A MODEL BASED DECISION SUPPORT SYSTEM FOR LOGISTICS MANAGEMENT

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ABSTRACT

This paper deals with the specification of a Decision Support System (DSS) that has to manage the flow of goods and the business transactions between a port and a dry port. The paper investigates the case of the broader area of Trieste port and specifies the DSS that manages the import flows of freights between dry port and seaport. An integrated approach is designed for the tactical level decision strategy based on simulation optimization, where metaheuristic algorithms are applied.

Keywords: Decision Support Systems, Discrete Event Simulation, Optimization, Metaheuristic algorithms

1. INTRODUCTION

The current concept of a dry port directly connected with a seaport (through a city center) is an essential matter since it opens a new series of problems to be faced. With the establishment of a dry port directly connected with a seaport, new operational problems arise, since the logistics operations between the two terminals must be coordinated and synchronized. Moreover, the informative systems of the two terminals must be integrated to manage all information regarding the operations of both the two terminals. For this problem, strategic, tactical and operational, (Giani et al., 2004), problems arise since it is necessary to define the better allocation of the various services between the two terminals at different scales. The term 'dry port' was introduced by the Economic Commission for Europe in 2001 to denote an inland terminal directly linked to a maritime port. Subsequently, Roso et al. (2008) formalized this term to denote not only a terminal linked to another one but also a terminal where some typical services of a seaport are moved to provide more available space and to require less service time at the port area. At the international literature there are several papers that analyze intermodal terminals and in particular container terminals (Stahlbock et al., 2008).

In addition, the connection between a seaport and a dry port is not yet investigated in depth by the research community. In fact, a few papers deal with the analysis of the impact of new road and railway networks on the logistic system in an intermodal container environment at strategic level via simulation models (Parola and Sciomachen, 2005). Moreover there are no studies on how and what services have to be moved to the dry port.

In such context, Discrete Event Simulation (DES) models are widely used to describe decision making and operational processes. In Ramstedt and Woxenius (2006) a thorough literature analysis about the simulation of the decision-making process within a transport chain is presented and in Gambardella et al., (1998), a resource allocation problem in an intermodal container terminal is simulated. Duinkerken et al. (2006) present a comparison among three transportation systems for the overland transport of containers between container terminals and a simulation model was developed to assist in this respect. The model is applied to a realistic scenario for the Maasvlakte situation in the near future. In (Ottjes et al., 2006), a generic simulation model structure for the design and evaluation of multi-terminal systems for container handling is proposed.

While several research activities have been realized, and are on-going, related to the intermodal transportation, it has to be outlined that no specific activities have been performed in the direction of applying modeling, simulation techniques and new technologies to address the dry-port challenges. Therefore this paper proposes and studies the impact of an integrated Information and Communication Technology (ICT) solution to manage the problem of the connection of a port and a dry port area. In particular, the proposed results are focusing on the management of the logistic operations at the tactical level.

The aim of this paper is to contribute in the specification of a model based Decision Support System (DSS) to integrate logistics management and decision support for intermodal port and dry port facilities. In particular, the case study that considers the port of Trieste (Italy) and the dry port of Fernetti is analyzed. This case study is examined in the SAIL project, sponsored by the EU 7th Framework Programme, Marie Curie IAPP.

The paper is organized as follows: Section 2 describes briefly the case study, Section 3 presents the methodology to specify the proposed DSS, Section 4 reports the discussion about the application of the DSS and Section 5 concludes the paper.

2. THE CASE STUDY

2.1. The port and the inland terminal of Trieste

The logistics system in the Friuli Venezia Giulia region (Italy) is particularly significant both for its geographical location, as the meeting point of the trans-European Corridor V and the Adriatic Corridor, and for its concentration of ports and land, sea and railway transport networks. A requirement analysis identified two different configurations for the specific test case: one for the containers and one for the trucks. In the port of Trieste, the traffic of trucks directed to Turkey through a Roll-on/roll-off Traffic (Ro-Ro) service represents a consolidated traffic. The containers have large areas to be warehoused in the port. On the contrary, a limited space is dedicated to the truck parking area. Hence, the study of the optimization of movements of trucks between the port area and the dry port area is crucial and needs the application of suitable management strategies.

