INTERMODAL LOGISTICS: SUPPORTING PLANNING AND SCHEDULING SERVICES OF FREIGHT FORWARDER

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ABSTRACT
Over the years the shipping sector has gained a fundamental role when talking about Global Trade. This paper presents a simulation platform for intermodal container shipping operations mainly devoted to support freight forwarders operations. The simulator is able to recreate long haul import and export container intermodal shipments with pick-up and delivery points on a world map. Input data for the simulations are available from two different databases, namely the Web Database able to retrieve data directly from the web and the Historical Database that makes use of historical data and time series collected by the forwarders companies operating long haul containers shipments in the port of Gioia Tauro, Italy. As part of the simulation, a number of different Key Performance Indicators are included and can be used to support expeditions planning, scheduling and scenarios comparison.

Keywords: long range container shipments, intermodal transportation, forecasting, planning, Simulation

1. INTRODUCTION
The container shipping sector is one of the most dynamic sectors inextricably connected to harbor business operations as well as to land transportation, due to its intermodal nature. A crucial development during the last twenty years was the increasing containerization rate with the aim of increasing the efficiency of shipping and cargo handling. Nowadays, international shipping can be regarded as a sophisticated network of scheduled services that transports goods from anywhere in the world to anywhere in the world and it is able to connects countries, markets, businesses and people, allowing them to buy and sell goods on a global scale. In such a context, seaports play a crucial role in the countries national economies by serving or driving import-export trade. They also influence viability, prospective and propensities for growth of regions. Today, the liner shipping industry transports goods representing approximately one-third of the total value of the Global Trade (Rajkovic et al. 2015). The latter depends mostly on the maritime network; its understanding in terms of services planning, scheduling, alternatives, etc. is a value added for: (i) those who require it (cargo owners, logistics service providers, forwarders companies), (ii) those who enable and shape it (shipping lines, port authorities), (iii) and those who regulate it (policy makers, regulators and governments), (Viljoen and Joubert, 2016). Focusing more on trade flows, Ducruet (2013) adds a commodity perspective to describe the diversity of maritime flows in the global network. The results show a strong influence of goods types on the specialization of maritime traffic at ports and on routes. This research is a first step in coupling the study of the global maritime network with the trade dynamics.
However, despite its average continuous growth, the global maritime industry, and the container shipping industry in particular, has become increasingly more volatile in the past decade (also due to the economic crises). Sudden changes in the world trade patterns and uncertain growth have resulted in a mismatch of demand and supply of container capacity (Neylan, 2015). Cost cutting and efficiency have become an imperative for the survival of container shipping companies as well as for all the other entities involved (e.g. logistics service providers, forwarders companies, etc.). To absorb capacity and ensure a more balanced use of their assets, shippers are deliberately slowing down their ships, so that more of them can be deployed on one service while maintaining the schedule of port calls. This is the so called slow-steaming and, while it was considered a drastic intervention a few years ago, it is now a common practice (causing, as side positive effect, environmental impacts reduction). Furthermore, shipping companies are able to plan and schedule their services in the most cost-efficient way. In fact, shippers may decide to discontinue a service due to profitability or to change it in favor of ports selection efficiencies or cargo volumes; or alliances may be formed to consolidate specific market segments. Luo and Fan (2010) investigates how ship-owners take decisions and invest their money according to the company dimensions, growth rate of demand, ships dimensions, possibility of ship replacement (new ship or second-hand ship) and ship speed. Basically, this research work quantitatively outlines the current ship-owners

behaviors and preferences. However, these are not the only factors taken into account when talking about the liner shipping industry. Song and Dong (2013) proposed a design for a maritime service line operating on long distance taking into account routes structure, deployment of ships and repositioning of empty containers with the objective of minimizing the total cost incurred a liner long-haul service route, while Bruzzone et al. (2002) propose the use of simulation based optimization for the fleet management.

A survey of the current state of the art reveals that there are a number of research works in this area, mostly related to intermodal transportation. SteadieSeifi et al. (2014) reports an updated review of the state of the art (from 2005 to 2014) while previous review can be found in Crainic and Kim (2007), Christiansen et al. (2007) and Bektaş and Crainic (2008). From the analysis of the review articles, it is also clear that, among others, simulation and optimization are among the most powerful and user methodologies to face planning and scheduling problems in supply chains (Bruzzone, 2002).

