SIMULATION OF THE PASSAGE OF CONTAINERS THROUGH LE HAVRE SEAPORT

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ABSTRACT

The huge volume of shipping containers leads to seeking a better performance of all container terminals in a seaport. Container terminals are spaces for transiting goods from origin point to a destination point. In recent years, several studies on seaport performance have been done to develop new optimization strategies and decision-making tools. After a description of a maritime environment as a state of the art, follows a flexsim-based simulation model of the flow and the massified transport of containers. This discrete-event Flexsim simulation is proposed to validate the massified transfer scenarios of containers from and to the future multimodal terminal of Le Havre seaport.

Keywords: Simulation, Seaport performance, Massification of flow, Flexsim, Multimodal terminal

1. INTRODUCTION

Nowadays, maritime transport plays an important role in the economic world. This emphasis is justified by the evolution of increased volume of shipping freight. Given this economic context, the seaports must be more powerful than before. For this purpose, the total or partial automation in seaport terminals is needed. Indeed with the era of new information technologies and communication, we are willing to keep pace and optimize the tasks of thousands of people who repeat the same things day after day. For instance, let us take the case of the seaport of Le Havre, the seaport Authority plans to construct a multimodal terminal (Benghalia, Boukachour, and Boudebous 2012). The project involves conducting a feasibility study for the technical, economic and socio-economic innovations to massify transportation of containers by railways between marine terminals and the futur multimodal platform. The goal is also to design and carry out news railway structures that consume less space with, significantly cheaper investment and exploitation. It is therefore necessary to look for a different time saving from the transfer scheme, and also sufficient fluidity to movement that transfers are common. Our research aims to design flexsim-based simulation model for analysis and performance evaluation. The objective is to obtain a sufficient frequency and an acceptable cost for such transfers between marine terminals and the multimodal terminal. In practice, the evaluation of seaport performance is a complex problem. For this problem, the criteria that need to be optimized can be classified into two categories (Benghalia, Boukachour, and Boudebous 2012):

1. Those related to the investment cost need to design a terminal (average cost per container, number of quay cranes, number of straddle carriers, and number of storage areas ...).
2. Those related to the productivity of the future multimodal terminal (dwell time of containers, waiting shuttle, ship turnaround time...).

Our research objective is to simulate the seaport passage of container in order to propose scenarios that optimize the performance of container terminals. Indeed, we interest in conducting a simulation model to propose scenarios for container transportation between the future multimodal terminal and container terminal seaport of Le Havre via discrete event simulation to describe the changes of states at precise moments in time following the occurrence of specific events. In this paper, we show our flexsim-based simulation model. In Section 2, a description of the container terminal with different management policies are presented. Section 3 presents the process of seaport transit containers and related works. In Section 4, after the presentation of the project Multimodal, follow a short state of the art about simulation and simulation tools and the implementation of our model. Results are presented in Section 5. Section 6 concludes the paper.

2. DESCRIPTION OF A CONTAINER TERMINAL

A container terminal is an equipped place for the handling and the storage of containers for both import and export processes. It is a set of platforms for the arrival and departure of ships, storage areas and resources for transport and the various operations associated with the handling of containers. Doing these operations involves the participation of different actors:

- Docker: the person who loads and unloads the ship.
- Inland transport: the person who carries (transports) the containers at the terminal.

- The port operator: the person who controls the operations within the seaport. It could be a public authority (seaport authority) which administrates the seaport and control the operations within the seaport.
- The terminal operator (stevedore): the person who takes care of the preparation (legal and material) of the receipt, movement and storage of marine cargo.
- The owner (shipping line / alliance): the person who provides transportation of goods by sea.
- The consignee: the person who is attached directly to the owner, he must ensure every operation for the receipt or delivery of goods and accomplish the tasks entrusted by the owner.

Each container terminal must have the following components:

- Quays: arriving and departure place of ships.
- Yard: space destined for storage of containers.

