

Container Terminal Modelling in Simul8 Environment

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Abstract: This paper gives overview of container terminal processes and related optimization models. Survey of some simulation-based model for intermodal systems is also presented. Upon the drawn conclusions from the surveyed papers, a novel simulation model is described which enables applicability of adaptive and intelligent methods, enables optimization of the certain modules and the whole model as well. The proposed simulation model was implemented in Simul8 logistic simulation software environment.

Keywords: *container terminals, logistics, simulation, modelling*

1. Introduction

The role of the intermodal transportation is steadily growing, and expected to grow further in the coming years. This statement is especially true for the container transportation segment. New technological achievements of the containers, handling machines and the related informatics were all necessary to reach the success of the intermodal containerization. The technology and particularly it's application processes however still embed great reserves, which may be surfaced only by overall analysis.

Container terminals implement complex processes using equipment of great value. In addition, for the incoming rail/road transport vehicles and ships waiting time is expensive. In order to operate economically, terminal's processes should be optimized. Optimization is however quite complicated in this case. The material handling system consists of different subsystems, and each faces different optimization problems. During operation of Quay cranes, most important factor is the greatest utilization available, and the minimization of serving time for the ships. Container transfer systems (towing tractors, straddle carriers, automated guided vehicles) however work by different principles: optimization of routing, scheduling, as well as traffic control. And yard cranes have entirely different priorities. For these handling machines important issues are container stacking problem and partitioning of yard space. Details of the above methods are discussed in Chapter 3. Preliminary it must be mentioned that for the different handling subsystems several well-formulated methods exist. However we

didn't find any methods dealing with the whole system. Cause of this that the terminals' structures and processes can be very different.

Seeking optimum for each subsystem may result undesired interference among them. Let's see an example. Optimization of quay cranes prioritizes such a serving container transport system that stands always for the cranes disposal. This means for the AGV or towing tractor and trailer subsystem that it should always position free transport vehicles for the quay cranes. This policy is however disadvantageous for the transport system, because it reduces utilization and influences the traffic patterns. We agree with authors saying that one of the most important performance measures in container terminals is the turnaround time of vessels, and quay cranes are the most expensive single units in terminals, therefore their optimized operation is very important [1]. However the transport system is not advisable to be subordinated entirely to the quay cranes, because there can be situations when the current status of the transport system causes unbearable problems at other segments of the terminal. Therefore we suggest monitoring and optimizing the processes at global level as well.

For the analysis of the terminal processes we see logistic simulation software the most appropriate tool. This has already been proposed by others (e.g.: [2], [3]). We started developing our model on these experiences but focusing more on the capability of handling global optimum as well. Next survey of terminal processes follows, which is necessary in order to set the focus of the model.

2. Container terminal processes

Due to increased volume of containers, intermodal terminals became important part of logistic networks. Intermodal container terminals may have various layouts, but can be divided into two main groups:

- inland, intermodal rail/road terminals,
- and maritime/waterway container terminals.

Airport-based terminals are not discussed, because air-cargo containers differ significantly from the widely used intermodal shipping containers.

Maritime terminals serve as hubs among sea, rail and road transport modes. Containers arrive at the seaside in special container ships. The containers are handled there using quay cranes, which place them on various, specialized transport systems. These can be various automated guided vehicles, manually driven towing tractors and trailers or straddle carriers. The above transporters carry the unit loads to the yard, where gantry cranes place them onto the container stacks. Movement of unit loads between the land side of the terminal and the storage blocks is carried out via the same transportation system. At the land side of the terminal loading and unloading of rail cars and trucks is executed by gantry cranes, reach stackers or container lift trucks. Besides the above there can also be direct movements between the sea and land sides of the terminal. The above elements are shown in Figure 1.