1.1 Contribution of this article

Similar problems to those outlined in the previous section, are also faced by freight forwarders; indeed, while freight forwarders do not move directly containers or goods, they are required to deal with carriers and shipping companies. Therefore, they continuously face strategic problems mostly related to delays during the shipment (e.g. customs & border protection controls), uncertainty in delivery times, unforeseen transshipment, bad weather conditions, etc.

This article reports the results of research project carried out by the Modeling & Simulation Center – Laboratory of Enterprise Solutions (MSC-LES, a simulation lab of University of Calabria, Italy) in collaboration with some Italian freight forwarders operating in the Gioia Tauro Harbor area, Italy. The main goal of the research project was the definition, design, development and testing of a simulation platform for long-range intermodal container shipments. The simulation platform has to be regarded as a tool for strategic planning issues that can be encountered by freight forwarders in long range intermodal container transportation, including problems in direct shipping, transshipment, services scheduling and uncertainty problems along the entire shipment. To this end, the simulation platform allows the forwarder to carry out stochastic simulations including:

- any desired pick-up and delivery points on a global scale,
- the entire shipment process (pre-haul for the container picking, long-haul and post-haul until the delivery to the final destination)
- two different databases for input data (web database and historical database)
- a set of Key performance Indicators to increase the reliability and the service level provided to the final customers.

The article is organized as follows: section 2 describes the conceptual models and the design of the two databases for input data. Section 3 presents the simulation platform architecture. Section 4 describes how the simulation platform has been implemented together with its main features, functionalities and Key Performance Indicators. Finally, section 5 summarizes the main results and conclusions.

2. ABSTRACTING THE LONG RANGE CONTAINER SHIPPING PROCESS

Long range intermodal container shipments have to be regarded as real-world complex processes; the main aim of this section is to abstract such complexity in a way that can be understood and successively implemented as a part of a simulation model. As mentioned in section 1, this research work was developed in cooperation with the forwarder companies operating in the Gioia Tauro harbor area, Italy. These companies mostly operate import and export long range intermodal container shipments. The figure 1 depicts a flow chart representing the export process (intended as a long range container shipment with its final destination somewhere outside Italy), while figure 2 depicts a flow chart representing the import process (intended as a long range container shipment with its final destination somewhere in Italy).

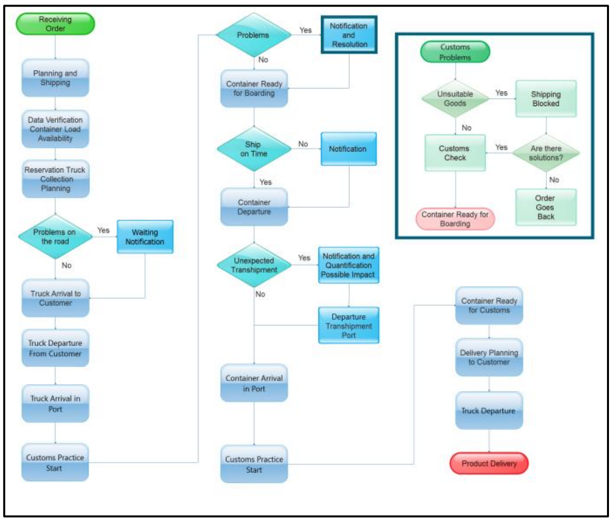

Figure 1 – Export Process Flowchart

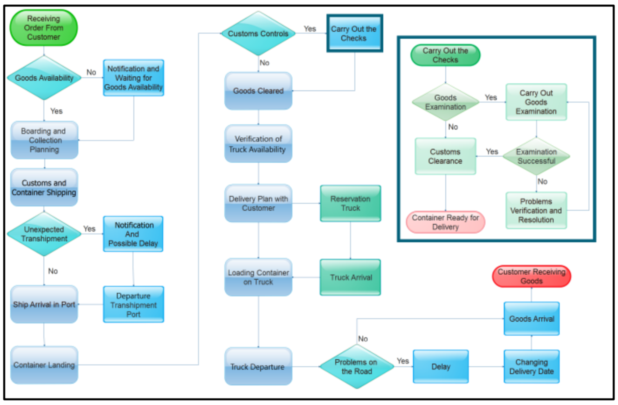

Figure 2 – Import Process Flowchart

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While the figures 1 and 2 clearly explain the forwarders activities in planning, scheduling and executing a long range expedition, they do not provide any insight about quantitative data needed to simulate the import and the export process.