To perform the handling, container terminal needs other resources that vary according to management policy of each terminal. In general, there are three different possible ways of management (Meriam 2008), for a Marine Terminal:

- Management Mode based on cranes: in fact this type of crane can move and navigate through the rows of cells depending on the location of containers for the current operation. Then the crane loads the searched container into the vehicle that will transport it to a quay crane (these tasks are executed in reverse order in import case).
- The second method of management or also called the alternative system is based on the use of straddle carriers ("yard machines") that are very expensive and require considerable space for their operation. In fact, a straddle carrier truck is able to load, unload a container or search a container and transport it to quay crane.
- The third mode is no longer applied; it requires a large space, although it facilitates the operation of the terminal. It stacks all the containers on chassis to transport them to the porticoes.

Good management of a seaport depends on the optimization of different processes within its terminals. In fact at the level of design and management of container terminals, several problems emerge. Several studies concerning the optimization of seaport operations which are based on simulation and operations research methods have increased (Meriam 2008; Meer and Van der 2000). These studies generally focus on specific problems such as scheduling a type of equipment, assignment of vessels to the docks or the optimization of storage space etc. Our case study concerns the future multimodal container terminal in Le Havre seaport which differs from a normal container terminal because at least two different modes of transport are used. Goods transfer can be done then by train, barge, and truck. Multimodal transport increases the competitiveness of a container terminal.

3. PROCESS IN A CONTAINER TERMINAL

After analyzing various handling activities in a container terminal and according to the work of (Meriam 2008), import and export process in a container terminal can be described as a series of events which can be classified into four levels (See Figure1) (Verjan 2010):

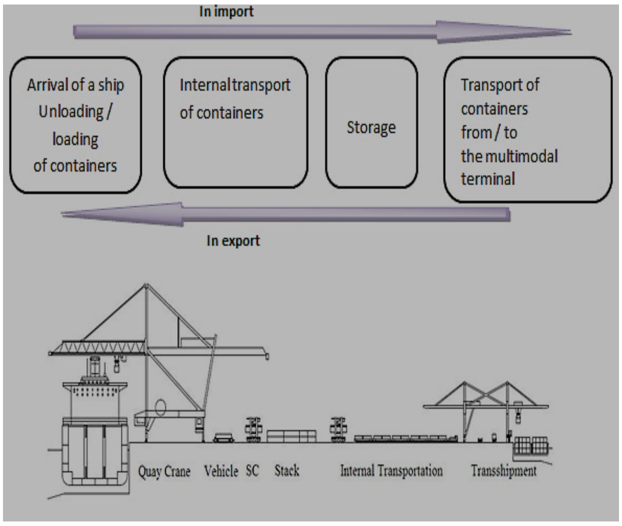

Figure 1: Process In A Terminal.

1. Maritime interface: this step is the point of departure and arrival of ships. In import and at the arrival of a ship on the quay, the relevant actors mobilize for unloading after performing various security controls concerning the container. In fact, at each quay crane an officer or a video system monitors the registration of the container and clarifies its position. For export, the same actors and resources are mobilized to perform the same operations in reverse order. Minimizing the time spent by a ship at the terminal is one of the criteria most studied in recent years. Several research studies have focused in this process (Legato and Mazza 2001) to deal with optimization problems concerning the planning for ships which involves the allocation of berths, storage of containers, and the allocation of gates (or see Gantry Crane).
2. The area of internal transport of containers: at this stage the containers are transported by vehicles from the cranes to the storage areas (Stack) and vice versa for the case "export". The optimization of each activity in this stage

plays a very important role in optimizing the entire chain of handling. Several methods have been proposed by (Meer and Van der 2000). A mixed linear program was developed by (Zehendner, Nabil, Stéphane, and Dominique 2011) to determine an optimized allocation of resources. The goal is to minimize the possible modes of land transportation while respecting the imposed delay of ships. Hartmann has proposed a genetic algorithm (Hartmann 2004) to minimize the average delays of tasks of straddle carriers, automated guided vehicles (AGVs), stacking cranes, and workers respecting the precedence constraints and the constraints of setup times for the Hamburg seaport. Behrokh and Asef-vaziri have developed a simulation model based on the storage systems configuration (automated loading and unloading) and automatic transport vehicles (AGV-ACT) (Behrokh and Asef 2000). They compare the performance of the new configuration with the old one. Finally, the results show that automation is feasible and has a significant impact on operational performance.

