

GENERIC SIMULATION FOR RAIL-ROAD CONTAINER TERMINALS

Thouraya Benna
Manfred Gronalt

Feistmantelstrasse 4
Institute of Production and Logistics
University of Natural Resources and Applied Life Sciences
Vienna, A-1180, AUSTRIA

ABSTRACT

Hinterland terminals enable the transshipment of containers between various modes of transport and play a significant role in intermodal freight transportation. In this paper we present a simulation-based tool, that can be used to plan and design a rail-road container terminal, by simulating different terminal configuration in advance and accessing performance and utilization limits of the planned terminal.

1 INTRODUCTION

Hinterland container terminals (HCTs) are important hubs in modern logistic-networks that ensure efficient and frictionless intermodal container turnover. In Fact HCTs play an important role in the distribution of containerized goods into the hinterland and are therefore significant for the development of industrial regions. Especially the combination of increasing number of container shipment and the overload on European roads causes a growing need for transshipment nodes. To meet these requirements HCTs have to be planned and coordinated carefully.

This paper presents a simulation based tool, which was developed to support terminal manager in their strategic decisions. The planning of new HCTs as well as the extension of existing ones, has to be done carefully and must take into account capacity and infrastructure requirements which can be defined by answering the following questions:

- What type of Infrastructure (handling equipment and transport modes) is needed?
- Which capacity (number of handling equipment, number of gates, yard capacity) is needed?
- Which layout (arrangement of blocks, routing and distances) optimizes the throughput?
- Which overall strategies are best for the terminal operation (offered services, yard segregation)?

The simulation we present, allows for detailed analysis of infrastructure and capacities needed and can therefore be used to minimize the risk of bad investment and avoid costly problems in daily terminal operations.

After a short literature review, we give an overview on HCT design and operation. The development of the simulation model is discussed in section 4 and some concluding remarks are drawn in Section 5.

2 LITERATURE REVIEW

A major part of the literature, written on container terminal operation and management, focus on optimization methods for individual sections or subareas of the terminal (Arnold et al. 2004; Kim and Park 2004; Kim and Kim 1998; Chen 1999). The main covered areas are dispatching and scheduling of handling equipment, berth allocation, storage space allocation and sequencing of the ship loading and unloading.

Although some of this work can be used to deduce strategic decisions for the future operation of HCTs, most of the optimizations methods remain primary suited for tactical and operational issues. Still there is some research dedicated to the overall definition of container terminal operation.

A complete overview of the relevant operations, equipment setting and literature is given by Steenken et al. (2004) and Murty et al. (2005). Vis and Koster (2003) give a further detailed description of container terminal processes; and Vis and Harika (2004) focus in their paper on the used equipment in automated container terminals to work out differences between automated guided vehicles (AGVs) and automated lifting vehicles (ALVs).

Simulation as an evaluation method has also been studied intensively. Studies can be grouped into 2 categories. The first category concentrates on a certain sub area (Yang et al. 2004), while the second category models the whole container terminal (Gambardella et al. 1966; Lee et al. 2003; Parola and Sciomachen 2004). This category is rather comparable with our study. But Due to the fact that nearly all relevant papers are devoted to open-sea Terminals, activities around the ship berthing, loading and unloading play a predominant role in the studies and are reflected in the process of goal setting, which is less suit-

able for our purpose. In fact, in HCTs activities and goals are rather centered on container shipment by railway.

3 THE MODEL

3.1 HCT-design

HCTs are commonly divided into three functional areas: truck gates, train interchange and yard. The first two areas represent external interfaces of the terminal and are used for the processing of incoming and outgoing trucks and trains. The yard of a HCT is the storage area that is used to bridge the time gap between container import and export; and consist of at least one block. Usually a part of the yard is dedicated to empty containers, which are characterized by a longer storage time and additional services provided like cleaning and repairing.

Truck gate, train interchange and yard are connected by the handling equipment, which transports, lifts and stacks the containers. In HCTs mainly two types of equipments can be found: gantry cranes and reach stackers. Gantry cranes can be rail mounted (RMGC) or rubber tired (RMGC) and have a spanning capacity of an entire block. While gantry cranes can reach any container within the block, reach stacker can be limited in their access, depending on the depth and height of the block. In fact reach stackers can only lift containers up to the fifth tier and into the second or third row.

3.2 HCT-operation

Upon their arrival at the terminal trains and trucks are listed at the corresponding interface and then sent to a pickup position, where they wait for the loading or unloading of their containers. While trucks can drive autonomously into the terminal, trains have to be assigned to a terminal track and may even be split if the train length is greater than the available truck length.

