain. A more efficient system like STM could solve the lack of coordination in communication and data sharing that is the starting point in losing time. To have an idea of the impact in terms of the cost/benefits analysis due to the time loss in this phase, we show an example considering a 20,000 TEUs ship.
The following tables show an approximate cost calculation in terms of consumption of the main engine, during navigation at the cruise speed, and of the auxiliary engines used in port operations and related costs.

Table 5. Container ship data

Container ship 20,000 TEUs	
Type	Container ship
Length	400 m
Beam	58.5 m
Draft	16.0 m
Depth	32.8 m
Installed Power	82,440 Kw
Cruising Speed	22.0 Knots
Capacity	20,170 TEUs

First let's calculate the power at cruise speed with this formula:

$$P_{cruise} = P_{max}\left({}^{V_{cruise}}/_{V_{max}}\right)^3 \tag{1}$$

Then the fuel consumption knowing the Specific Fuel Consumption (SFC) data:

$$FC = (P_{cruise} \cdot SFC)/1000000 \tag{2}$$

Through these formulas it's possible to calculate fuel consumption and its relative cost for main engine:

Table 6. Main engine data

Main Engine Data	
EP cruise	65,500 Kw
Specific Fuel Consumption (77% manual)	161 g/Kwh
Fuel Consumption per hour	10,227 ton/h
Fuel Consumption per day	245,4546 ton/d
Fuel Cost	292 $/ton
Fuel Cost per hour	2,986.36 $/h
Fuel Cost per day	71,672.75 $/d

And for auxiliary engine:

Table 7. Auxiliary engine data

Auxiliary Engine Data	
EP	10 Kw
Specific Fuel Consumption	180 g/Kwh
Fuel Consumption per hour	1.8 ton/h
Fuel Consumption per day	43.2 ton/d
Fuel Cost	292 $/ton
Fuel Cost per hour	526.6 $/h
Fuel Cost per day	12,614.4 $/d

These tables and cost analysis show how the time loss could affect the entire process in terms of costs.

STM, with its particular tool based on data management and data sharing, can guarantee just in time operations by creating a link of interactive real time data sharing during navigation between ship's master and terminal ship planner, so that they could decide the final plan before ship's arrival at the port. This can avoid time loss in ports operations because the loading plan could be done during the navigation so that, when the ship enters the port, all the commercial operations can start without any loss of time. Coordinate communication and data sharing during navigation means saving time, saving money, more efficiency and more reliability.
The resumed idea is represented in the following figures: Figure 5 represents the data exchange during navigation between terminal and ship; Figure 6 resumes the developed model with the STM tool implementation effect. It's able to avoid the time loss. Then, in the Figure 7 a comparison model between nowadays process and the future one improved by STM is presented. As shown, the STM improvement can avoid the time loss of nowadays process and consequently the logistic chain can obtain benefits in term of time saving and just in time operations.