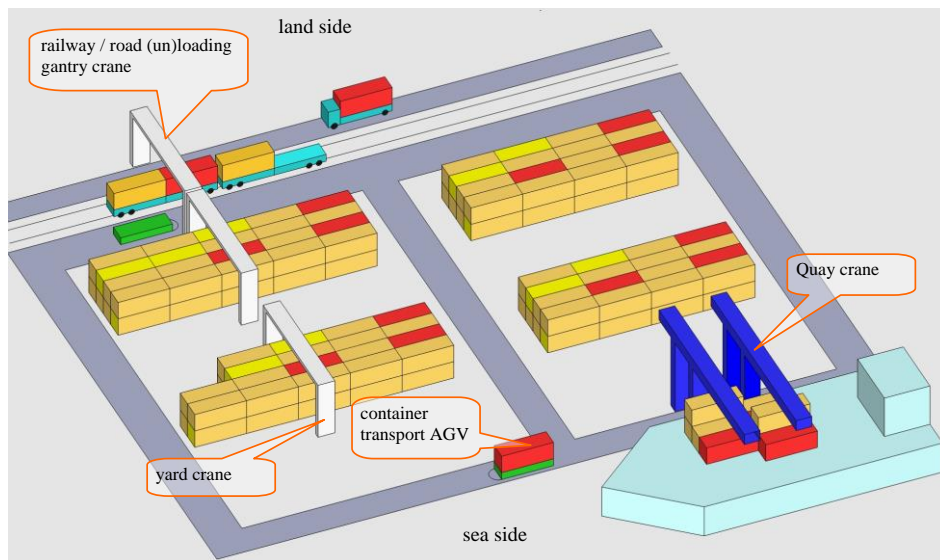


Figure 1. Material handling processes in container terminal

Next chapter surveys most typical optimizing problems and modelling for each subsystems, in order to gather information for the elements of the proposed model.

3. Modelling and optimization of container terminal processes

Modelling and optimization can't be handled separately because the first limits the applicable optimization method. From our point of view models are divided into simulation based and solely equation based numeric models. Next a brief overview about the already researched models is given. First the numerical models are described, afterwards simulation based models follow.

Numerical models can be divided after the field of application, into the following groups:

- Modelling of the berthing and loading/unloading of ships via quay cranes is an important part of the container terminal research. A good overview is contained in [4]. The paper divides the ship loading/unloading process into 3 sub-problems. First of them is the berth allocation problem, where the ships' serving is planned for berthing time and the occupied position. The berthing time depends not only on the number of the moved containers, but on the number of the assigned quay cranes. Quay crane assignment is thus the second problem of the planning. Finally the load handling movements have to be optimized as well, this is called the quay crane scheduling problem. However the loading/unloading of ships is essential for the terminal modelling, in our case it will be a complicated part of the simulation, because the optimizing require complicated combinatorial numerical/heuristic methods, and it's implementation can't use beneficial features of a logistic simulation software.

- Transport systems' modelling can be best observed in the case of automated guided vehicles (AGV). Due to the automated operation these systems can be modelled deterministically. Main optimization issue for AGV's is the handling of the scheduling problem. Paper [5] presents a numerical optimization method for the AGV scheduling problem. The authors applied a complex goal function which minimizes the total AGV waiting time at the quay side, the total AGV travelling time in the route to the port and the total lateness times to serve the jobs. This method can be implemented in simulation environment as well, but it must be considered if it is necessary at all in our case, or a more simple method is preferred. Further there are some other works dealing with the finding of optimal vehicle routing in the terminal.
- Inside the terminals containers are stored at the yard in so called blocks. There are two types of related optimizing problems. First, some papers analyze optimal crane deployment among the blocks. Zhang et. al. [6] presents scheduling optimization for rubber tired gantry cranes. They formed an equations-based numerical model, which is solved via Lagrangean heuristics. The second problem for containers is the placing of the containers, in the blocks (called the container stacking problem). These must be placed so that the containers' movements are minimized, and the actual containers can be unloaded in short time. Both problems have complicated solutions and can be solved only by heuristics.
- Optimization of the land side processes at container terminals is rarely researched. An important paper for this part is [7], which presents yard partitioning problem for gantry cranes of intermodal rail/road terminals (the analyzed terminal layout can be seen in Fig. 2). This problem includes scheduling of service slots of trains, and the decision on the containers' positions on trains. Finally container moves are assigned to the cranes.