3. Storage area: storage areas are composed by a number of rows (channels) called bays allowing the stacking of containers. They can be equipped with cranes (Cranes), fork lift trucks, straddle carriers, etc. Several research studies (Meriam 2008) focused on the optimization of a storage area, Zhang and al are interested in minimizing the distance between the storage area (yard) and berths for the seaport of Hong Kong by providing a decomposition of the problem into two subproblems (Zhang, Liu, Wan, Murty, and Linn 2003).
4. The transfer zone of containers or land side interface: After a period spent in the storage area, the stored containers will be loaded by cranes to transport them through waterway, rail or land. Our study concerns the massified transportation of containers between maritime terminals after spending the previous steps. In fact we will present the multimodal project and our approach to simulate the transfer of containers by train.

4. CONTAINER TERMINAL MULTIMODAL OF LE HAVRE

The multimodal project is one of the major projects of Le Havre seaport. It concerns the transport of containers between different container terminals and the new multimodal terminal. Specially, the flow of containers is between the multimodal terminal and the terminal Atlantic on the one hand, and secondly, between the multimodal terminal and the terminal port 2000 (See Figure 2). The objective is to build a simulation model for describing the transfer of containers between some container terminals and the future multimodal terminal. We have designed a simulation tool in order to validate some containers transfer scenarios. The simulation is based on the software Flexsim (http://www.flexsim.com/). It is designed to model and simulate the evolution of the physical flow within a seaport. It also offers great possibilities for reuse in developing and presenting in 3D mode. It is an object-oriented tool adapted to model and simulates the flow of containers in seaport terminals and the process of passing through its seaport thanks to its library CT (Container Terminal).

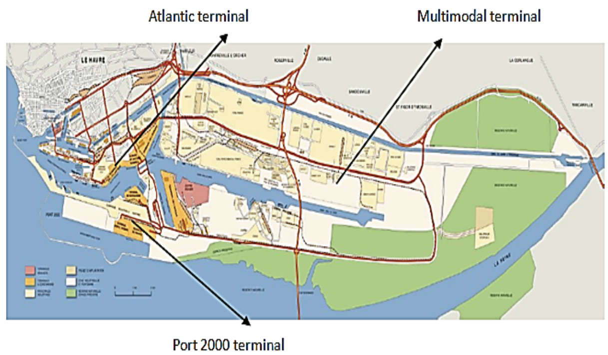

Figure 2: Le Havre Seaport.

4.1. Simulation

Simulation is the development of experiences of a model (Bernard, Herbert, and Tag Gon 1976). It allows the representation of a real system, to assess its performance and the properties of its behavior. Moreover, the simulation can be used to size a system, improve the utilization rate of equipment and also demonstrate the potential of the installation of new equipment. Simulation-based approaches based allow dynamic modeling of behaviors of the company, with varying degrees of constraints and different policies. They can deal with various contingencies caused by the uncertainties of supply and demand. They cannot generate a solution by themselves; they can only run models using parameters and conditions prespecified. Generally they are used to evaluate and compare different possible scenarios. Fredrik and Mirko argue that the simulation allows to take into account the dynamic of systems, to facilitate modeling and capturing the complexities and uncertainties of the analysis of the supply chain (Fredrik and Mirko 2007). (Yuh-Jen and Yuh-Min 2007) propose a modular approach to model and simulate the process of supply chain taking into account the communication system, information and knowledge. They use the simulation tool SIMAN and C++ language to develop the simulation generator.