Incoming containers are grouped into containers with intermediate storage and containers with direct transshipment. Both types of incoming containers have to compete for the handling equipment. First, equipment has to be assigned to each container; then the pick up activity has to be scheduled according to its priority. Containers with intermediate storage have furthermore to be allocated a storage place in the yard. The determination of a free storage space depends on container attributes like length, weight or planned pick up time.

Finally when outgoing containers are ready for pick up, they compete once again for the handling equipment and are lifted out of the block and handed over to the picking train or truck.

In accordance to the terminal structure and operation described above the main goals of a HCT are:

- To allocate terminal resources like handling equipment, gates, trucks and storage space efficiently,
- To reduce the total waiting time for trains and trucks in the terminal and
- To maximize the overall throughput of the terminal defined by the total number of handled containers.

4 THE SIMULATION

4.1 Developing the simulation

The simulation presented in this paper was developed on the basis of Austrian HCTs and with the cooperation of major Austrian terminal operators. The goal of the simulation is to support terminal managers in their strategic decisions. We had therefore to make sure that the model developed takes into account all relevant processes and problems that can arise while operating a terminal. For this purpose we made several field visits and expert interviews to gather the necessary information.

As we wanted the simulation to be usable for any possible terminal, we had to standardize terminal operations and to develop a generic simulation that works with any terminal configuration as input. For this purpose we implemented a user-interface called “Configurator” that can be used to enter all relevant input data.

To verify and validate the simulation we organized several workshops with the terminal managers. Although we had access to all terminal data, validating the simulation was difficult. In fact, due to the manageable size- in terms of space and throughput- of most HCTs, the use of information management systems is still scarce. Therefore information concerning lead times or resource utilization is often incomplete due to the lack in automated reporting.

4.2 Simulation components

The Simulation consists, as shown by figure 1, of three sequential modules: “Configurator”, simulation and report generator.

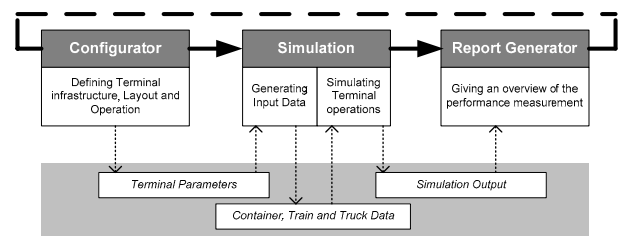


Figure 1: Simulation Components

The “Configurator” is the interface used to define the terminal to analyse and is hence used to determine all relevant parameters. The Terminal data is then passed automatically to the simulation which evaluates the performance of the terminal. Finally the results of the simulation are passed to the report generator where they are aggregated in a clear and comprehensive overview.

4.3 Input data

The input data is entered in the “Configurator” and can be separated into two groups. The first group defines layout and infrastructure of the terminal and contains for instance information about the handling equipment, the yard blocks or the train interchange (see table 1). The second group is used to describe terminal operation and includes parameters as average throughput, arrival patterns, uncertainty level and container characteristics (see table 2). Both groups can be changed autonomously, as terminal analysis is often done with respect to its design (which layout and infrastructure performs best?) or to its operation (how the container flow through the terminal takes place?).

Table 1: Parameters Describing Terminal Design

Master Data	Layout Data
Means of Transport	Terminal layout
— Handling tracks	— Block arrangement
— Truck gates	— Track arrangement
— Truck parking	
Yard	Assignment
— Number of blocks	— Equipment to blocks
— Block dedication (mixed, empty containers)	— Equipment to tracks
— Block size (rows, bays, tiers)	— Tracks to blocks
Equipment	Distances
— Equipment type	— Relevant distances for equipment
— Number of equipment	— Distances for trains and trucks
— Technical specification	

Table 2: Parameters Describing Terminal Operation

Traffic	Containers
Number of import containers per train and truck	Container length and weight
Seasonality in train and truck arrivals	Average storage time
Type of incoming trains	Ratio stackable to non-stackable

All parameters are then automatically passed to the simulation, which generates in a first step detailed lists of arriving trains, trucks and containers. This approach is, especially in the case of non-existing terminals, relevant as detailed information about daily terminal operation may not be available yet.

The generation scheme used in our research follows the procedure proposed by Hartmann (2004) which was used to produce data for the simulation study of the new container terminal Altenwerder in Hamburg, Germany.

Based on the total number of containers arriving in the simulation time, a number of incoming trains and trucks is generated. In a next step detailed information (identification number, arriving day and time, number of container delivered, number of container to pick up, etc.) for each transport unit is defined. In Accordance with the total number of delivered containers, individual containers are generated and assigned attributes as container type, length and weight. Finally the planned pick up time for each container is calculated and used to choose an outgoing transport mode. If the total number of incoming trains do not satisfy the pickup demand, then additional wagons are defined.