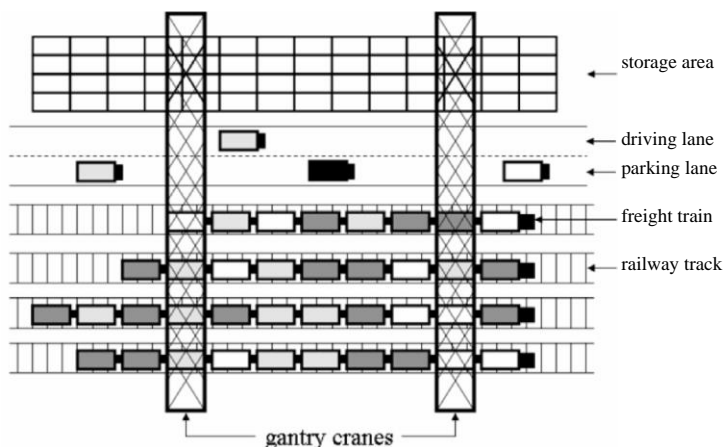


Figure 2. Intermodal rail/road terminal with gantry cranes (from [7])

There exist several simulation models for container terminals as well. We focus on one publication in this direction. Rizzoli et. al. [2] presented a commercial MODSIM III

based model. The used software is an object-oriented and process-oriented simulation language, which allows application of 'real world'-like software components. The paper outlines that features of an intermodal land rail/road terminal differs from its maritime counterpart, because the residence time of the containers is much smaller (approx 24 h). We remark that the various types of handled units is also greater than maritime terminals, because solely land based intermodal system can handle additionally various domestic containers and swap bodies. The paper proposes four model modules by which modelling of the whole terminal can be solved. These are:

- the road gate, where the road traffic of empty and full containers enter and leave the terminal,
- the rail gate, where trains enter and leave the terminal,
- the platforms, which is a puffer area and a set of gantry cranes for the loading/unloading of rail/road vehicles,
- and the storage area, which is used for the longer storing of the containers, and served by reach stackers.

This simulation models the whole terminal; however it lacks sophisticated algorithms for the optimization of the various modules. The simulation doesn't contain spatial information (e.g. containers' position inside the terminal), it operates using directly given deterministic and stochastic parameters and distributions.

We outline this important difference between numerical and simulation based models: the first ones concentrate usually on a single module of the process, but the optimization algorithm is more sophisticated. Cross effect of the optimization of various modules is however not analyzed. Simulation models give a good overview of the whole process and it allows analysis of various scenarios, but the implemented processes are usually not supported by complex algorithms, only empirical data.

4. Characteristics and structure of the proposed simulation model

Upon the experiences from the described papers we concluded that modelling and optimization of terminals results in economic benefits. For the proposed simulation model following priorities has been set:

- Simulation model should be modular like in [2].
- For the various simulation modules we propose implementation of behaviour-based control. These methods are widely used at other areas of intelligent computing. That means each module may work in various operational modes. The modules continuously observe behavioural-states of the other modules and change their own behavioural-state if necessary. For example, if the container yard module recognises that the berthing module requires more intensive container placement then it will change his priority from 'placing the container to the optimal position' into 'placing the container into the quickest available position'.
- We intend to implement our model with adaptive features as well. For the implementation we intend to use soft computing e.g.: neuro-fuzzy

algorithms. This way we expect that the operational features are improved as well. Such methods are known in logistics, for example Orbán and Várlaki [8] proposed an adaptive fuzzy system for the modelling of loading systems in logistics. This systems can change it's behaviour depending on the relation of current demand and serving capacity of the loading system.

- We intend to give the containers a more active role in the processes. We analyze the effect of handling the containers like passengers in traffic systems. That means each container tries to leave the incoming transport vehicle as soon as possible, tries to get into the most appropriate position in the stacking, and tries to reach the outgoing transport vehicle in time. These will generate prioritized transport demands, carried out by the load handling cranes, stackers, AGVs.

Development will be carried out using Simul8 2008 logistic simulation software. Main features of this software are the modular structure, and the object oriented capability of the models. There are several components available in the Simul8 environment but we need to use two of them. Static container stacks, other storage areas, decks and cargo bays of ships and the railway carriages are modelled using a set of simple static 'Storage Bin' elements with LIFO principle (see Fig. 3.). Each stack represents containers loaded at the top of each other, that means only the top container is available for unloading. If a lower container should be accessed then it generates additional loading operations for movement of the upper container.