2.1 Data Collection and Analysis

A quick look to the flow charts clearly shows that most of the times and events related to the activities depicted in the flow charts can be regarded as stochastic variables. To this end, particular attention has been given to data collection that represents a preparatory phase in the probability distributions determination, through statistical techniques.

The approach used to model the input data was to determine theoretical distributions rather than empirical distributions. The following operational procedure has been adopted and applied to determine the theoretical distributions suitable to represent the available data samples:

- verification of the data independence (all the data observations are probabilistically independent of one other)
- determination of candidate distributions families
- estimation of distribution parameters
- verification of the representativeness of the theoretical distributions identified

As far as the verification of the data independence is concerned, a correlation coefficient $\hat{\rho}_j$ is calculated according to equation 1:

$$\hat{\rho}_j = \frac{\sum_{i=1}^{n-j}(X_i-\overline{X_n})(X_{i+j}-\overline{X_n})}{(n-j)s_n^2} \quad (1)$$

Where X_i represent the generic observation, n is the total number of observations, $j = 1 \ldots, n-1$ is a generic distance between two observations (in order to check all the possible combinations) and $\overline{X_n}$, ${s_n}^2$ represent observations mean and variance values.

In addition to the value of $\hat{\rho}_j$ (absence of correlation means $\hat{\rho}_j = 0$ or $\hat{\rho}_j \sim 0$), the independence requirement can be easily evaluated by plotting the $\hat{\rho}_j$ value against the j value or the $(X_i, X_{i+1}), i = 1,2, \ldots n-1$ points (dispersion plot). The figure 3 shows an example of correlation coefficient for a road transit time, from the pick-up location to the nearest selected port for the expedition. Specifically, the data refer to a pick-up location in Naples (Italy) and a road transit toward the port of Gioia Tauro (Italy) for an export long-range container shipment, while figure 4 shows the dispersion plot for the same variable. The independence of the observations can be observed by the random distribution of the points and the absence of traceable patterns and polynomial functions.

The preliminary determination of candidate distributions families is done according to the summary statistics (mean, variance, Skewness, etc.).

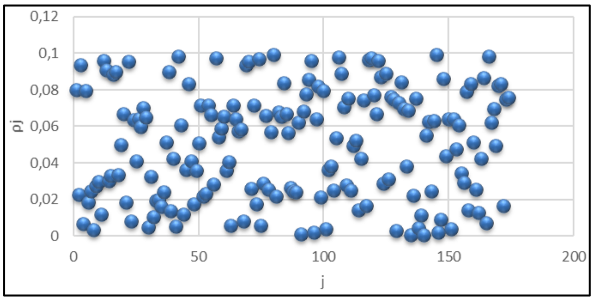

Figure 3 - Correlation coefficient trend for a road transit time

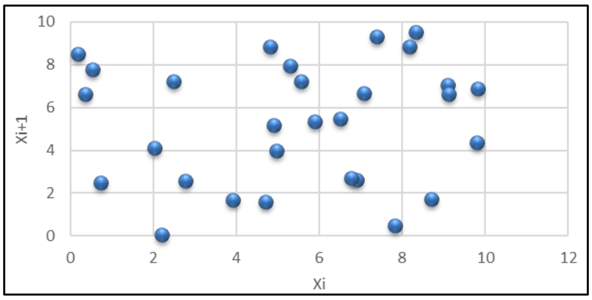

Figure 4 - Dispersion plot for a road transit time

Summary statistics together with histograms and a-priori knowledge (e.g. inter-arrival times are usually distributed according to exponential distribution) provide help in selecting the "most promising" distributions. The figure 5 shows a comparison between a histogram coming from a data sample and a probability distribution. Eventually, the final distribution selection is done according to goodness of fit test (e.g. Chi-Square, Anderson-Darling, etc.).