Many models and algorithms have been developed to address decision problems in container terminals to help improve operational efficiency. The simulation has been widely used to study processes in container terminals. (Kia, Shayan, and Ghotb 2002) use simulation to compare two statistically different operational systems and propose an operational method to reduce congestion and increase the terminal capacity. (Nam, Kwak,and Yu 2002) used a simulation model with four scenarios to examine the optimal size in terms of positions and quay cranes for a container terminal. As for (Demirci 2003), he used the simulation to determine the bottlenecks of the most critical processes in the seaport system, and an investment strategy was developed to balance the load in the seaport. (Lee, Park ,and Lee 2003) developed a simulation model to evaluate seaport operations in a supply chain. Finally (Zeng and Yang 2009) proposed a simulation model for the scheduling of loading operations in container terminals.

In this work, we develop a discrete-event simulation to validate some scenarios of container transportation between terminals taking into account different states (on the road, loading, unloading, busy operator, free operator ...). There are several simulation tools (See Table 1). Our choice was focused on the software Flexsim with its particularity Flexsim CT library dedicated specifically to the simulation of container terminals. Our choice is motivated by the benefits offered through to his libraries. Flexim tool has a wide variety of reporting capabilities including statistics on the docks and storage areas: amount per unit time, queue access doors, cycle time of trucks, use of resources to the docks, etc.

Table 1: Flow Simulation Tools.

Simulation tools	
Simulation tools	specifications
Anylogic	GUI : 2D + 3D Programming language : Java
Arena	GUI : 2D + 3D Programming language : VBA
Automod	GUI : 2D + 3D Programming language : Automod
Plant simulation	GUI : 2D + 3D Programming language : Simtalk
Flexsim	GUI : 2D + 3D Programming language : C++ Library Flexsim CT "For Container Terminals" Data exchange with Microsoft Excel
Witness	GUI : 2D + 3D Programming language : Witness
DelmiaQuest	GUI : 2D + 3D Programming language : C++

The performance of a container terminal has been studied intensively in recent years to develop new optimization strategies and tools for decision support. In practice the evaluation of seaport performance is a complex task because the criteria to optimize are related directly to the investment cost (cost per container, number of quay cranes, number of straddle carriers and number of storage areas ...), and by productivity (dwell time of containers, waiting times for shuttles ...).
Table 2 shows some of the criteria cited in the literature (Verjan 2010):

Table 2: Performance Criteria.

Performance criteria	
Average Cycle time	To measure the performance of loading and unloading operations (movements per hour).
Throughput	Average number of movements per hour for a crane
Throughput par acre	Criterion used to consider the field because it is a limited resource.
Ship turnaround time	Time taken by a ship in berth.
Truck turnaround time	Time spent by a truck in the terminal. This time does not consider the time of trial in the gate.
Gate utilization	Percentage of time taken to serve the traffic inbound and outbound of containers.
Container dwell time	Residence time of a container in the terminal before being transported
Idle rate of the equipment	Percentage of idle time of equipment.
Average cost per container	This is the average cost per container. This is one of the most important measures of cost.

The choice of the passage of containers though the seaport is justified by the fact that this link is part of almost the all of the supply chain. The complexity of this link requires a comprehensive assessment of its performance. Indeed, the performance cannot be restricted solely to the sum of performance of different entities, considered independently of each other, but it is necessarily based on overall approach. The life cycle of our application involves the following steps. Indeed our approach (See Figure 3) is structured in four phases:

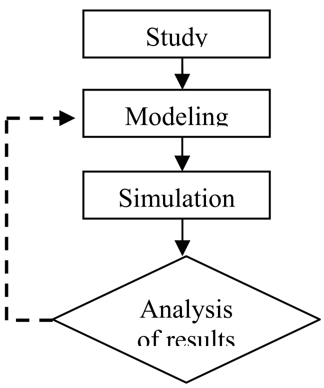

Figure3: Approach.

We simulate the start shuttles multimodal terminal, container terminal at the arrival, loading and unloading of containers and finally the arrival of the multimodal terminal shuttle. The first task was to convert the plan of Le Havre seaport from dwg format to dxf format supported by Flexsim. Then we use Rail API Library (http://nordgrenhome.com/community/forum/downloads.php?do=file&id=127) to build railway, wagons and trains, the first railway is between the multimodal terminal and the terminal of the Atlantic and a second railway connects the multimodal terminal to the terminal port 2000 (See Figure 4). This API is used to size the convoys of cars, track to track, simulate the movement of convoys and operations of coupling and uncoupling cars.