Before going into the details of the freight flow, this section aims at defining the main involved actors, users and stakeholders. We are mainly focusing on the connections between the port of Trieste and the Intermodal Terminal of Fernetti that operates also as a dry port area of the Trieste port. In particular, the port of Trieste is a free port and the Port Authority has the role of controlling, coordinating and managing the port operations.

In the analysis of the case study, we consider the flow of goods that are managed by the following actors:

- the freight forwarder: it is represented by a company operating as intermediary, taking care of authorization procedures and documents. The freight forwarder has a key role for the organization of the flow of goods and information;
- the final customer: there are several customers involved and the flow of goods always begins with an order of the customer;
- the shipping agent: it operates as intermediary, taking care of authorization and booking procedures. The shipping agent also has a key role in the organization of the flow of goods and information;
- the terminal operator: it provides a full range of additional services including container freight station, warehousing and storage, survey, container repair and maintenance and dedicated areas. Goods transported in containers are unloaded in the terminal area ;
- customs: The Custom Agencies of Fernetti and Trieste. Customs is the authority responsible for collecting and safeguarding customs duties and for checking the flow of goods. The customs clearance procedures can be performed at the origin of the flow, in Fernetti or in the Port of Trieste.

We present two different ways of managing the typical interactions of cargo with the authorities and the infrastructure operators in the export phase: a) the current situation, called case “as is”, b) the new solution, called case “to be”. In this paper, for the sake of brevity we do not describe the import phase.

2.2. Description of the export phase: case AS IS

The export flow of goods considered for this case study is divided in the following phases:

1. *New order from the customer*: if the proprietary of the goods decides to perform all the customs clearance procedures in the plant, the domiciled procedure authorized by the Customs Authority is carried out. Otherwise, the customs clearance will be performed in another point of the transportation flow. It must be noted that for containers, at this stage, booking of a place on ship can be performed, while in the case study such anticipated booking of a place on ship for trucks is not accepted by the shipping agents.
2. *Choice of transportation mode*: the goods are ready to be sent. There are two different possibilities: by road (i.e. goods boarded as a complete truck or trailer) or by railway (i.e. goods boarded as a complete truck).
3. *Arrival of trucks*: the flow is organized in two different ways depending on the type of means of transport to be boarded. More precisely, a complete truck (with the trailer and the cab) has to stop in the dry port area before entering the port; a trailer has the possibility to choose either to go directly to the port or to pass through the dry port area (typically these represent the 30% of the total flow of trailers). When a truck arrives at the Fernetti intermodal terminal, its arrival is registered.
4. *Inside the Fernetti terminal*: if goods are already cleared, then there is a truck parking area, where truck is waiting to be called for the boarding in the port of Trieste. Otherwise, there is a dedicated area where the truck will be moved and the customs clearance procedures will take place.
5. *Customs clearance procedures*: the bill of loading and the “cargo manifest” are transferred to the customs in order to transfer information about all the transported goods. Then the bill regarding all the customs duties is prepared: it contains a customs code, the origin of the goods, its value and profit. Successively, the customs duties are paid.

6. *Booking*: when a truck arrives at Fernetti, the truck driver books a place on a Ro-Ro vessels and gives to the shipping agents all the needed documents. When the ship arrives at the port and it is ready to be loaded, the truck driver receives a communication through a variable message panel. At this point, the truck driver receives back a certificate that enables him to go in the port.
7. *Transportation phase to the port*: the truck driver leaves the Fernetti terminal and goes to the port of Trieste. In order to avoid too many delays, each truck driver has an hour and a half to reach the port.
8. *Security checks*: goods arriving at the port may have to be checked by the customs. If the freight has to be checked, the truck driver has to move the truck to a special area for the security check operations, made by the Customs Agency and by a Customs Anti-Fraud Service (Italian acronym is SVAD), to take place.
9. *Boarding*: at this point of the flow the trucks or the trailers are ready to be loaded on ship.

Looking at the intermodal terminal of Fernetti, there are two different areas: A) an area for the trucks that have to perform customs clearance operations which has 252 numbered parking places and there is a ticket to be paid of 10€ for 72 hours. For each ship about 15-20 trucks perform the customs clearance in this area. B) a second area where the trucks are waiting to be called in the port: it has 120 non numerated places and the ticket is paid by the shipping agent. This is the zone that has a function of a real dry port area.