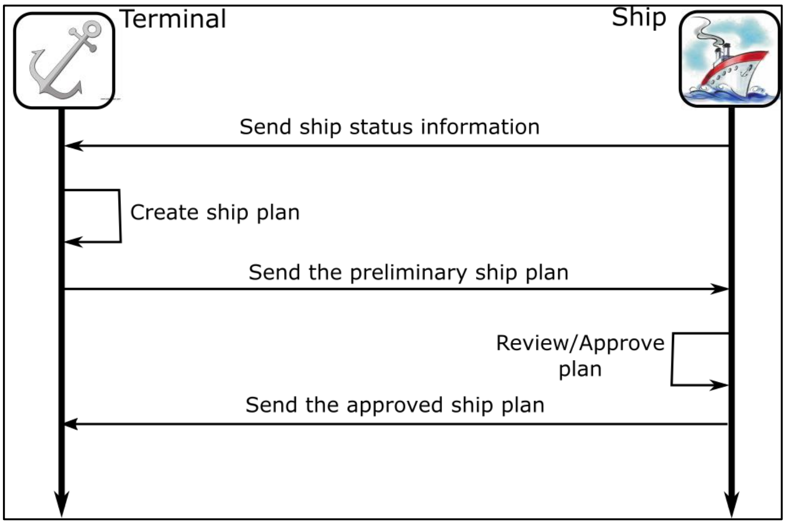

Fig. 5 Ship plan with STM effect

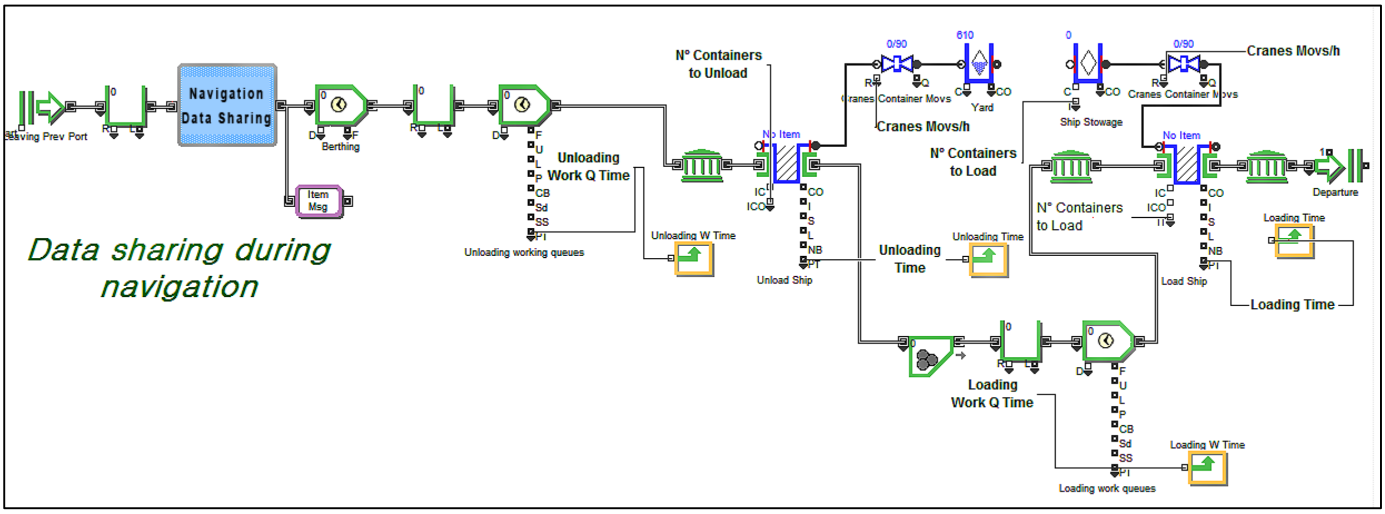

Fig.6 Model for data sharing during navigation

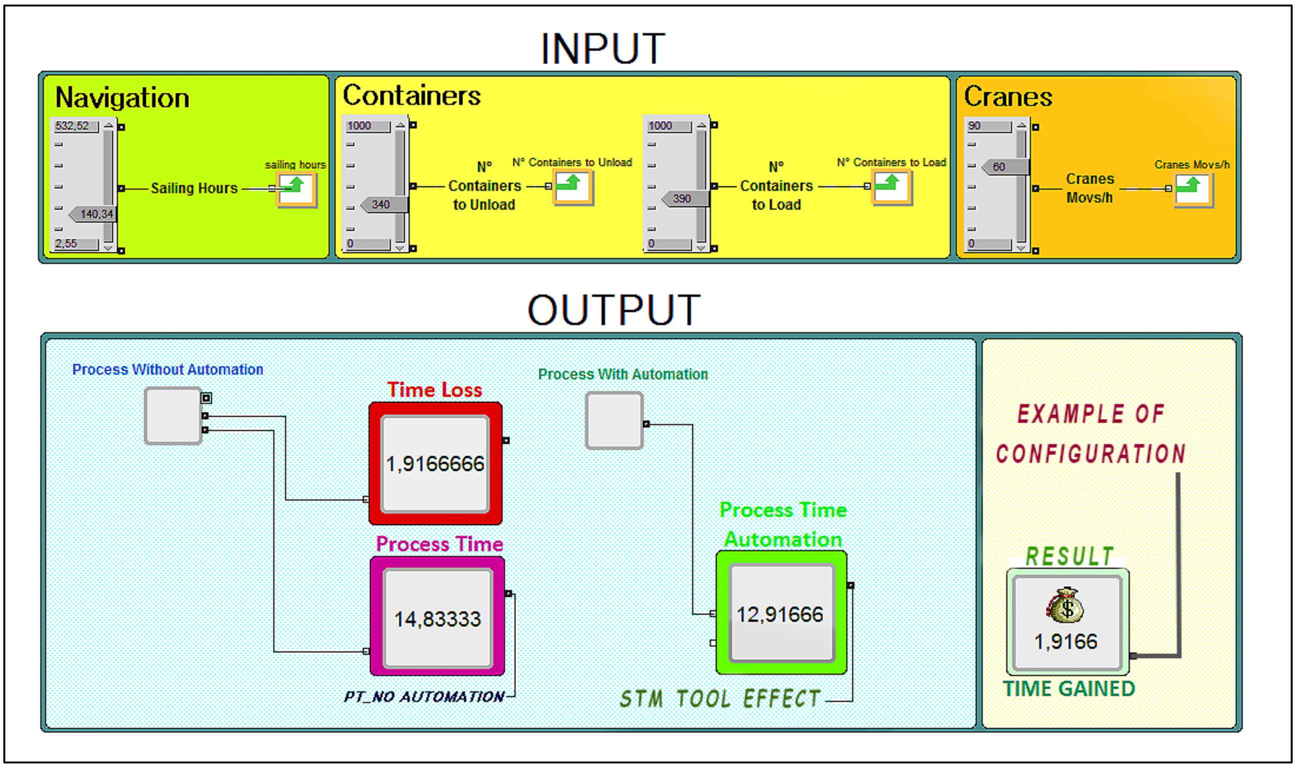

Fig. 7 Example of comparison between nowadays process and STM implemented tool process

STM is able to manage this kind of information sharing thanks to the connection among all the actors involved that is one of its major advantages. As mentioned before this is possible by using EDI standard messages and real time data exchange using any kind of device existing through, for example, web application managed by STM server. This real time connection is a great advantage for all the actors involved in the whole chain: all the ports listed in ships planned voyage, port authorities, terminals, lines, customs. The lack of coordination, that is the first point in losing time, can be solved with the system defined above in STM project. More efficient operations and the data sharing updating can be guaranteed.

6. Conclusions

This study presented how a better and well-coordinated data sharing could improve the freight maritime shipping efficiency. STM is one of the possible tools to generate this benefit. First, we presented an analysis on a real problem in a pre-phase of the stowage planning that causes time and efficiency loss and how the STM management can solve it.
Through a DES simulation tool we built a model which can be adapted to meet the performance rate of each terminal depending on cranes' movements per hour, duration of navigation, number of containers to unload and number of containers to load. Real data examples from terminals in Genoa have been tested and have shown how the time loss of that phase depends on the lack of coordination and affects money and efficiency loss inside the whole logistic chain regarding maritime transportation. The main cause of this problem is due to an inefficient data sharing in the port call process. For that reason, we described how STM, thanks to its real time data coordination and sharing, can face out this problem implementing EDI messages and managing the information sharing among involved actors. This will mean saving money, guarantee just in time operations and efficiency for ports, ships, agencies, customs, lines, etc... In fact, thanks to just in time operations it will be easier to manage the port call process in a completely efficient way. Our research presented a detailed and particular case of study in which STM can be the solution for optimized effects. The logistic chain is characterized by different phases: the optimization of one among these phases means improvements in the whole process. For this reason, the optimized data sharing in stowage planning and in its pre-phase, thanks to coordination and interactive information exchange, as presented in our study, improves the work management for all the involved actors.
Following ports, agencies, port authorities, customs etc… can foresee and manage better their work thanks to the previous just in time phase. The updating and the real time data sharing managed by STM become the starting point for the following actors to optimize their own process. STM is an ongoing project and so we will continue investigating how to apply all its benefits concerning container digitalisation and trucks' booking appointments to improve efficiency and reliability at the land side too and optimize the logistic chain data sharing from customer to user.

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