The next step was to model each container terminal, rails and coupons cars (See Figure 5).

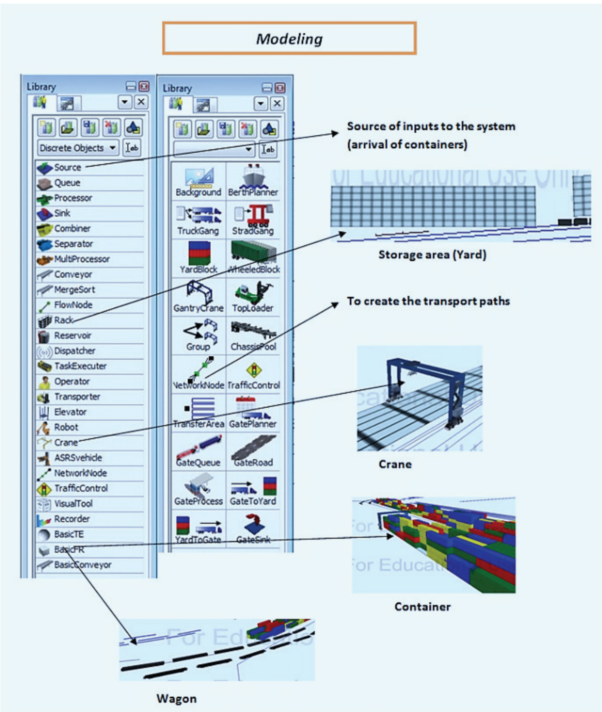

Figure 4: Modeling

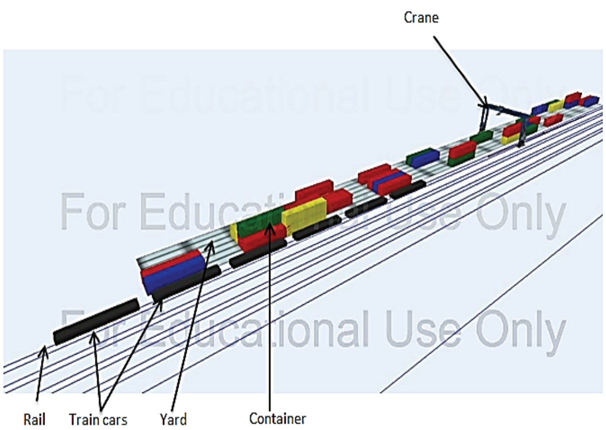

Figure 5: Terminal Container

5. RESULTS

The simulation can be started either by planning the input of containers into the system through a predefined distribution or by imported data from an Excel file containing, among other, the identifiers of containers, their initial position, destination, their date of departure and arrival.

After completing the simulation, Flexsim CT allows to generate a database containing the results. Analysis of the results leads to an improvement of the modeling of our simulation model following the approach outlined above.

Each row in the table represents a single object in the model. The first column contains the path of the object in the simulation model and the second column shows the class of the object. Each of the other columns shows the utilization percentage, the percentage of vacancy or blocking ... of each object. Then through the column travel empty offset and the column travel loaded offset, we can compare the cranes relative to the percentage indicating the movements made (moving: crane in loaded mode or empty crane), which will eliminate unnecessary movements. (See Figure 6).

State Report

Model Stop Time: 44245.48

Object	Class	idle	blocked	generating	offset travel empty	offset travel loaded
/Cranes/Crane_TPO	Crane	97.32%	0.00%	0.00%	1.33%	1.35%
/Cranes/Crane_multi_T	Crane	95.11%	0.00%	0.00%	2.69%	2.20%
/Cranes/Crane_multi_A	Crane	98.18%	0.00%	0.00%	1.00%	0.81%
/Cranes/Crane_atlantique	Crane	97.36%	0.00%	0.00%	1.46%	1.18%
/Terminaux/MULTIMODAL_TPO	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/MULTIMODAL_TDF	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/MULTIMODAL_ATLANTIQUE	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/ATLANTIQUE	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/TPO	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/TDF	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/RailNetworkManager	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%
/SourceConteneurs	Source	0.00%	0.00%	100.00%	0.00%	0.00%
/Cars	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%
/Yard	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%
/Cars2	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 6: State Report

In Table State Report and for all objects we have 0% blocking which shows the operation of all objects at 100%. Then the subject source has also generated all containers listed in the excel file (Generating 100%).