Of the total number of trucks arriving at the port of Trieste, the 30% of them pass through Fernetti. In particular, there is a local regulation imposing that all the complete trucks have to stop at Fernetti. Therefore, the remaining truck trailers that have to be loaded on the Ro-Ro ship arrive directly at the port by motorway or by railway. There are 3 trains per day arriving at the port and the traffic arriving by the railway represents the 15% of the total Ro-Ro traffic.

It is very important for the shipping agent to monitor the freight once it has left the Fernetti terminal to reach the port. The shipping agent calls the truck driver to come in the port one hour and half before the loading while the travelling time is about half an hour. Nevertheless, there is a percentage of 5% of trucks that do not arrive on time and therefore the customs have to check the freight and often because of this extra imposed delay the truck cannot be loaded. Currently the freight is not continuously monitored and that causes several problems to the planning of the loading of the ship.

Normally a Ro-Ro ship transports 238 units, and one third of them are complete trucks. The volume of the traffic in 2010 was of about 105.000 loaded units (37.000 complete trucks and 68.000 truck trailers), divided in 15 ships per week. In normal conditions the waiting time before loading is about 25/30 hours but in case of congestion it can even reach 100 hours.

2.3. Description of the export phase: case TO BE

The following description aims to highlight the changes that are foreseen in our "to be" solution after the introduction of the DSS. The following description concerns only the changes of the new scenario:

1. *New order from the customer*.
2. *Transportation planning*: through the booking service provided by the ICT platform, customers will be able to buy services from suppliers (e.g., freight forwarders). The supplier will be able to book a place on a vessel and to start the delivery processes.
3. *Arrival of trucks*: if a ship is ready and there is enough available space, then the DSS communicates it to the truck driver before entering in Fernetti through the ICT platform and the Variable Message System signals. Therefore, the truck driver can go directly to the port or, proceed, as planned at the beginning, through Fernetti. A truck that arrives to Fernetti is automatically registered and communicated through the ICT system to the shipping agent and to the terminal operator.
4. *Inside the Fernetti terminal*.
5. *Customs clearance procedures*: the customs receive in advance in electronic format the data needed for the customs clearing operations. Truck will be assigned an on board computer: in such a way the transport will be easily recognized/detected and the clearance procedures can proceed faster. In such a case all the information can be elaborated in advance and the on board system guarantees that the transport will be completed without delays. Hence, the local Customs Office will eventually have to undertake a reduced number of checks, being sure that what was found/registered in previous control has not changed during the transport.
6. *Booking*: through the ICT platforms it is possible to book a place in the ship for the truck using the booking service application. Then the DSS plans the bookings and through the ICT integrated tools sends back the information at the shipping agency, which calls the truck driver as soon as the ship is ready to be loaded.
7. *Transportation phase to the port*: when the truck driver leaves the Fernetti terminal, the ICT platform checks if the ticket has been paid and communicates to the shipping agent the exit time. Once the truck arrives at the port, the entrance time is communicated to the shipping agent.
8. *Security checks*: by monitoring the truck by GPS system, the ICT platform is able to

communicate to the customs if there is a need of security check. In particular, if there are not anomalies or if a delay is registered but the truck has respected the foreseen path, security checks may be avoided; otherwise the truck will be checked. Thus, the ICT platform helps to reduce the number of unnecessary inspections and to improve the targeted checks.

9. *Boarding*.

Summing up, the DSS leads to an optimized utilization of resources, both human and machines, that are involved in the process of management of goods.

3. MODEL BASED DECISION SUPPORT SYSTEM

Modern DSS spans a wide range of technologies (Turban et al. 2010). In this paper, we consider a model-based DSS to tackle at the tactical level of the logistics processes. Model based DSSs give the possibility for the user to manipulate model parameters, to examine the sensitivity of the results or to conduct what-if analysis.