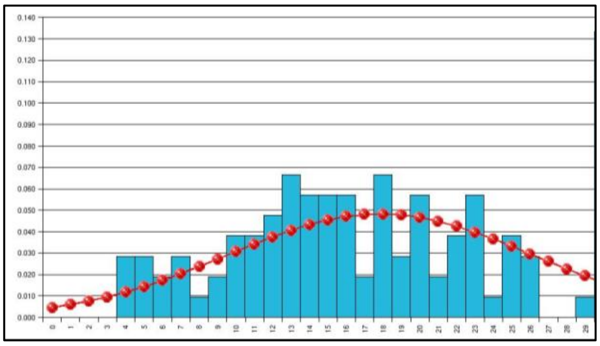
Figure 5 - Comparison between histogram and probability density function

2.2 Web Database and Historical Database

All the input data has been organized in two main databases:

- The web database;
- The historical database.

The web database collects data retrieved directly from the web. While data regarding road transportation can be easily retrieved from Google Map®, Open Street Map or similar platforms, port-to-port transportation times (sea times) can be retrieved by using online services and platforms (e.g. SeaRates); usually such services provide the user with multiple options (and data) as there could be more liners operating on the same route (on the selected departure dates) and more ships belonging to the same liner.

The historical database collects all the data provided by the forwarders companies operating in the port of Gioia Tauro and includes all the long-range container shipments they operated along the last 10 years. It is worth mentioning that both databases can be used to carry out simulations, however there are two major differences:

- by using the web database, the user can select any pick-up and delivery point on a world scale, while, by using the historical database, the pick-up and delivery points can be only those already served by the forwarders in the past. To this end, the web database offers the possibility to carry-out what if analysis investigating new business opportunities, providing customers with more accurate estimates on new routes.
- According to forwarders experts opinions (forwarders can be regarded as Subject Matter Experts), historical data (and therefore simulation results) are more reliable as they are able to reflect more accurately the shipment times.

3. SIMULATION MODEL ARCHITECTURE

The simulation architecture was conceived according to a three-level approach, MVC (Model-Controller-View), as shown in Figure 6. This approach was particularly used to respect two of the project requirements: (i) the simulation should be able to work on mobile devices (e.g. tablet and smartphone), (ii) the simulation should be able to work online over the internet.

The MVC architecture allows a separation among the simulation model and its logics including input data (implemented as part of the Model), the interpretation of all the commands received by the user, the simulation views updates and the correct formulation of the query to access the input data (implemented as part of the Controller) and the presentation of the simulation functionalities and results to the user (implemented as part of the View).

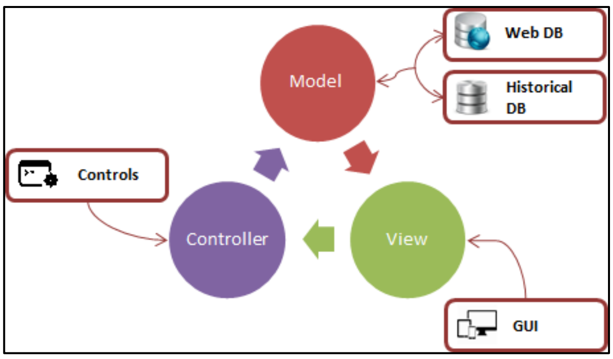

Figure 6 – MVC Simulation Architecture

3.1 Technological and Operational Architecture View

The simulation architecture was then developed according to a Server-Client logic by using the Laravel (version 5) framework. This is a PHP framework, oriented to MVC architecture and object-oriented programming. Laravel was used jointly with other programming languages and software tools: namely CSS 3, HTML 5, JQuery and Bootstrap for the Desktop client development (when the simulation is used online through a desktop computer), Android for the Mobile Client Development (when the simulation is used online from Android mobile devices). The technology view of the architecture is shown in figure 7.