For the first instance simulated, the cranes were used with a rate between 2% and 4%. The crane of the marine terminal TPO was used with 2.68% whose 1.33% displacement vacuum (It is not a container) and 1.35% displacement loaded. The skull of the Atlantic Terminal was used in which 2.64% whose 1.46% movement of empty (container) and 1.18% of charge movement. At the terminal multimodal, multi skull T is for loading and unloading containers on TDF Marine Terminal (Port 2000). It was used at 4.89% with 2.69% in moving empty and loaded displacement of 2.20%.Finally the crane multi A is for loading and unloading containers on the Atlantic Maritime Terminal. This crane was used at 1.82% including 1% of container movements without and with a rate of 0.81% of loaded movements. These statistical results generated by Flexsim can find performance criteria as the criterion "time vacancy equipment (Idle rate of the equipment): Percentage of idle time of equipment."

The bar graph "current content" shows the statistical results concerning the actual content variable which allows a comparison between the contents of the various terminals. (See Figure 7)

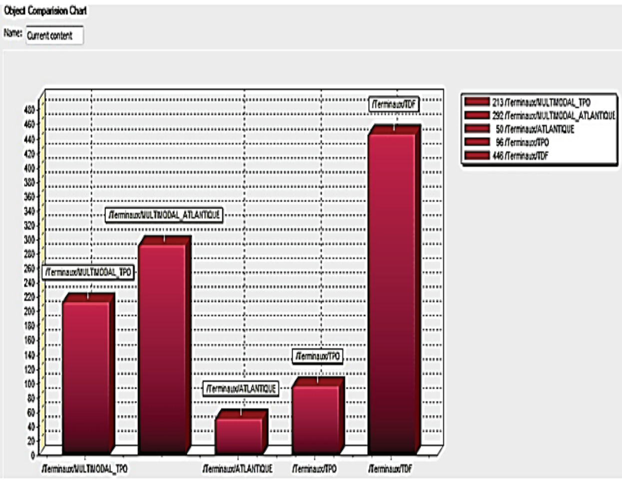

Figure 7: Statistical Results

At the multimodal terminal, 213 containers must be transferred to the maritime terminal TPO and 292 containers must be transferred to the atlantic maritime terminal. There are 592 containers to be transported to the multimodal terminal:

- 50 containers from the atlantic maritime terminal;
- 96 containers from the port maritime terminal 2000 (TPO);
- 446 containers from the port maritime terminal 2000 (TDF).

The figures concerning the flow of containers between the multimodal terminal and maritime terminals are essential for the design of resources necessary for handling and transporting containers.

6. CONCLUSION

This work concerns the transport of containers between marine terminals. The aim of this approach was to develop of a demonstrator and the simulation of the transfer of containers in order to dispose a tool for the achievement and validation of different scenarios. The realization of the simulation model has been based on the software Flexsim especially Flexsim CT. The results obtained allow improve the proposed scenario for the massified transfer of containers.

We are working to develop a simulation model. Le Havre Port Authority wants to rethink the short-distance rail transport on the port domain in the first stage, and the Seine Axis (Paris, Rouen, Le Havre). Thus, Le Havre Port Authority wants to improve implementation and uses trains on the transfer sites in order to increase the performance of these tools and therefore, the performance (delay / reliability / cost) of mass transport:

- For rail cars, more frequencies, less downtime on terminals for related operations such as brake tests.
- For equipment such as cranes and riders, fewer longitudinal displacements.

The objective is to obtain a sufficient frequency and an acceptable cost for such transfers between marine terminals and multimodal terminal.

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