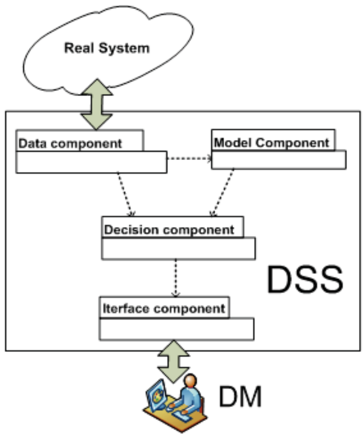

Fig.1: The general DSS Configuration

Figure 1 sketches the overall structure of the DSS: it receives data from the real system, elaborates them and finally suggests decisions to the Decision Maker (DM). Then the DM can use the DSS to change and set the parameters of the real system. Several categories of DSSs exist but almost all of them share common characteristics. DSS include three main components: the data component, the model component and the interface component (Turban et al., 2010).

The data component usually consists of a database and a database management system (DBMS). The used data can be internal, if they come from organization's internal procedures and sources such as products and services prices, recourse and budget allocation data, payroll cost, cost-per-product etc. (Turban et al., 2010). External data can be related with competition market share, government regulations and may come from various resources such as market research firm, government agencies, the web etc. In some cases, the DSS can have its own built database or it may use other organizational databases either by connecting directly with them or by using data available from reports (Turban et al., 2010).

The model component mainly includes mathematical models describing the operations of the organization in various levels and the type of functions used according to the operation that they have to support.

The decision component is in charge to suggest and support the DM during his decision process. It can merge information coming from the data component and the model component in order to propose solutions to the DM through the interface model.

The interface component is responsible for the communication and interaction of the system with the decision makers. Regardless of the quality and quantity of the available data, the precision of the model in describing the organizations procedures and even the hardware capabilities, the interface of the system must ensure that the decision maker will be able to take advance of the system capabilities.

3.1. The Discrete Event Simulation

Simulation is a descriptive tool that can be used for both prediction and exploration of the behavior of a specific system. A complex simulation embedded in a model-driven DSS can help a decision maker plan activities, anticipate the effects of specific resource allocations and assess the consequences of actions and events (Power et al. 2007). "What if analysis" performed via a simulation tool can offer extra confidence to the DM than just the simple presentation of numbers in a tabular format. Simulation enables the evaluation of the behavior of a particular configuration or policy by considering the dynamics of the system.

The starting point of the simulation model developed for the DSS is the description of the system by Unified Modeling Language (UML) (Boschian et al., 2011, Fanti et al., 2012). Successively the UML model is translated into a simulation model, whose dynamics depend 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. In particular, we implement the model described in the UML framework in the Arena environment (Kelton et al., 2009), a discrete event simulation software particularly suitable for dealing with large-scale and modular systems. The following steps can be performed in order to specify the simulation:

1. the Arena modules are derived from the UML activity diagram elements, by establishing a kind of mapping between each Arena module and the UML graphical element of the activity diagrams;
2. the simulation parameters are included in the Arena environment, i.e., the activity times, the process probabilities, the resource capacities,

and the average input rates are assigned. Nevertheless, these specifications can be modified in every simulation cycle and enable the choice of the scenarios for the case study implementation and management;

3. the simulation run of the experiments is singled out. The performance indices are determined and evaluated with suitable statistics functions.

In order to analyze the system behavior, a set of performance indices are selected:

- the system throughput, i.e., the average number of containers delivered per time unit by the inland terminal;
- the lead time (LT), i.e., the average time elapsed from two particular activities in the system;
- the average percentage utilization of the resources.

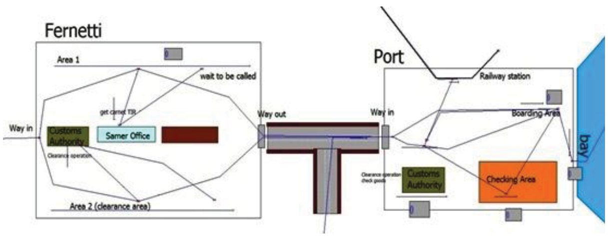

Fig.2: The snapshot of the Arena Model.

Figure 2 shows a snapshot of the model implemented in ARENA environment depicting the main components of the system:

- the Fernetti inland terminal is described by two areas: Area 2 for units that have to do the Customs operation and Area 1;
- the transport system is the stretch of highway connecting the Fernetti area to the Port;
- the port area, including Railway, the Customs Authority office, the checking area, the boarding zone and the bay.