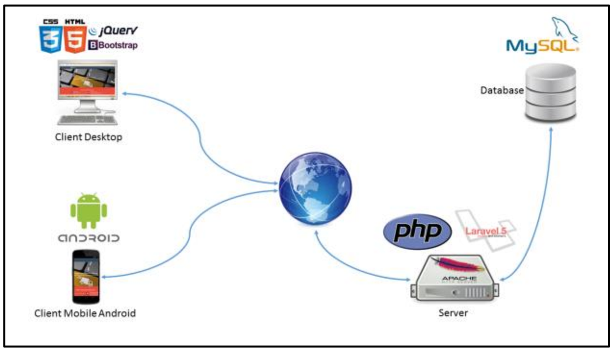

Figure 7 – Technological view of the MVC simulation architecture

From a conceptual point of view, the architecture operating diagram is shown in Figure 8. At the beginning of the simulation the user is required to select the operating mode (web Database or Historical Database), after he is required to insert information about the routes and start the simulation; in the end simulation results and KPIs are visualized.

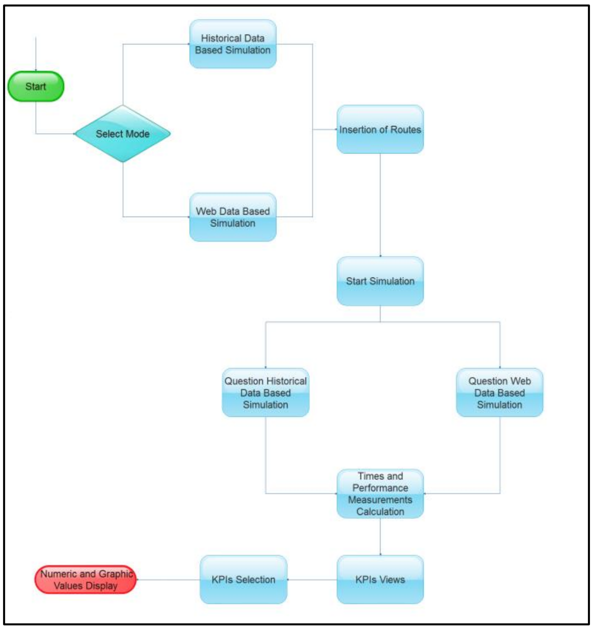

Figure 8 – Architecture Operating Diagram

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4. RUNNING THE SIMULATION

The execution of the simulation can be done by a standard web browser by using a desktop PC or a mobile device. This modeling and coding effort have been carried out with the aim of allowing users to avoid obstacles that are typical of non-service-oriented software and to come up with a Simulation as a Service (SaS) solution. Figure 9 shows the simulation model homepage allows the user to choose between two options: Web Data Simulation e Historical Data Simulation.

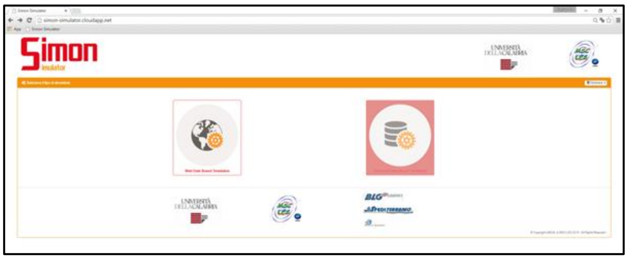

Figure 8 – Simulation model homepage

The user is then required to insert information about the routes that consists in specifying the following information:

- Departure city;
- Port of departure;
- Port of arrival;
- Arrival city;

Routes information can be directly typed in or can be pinned directly on the map as shown in figure 9.

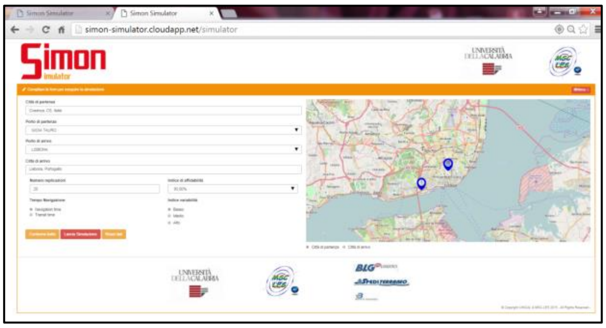

Figure 8 – Routes information, map and simulation commands

The user can change at any time the data entered or possibly decide to reset all fields by selecting the Data Reset button. Other parameters to be provided in input to launch the simulation are:

- *Confidence Interval*, used to determine the reliability of the simulation results (e.g. 95%, 99%, etc.).
- *Replication Number* determines the number of replication for each simulation run.
- *Variability Index*, a parameter used to increase or decrease the stochastic variability affecting sea transportation times.