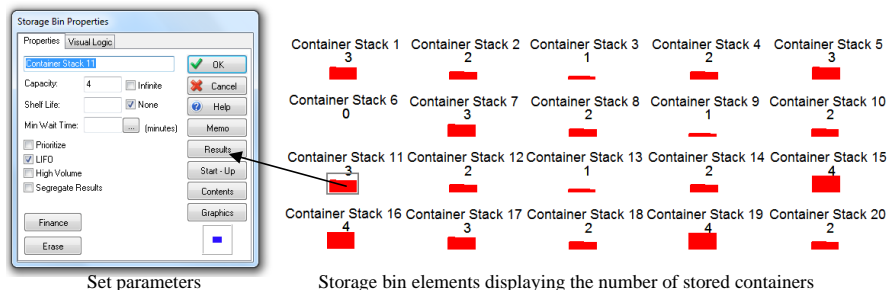


Figure 3. Proposed modelling of container stacks in Simul8

Loading and transporting machinery, such as quay cranes, reach stackers, AGVs are modelled by a set of 'Work Centers' and 'Storage Bins', see Fig. 4. Each machine's movement is divided into empty move in order to reach the container and loaded move, which include load handling as well. If Quay crane 1 in the example receives a container handling task, it gets a virtual work item into the 'Container demand for QC1' Storage Bin. When it is appropriate the model starts Quay crane 1 by putting a virtual work item into 'Start Quay crane 1' Storage Bin. This virtual work item will 'go through' the loop of simulation elements, signaling the actual state of the handling process. After the handling process Quay crane 1 will only be free for other tasks again, if it gets a signal about the successful transition of the container to another material handling unit, via a virtual work item into 'Finished Quay crane 1' element.

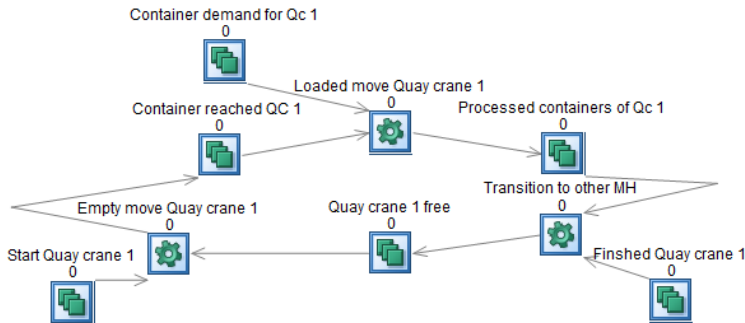


Figure 4. Proposed modelling of loading and transporting machines in Simul8

Each container should be supplied by the following parameters (in Simul8 so called 'labels').

- container type (important for proper stacking)
- destination information (ID of the outgoing transport train/truck/ship)
- 'reserved' state (if the container is assigned to a loading/transport machine but it hasn't been taken)

In container terminals material handling relations of the loading machines are not static, because for example reach stackers may work at different areas of the terminal. Therefore global functions should be implemented in the model as well. These have following functionality:

- Loading machines' allocation,
- computing of actual behaviour of the modules via adaptive soft computing methods,
- assignment of the containers to the loading machines, depending on the operational behaviour of the modules and the state of the machines,
- determination of the containers' position inside the stacking areas.

We remark that these functions can be supported by numerical algorithms given in chapter 3.

There are two proposed inputs for the model. The long-time scheduling of incoming and outgoing containers gives the number of containers, their destination approximate arrival time of the vessel/train/truck. Using this information the model can arrange quay cranes and storage areas in advance. The other input is the actual arrival, this way effect of the difference between the actual and the planned time can be analyzed as well.

Outputs of the model can be several. A Simul8 based model can easily compute the used total material handling capacity, the utilization of the machines, and lateness of the incoming/outgoing transport vehicles.

5. Summary and further steps

This paper presents possibilities and highlights of container terminals' modelling in logistic simulation environment. In the current state simulation modules of the terminal have been developed, and the necessary computational methods for global functions have been surveyed. Next steps of the research are to construct and analyse a model of a typical container terminal, in order to research the necessary behaviours of the modules and to develop the necessary global modules.

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