3.2. Harmony Search Optimization

The Metaheuristics are methods that guide other procedures (heuristic or truncated exact methods) to enable them to overcome the trap of local optimality. Although these methods (tabu search, simulated annealing, etc.) are generally designed for combinatorial optimization in the deterministic context (Zapfel et al., 2010) and may not guarantee the convergence, they have been quite successful when applied to simulation optimization. Among the various metaheuristic approaches Harmony Search (HS) is quite new method that has been applied successfully in various areas (Geem 2010).

HS is a metaheuristic that mimics in a way the musicians improvising process (Geem et al., 2001). It was originally developed for integer variables but since then variants for both integer and binary variables have been proposed. The method uses a Harmony Memory (HM) that stores the best so far candidate solutions which form a pool for creating new candidate solutions.

The set of operators include:

A) Random selection: a new value is chosen randomly out of a candidate set with a probability (1-HMCR). B) Memory consideration: one value is chosen out of the HM set, with a probability equal to the harmony memory considering rate (HMCR). C) Pitch adjustment: a value that has been selected in the previous step of memory consideration is further changed into neighboring values with a probability equal to the pitch adjusting rate (PAR).

If the newly generated vector is better than the worst vector in HM with respect to the objective function, the former takes the place of the latter.

As it has been identified by many studies, in a simulation optimization framework, for each candidate solution we need to use at least some predefined number of replications in order to reduce the effect of the simulation noise (Schmidt et al., 2006). As it was described above, HS is searching the solution space based on the information stored in the HM. It is therefore important to update the HM in a consistent manner in the presence of (simulation) noise.

Therefore after each iteration of the algorithm, which involves a predefined number of replications for the new candidate solution (in the case of integer variables a lookup table for already visited solution can save some execution time at the expense of increasing the memory requirements) an Optimal Computing Budget allocation (OCBA) step is involved to assign the number of replications to a set, including the new position as well as the harmonies stored in HM in order to exclude the worst of them from the HM.

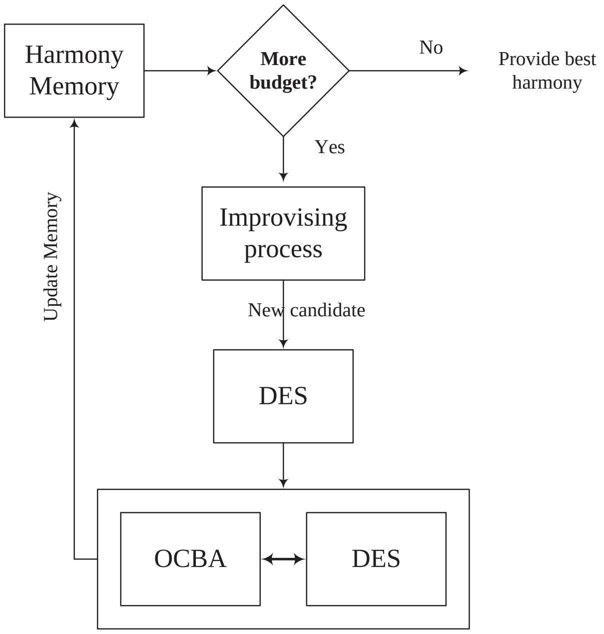

Fig.3: Schematic representation of the integration of DES+HS+OCBA for DSS.

OCBA was recently proposed (Chen et al., 2010) as a procedure to optimally allocate a predefined number of trials/replications in order to maximize the probability of selecting the best system/design. OCBA tries to maximize the probability of Correct Selection P (CS) (the probability of actually selecting the best among the k designs). More specifically the Approximate Probability of Correct Selection is a lower bound of the P (CS).

The aforementioned technologies are integrated in order to provide the DM with a tool to make (near) optimal decisions in a reasonable amount of time. Figure 3 depicts the architecture of the system.

4. CONCLUSIONS

This paper specifies a DSS for the management of complex logistic system. In particular, we examine the case of the Trieste port with the terminal of Fernetti (Italy) where we model, simulate and optimize the vehicle flows between these two coupled ports. There is proposed an integrated system to optimize the operation for the export phase. The integrated Decision Support System is based on a Discrete Event Simulation Module combined with Optimal Computing Budget Allocation (OCBA) that are further optimized with the Metaheuristic approach of Harmony Search (HA). The proposed framework is going to be further tested and it seems to be suitable for many other applications areas.

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