Data generation takes into account all existing interdependencies among container, train and truck attributes, and generates therefore consistent and executable terminal operation data. Especially the detection of each individual container, train and truck by an internal identification number, is important for a correct simulation.

4.4 Control logic

The simulation model consists of four control units: train interchange control, truck gate control, storage control and equipment control.

The train interchange unit coordinates the arrival of trains and the allocation of terminal tracks. The dynamic allocation problem of tracks is mainly important in the case of a terminal configuration with terminal tracks which are shorter than the total length of the arriving trains and even more in the case of the complete separation between import and export trains.

The control unit for the truck gate is similar to the first train interchange unit. Its purpose is to allocate trucks to the gates and to avoid bottlenecks in the terminal, by making sure that trucks waiting (for example because the container has not yet arrived or the transport document are incomplete) do not hinder the import and export flow at the road side. This is basically solved by routing, when necessary, the waiting truck to a parking area.

The control unit for the storage yard determines for each import container the best storage position in accordance to the storage strategy, the actual fill rate of the block and the container properties. When a container is

picked up, the storage control localizes the exact storage position and determines the pickup position for the truck.

The last unit is used to solve the dynamic allocation and scheduling problem for the terminal equipment. It is also responsible for the routing problem that can occur when more than one equipment try to access the same bay, stack or transport mode.

All control units interact with each other and are implemented in respect to the following dynamic allocation and scheduling rules:

- Feasibility: The allocation of equipment or storage space has to be consistent with the defined layout and access possibilities for the equipment. Some combination of yard blocks and tracks or equipment may be forbidden and have to be therefore excluded in the planning phase.
- Availability: When requested the equipment has to be idle, this means that it is not busy or reserved.
- Priority: to reduce the fill rate of blocks and to ensure the constant flow of containers in the terminal, export containers are granted a higher priority than import containers. Further the service level of trucks, measured by their dwell time in the terminal, tends to be more critical and therefore trucks are served with higher priority.
- Performance Goals: to improve the overall performance of the container terminal, unproductive moves have to be reduced, the equipment has to be allocated according to the shortest path rule and due times of container and transport modes have to be met.

4.5 Simulation Output

Based on the expert interviews we define three sets of performance indicators which are collected by the simulation: throughput and lifting performance, system capacity and service level.

The first set of indicators is related to the overall performance of the terminal and describes the achieved throughput. The main performance indicators are total number of containers flowing through the terminal, average number of containers delivered per day, average number of containers picked up per day, total number of equipment moves, rate of unproductive moves and average lifting time per container. This set of indicators is used by terminal managers to analyze the terminal in terms of profitability and economic efficiency, and is therefore used to see if the defined terminal configuration is able to perform the needed throughput.

The second set of indicators describes the utilization level of the terminal. Example of indicators are the usage rate of the resources (equipment, truck gate and tracks), the fill rate of the yard and the average and maximum number

of stored containers. This set can be used to deduce the remaining capacity of the terminal and to identify possible bottlenecks.

The last set of indicators is used to define how good the terminal is operating in terms of service level and consists of the average dwell time of trains, trucks and containers. In fact, the average waiting time of trucks delivering and picking up containers is a critical factor for customer satisfaction. Further, avoiding train delays caused by the terminal, is important, as it not only affects train schedules, but also can cause holdups in the terminal.

5 CONCLUSION

The goal of the simulation presented in this paper is to provide a reliable decision tool for the evaluation and comparison of different hinterland container terminal configurations. Testing and analyzing design and operation of future terminals with computer simulation, can in fact reduce the risk of stranded costs.

An important feature of our simulation is, that even if it takes into account all terminal process and problems, it still is generic and therefore applicable to any terminal configuration. Further, the simulation is specially devoted to rail-road transshipment and fulfils the specific needs of this type of terminals.

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AUTHOR BIOGRAPHIES

THOURAYA BENNA studied at the University of Vienna at the Faculty of Business, Economics and Statistics and received her MBA in international business administration. Since 2005 she is project assistant at the University of Natural Resources and Applied Life Sciences in Vienna and works on the project SimConT (Simulation of Hinterland Container Terminal operations). Her research and teaching interests include production management and operations research with a special focus on simulation and neural networks.

MANFRED GRONALT is professor at the University of Natural Resources and Applied Life Sciences in Vienna and Head of the Institute of Production and Logistics. His expertise and research interests include computer-aided simulation, logistics and operations research and production management. Dr. Gronalt has published over 55 journal articles, book chapters, and conference papers. He is also a member of the Austrian Society for Operations Research (ÖGOR) and the Production and Operations Management Society (POMS).