During the simulation, an animation is displayed on the map that is intended to show the shipment path.

4.1 Key Performance Indicators

Once the simulation is completed, a number of buttons become available in the output window, to allow the user accessing the simulation results available in terms of KPIs (Key Performance Indicators). The following KPIs can be calculated as part of the historical based simulation:

- average shipping time per customer, liner and commodity (respectively KPI1, KPI2 and KPI3): the average value of the total shipping time for a given customer, liner and commodity;
- average sea transit time per customer, liner and commodity (KPI4, KPI5 and KPI6): the average value of the sea transit time for a given customer, liner and commodity.
- average road transit time from the pick-up point to the port (KPI7): calculated as difference between the delivery time at the port and the pick-up time at the point of origin;
- average road transit time from the port to the delivery point (KPI8): calculated as difference between the delivery time at destination and the pick-up time at the port.
- average lateness (KPI9): the average value of the advance or delay compared to the estimated delivery time;
- average waiting time in the terminal area per commodity (KPI10)
- average customs and border protection clearance time per commodity and per liner (KPI11 and KPI12).

For the web based simulation the following KPIs can be calculated:

- average shipping time (KPI1): the average value of the total shipping time;
- average sea transit-time (KPI2): the average value of the sea transportation time;
- average road transit time from the pick-up point to the port (KPI7): calculated as difference between the delivery time at the port and the pick-up time at the point of origin;
- average road transit time from the port to the delivery point (KPI8): calculated as difference between the delivery time at destination and the pick-up time at the port.
- average waiting time in the terminal area (KPI10)
- average customs and border protection clearance time (KPI11).

As the input data for the web based simulation are retrieved on line, a reduced set of KPIs are available from the web based simulation (e.g. it is not possible to carry-out simulation for specific commodities, customers or liners).

4.1 Example of Simulation Results

The following section presents the use of the simulation for two different intermodal (road-sea) shipments. Table 1 reports the details of the two shipments.

Table 1: details about two intermodal shipments

ID	City of Origin	Port of Origin	Port of Destination	City of Destination
1	Cosenza, Italy	Gioia Tauro, Italy	Lisbon, Portugal	Lisbon, Portugal
2	Livorno, Italy	Genoa, Italy	Istanbul, Turkey	Istanbul, Turkey

The shipment ID 1 has been simulated by using the web based simulation while the shipment ID 2 has been simulated by using the historical based simulation. As far as the simulation results for the shipment ID 1 are concerned, the user can easily access the results by using the results view, as shown in figure 9. In particular, figure 9 shows the simulation results (the main view is on the KPI1, however all the KPIs are included). The figure is split in 3 parts: (i) the graph including the KPI1 (shipping time) along all the simulation replications; (ii) the KPI1 confidence interval plot; (iii) a pie charts including the values of all the others KPIs (2, 7, 8, 10, 11). It is also possible to access the main view for the KPIs 2, 7, 8, 10, 11 that will show (in a similar way) the KPIs values along all the replications and the related confidence intervals.

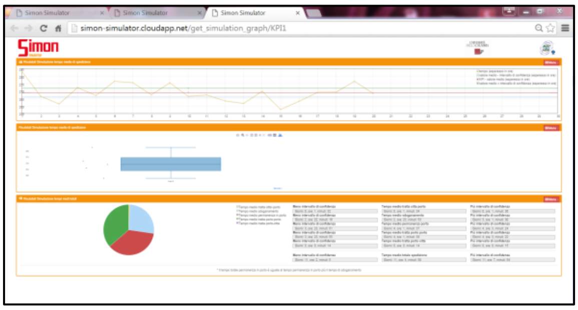

Figure 9 – Simulation results for shipment 1

As far as the simulation results for the shipment ID 2 are concerned, the results are shown in figure 10. In addition to the pie chart and numerical values (in terms of average values and related confidence intervals) of the KPIs 1, 2, 7, 8, 10 and 11, in the lower part of the screen, the user can access all the KPIs selecting a specific commodity, liner or customer.

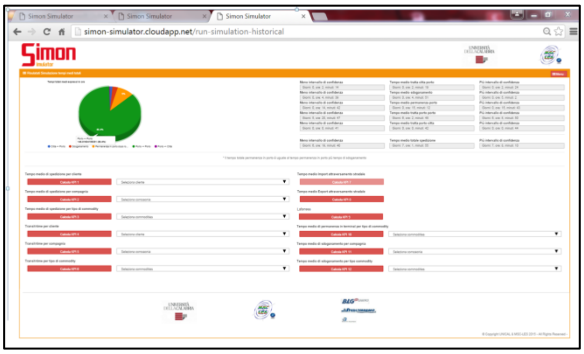

Figure 10 – Simulation results for shipment 2

Many other simulations (long range shipments) have been executed, mainly to carry out validation activities by using (as reference) the historical data provided by the forwarder companies.

5. CONCLUSIONS

The paper presents the results of a research project developed at MSC-LES lab of University of Calabria. The project was devoted to conceive, design and develop a simulation service to support strategic planning and scheduling of forwarders companies operating in the Harbor area of Gioia Tauro, Italy. The authors have conceived a MVC architecture able to work over the internet (providing the simulation as a service) and on mobile devices. This has mainly required the use and adaption of web technologies and software for simulation purposes. The simulation comes with a dedicated Graphic Interface that allows user executing simulations and accessing results (multiple KPIs). The authors have also executed preliminary simulation experiments to show the potentials of the services and to carry out validation activities.

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BIOGRAPHIES

Francesco Longo is Director of the Modeling & Simulation Center – Laboratory of Enterprise Solutions (MSC-LES), a laboratory operating at the Department of Mechanical, Energy and Management Engineering of University of Calabria. He has published more than 200 scientific papers in international conferences and journals, and has participated as speaker and chairman in a broad range of international conferences. His research activities focus on innovative ways to use simulation paradigms (discrete event, agent based, distributed, etc.) and serious games to achieve new scientific advances in various application areas including Industry, Logistics, Defense and Cultural Heritage. He has also served as General Chair and Program Chair for the most prominent international conferences in the area of Modeling and Simulation (EMSS, SCS, I3M, etc.)

Letizia Nicoletti was CEO of Cal-tek Srl from 2012 to 2014 and she is currently Senior Manager at CAL-TEK. She obtained her Bachelor Degree in Management Engineering, Summa cum Laude, her Master Degree in Management Engineering, Summa cum Laude as well as her PhD in Mechanical Engineering from University of Calabria, Italy. She has followed as Scientific Responsible many research projects in different areas including logistics and distribution, Defense and Cultural Heritage. Her skills include requirements definition and development, conceptual modelling, model simplification, data collection and analysis, representing unpredictable variability and selecting statistical distributions, models and software coding, experimentation, verification and validation, serious games development, visualization, simulation software.

Antonio Padovano is currently conducting research in the area of Modeling & Simulation with applications in Industry and Logistics at MSC-LES University of Calabria. Since 2014, he carried out several work experiences travelling in Europe and United States (e.g. he spent 3 months at Rutgers University, USA). He is expert in discrete event simulation and in developing simulation solutions as a service. He has been supporting the organization of the International Multidisciplinary Modeling & Simulation Multiconference since 2014.

Agostino Bruzzone is Full Professor of at the University of Genoa. He is President of Simulation Team, Director of the International Master Program MIPET, member of the BoD of the Society for Modeling and Simulation International, Director of M&S Net, Senior Lecturer within the PhD program on Modeling&Simulation. He also served as M&S Responsible in NATO STO CMRE, Director of the McLeod Institute of Simulation Science, Vice-President of the Board of MIMOS (Movimento Italiano di Simulazione) He was involved in research projects in cooperation among EDA, Italian and French MoD, NATO M&S CoE. He has published over 200 journal and conference papers. E-mail: agostino@itim.unige.it

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Beatrice Zaccaro is currently a master degree student in Mechanical Engineering at University of Calabria, Italy. Her research interests includes Modeling & Simulation with applications in Logistics and Safety & Security in industrial plants.