SIMCONT – THEORY AND PRACTICE IN SIMULATION OF BINNENLAND CONTAINER TERMINALS

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ABSTRACT

In this paper we show the SimConT approach in símulation of Binnenland Container Terminals (BCT). SimConT was used during the last years in several projects on capacity evaluation of BCT. During these works we collected some experiences on how to carry out simulation studies for BCT. Especially, main important steps are data collection of infrastructure, train related and load carrier data. Secondly, the detailed operation of the yard and finally during the analysis phase to adapt the study steps to the marginal productivity rate of the BCT. We will provide a guideline for conducting the simulation studies and connect it to the theoretical architecture of the SimConT simulation model(s). The guidelines also focus on how scenarios for the up following simulation runs are constructed in order to reach the marginal rates of the yard. During the works we were also able to identify relevant key data and indicators reflecting the BCT's performance. These indicators may be used for comparing the performance of different sites.

Keywords: Binnenland Container Terminal, rail-rail and rail-truck terminal, simulation study approach

1. INTRODUCTION

Inland container terminals hold a crucial role in modern supply chains, as they are the essential transshipment points for containerized freight between transport modes by land and sea, and function as feeder terminals for open sea terminals. Given the increasing importance of inland terminals and increasing flows of goods, rail transport must be strengthened as favoured mode of transport. Over the last years a simulation tool called SimConT was developed which is tailored to the special characteristics and requirements of inland container terminals. The tool allows for strategic and tactical simulation of terminal infrastructure and operations. By means of simulation, decision makers are actively supported in planning processes, while minimizing the risk of bad investments and stranded costs when planning and (re)building terminal infrastructure and enlarge terminal capacity.

BCT mark the peripheral nodes in efficient freight transport. They distribute and collect containers and

other intermodal load carriers like swap bodies and 'liftable' semi trailers. BCT receive and ship containers from sea terminals, another BCT or from local industries. In BCT Intermodal Transportation Units (ITE) usually represent a mix of the above mentioned load carriers. We can observe that in the recent past the portion of liftable trailers was steadily increasing. This is an effect of increasing intra European freight transport modus shift from road to rail.

All over Europe there are approx. 800 BCT of different sizes and networks roles operating in the intermodal transportation network. An ongoing change in European transport infrastructure also leads to requirements to adapt BCT to new tasks.



One key element in the operation of these BCT is the organization of ITE - exchange. We denote this as operation strategies (Benna and Gronalt, 2008) for

BCTs. The second element which contributes to the performance of BCT is infrastructure: rail yard tracks, cranes, stacker for single or multi terminal environment and terminal infrastructure network for movement of stackers, trucks, terminal tractors and storage capacity and portion of dedicated storage areas of the BCT. In **Figure 1** a typical BCT Layout is shown.

Further, we have to consider the arrival pattern of trains and trucks, the ITE-mix on trains and the relation between import and export ITE as order systems of the BCT. Figure 2 shows how these elements are used as a standard input for SimConT Simulation module in order to analyze BCT performance.



Figure 2: SimConT modules dependencies

2. METHODS AND TOOLS FOR ANALYZING BCT

Several authors propose analytical approaches, mainly MILP models for selecting various design options for rail-rail and rail-road terminals. Boysen et al. (2010) propose a dynamic programming approach, to determine yard areas for gantry cranes for balancing workload in order to improve the operation of the cranes. Wiese et al. (2011) describe different technologies in container terminal operation and their impact on the terminal layout. For a layout which is typical for the use of automated rail-mounted gantry cranes they propose a procedure to calculate promising storage yard configurations.

Simulation as an evaluation method has also been studied intensively. Studies can be grouped into two categories. The first category concentrates on a certain subarea (see Yang et al. 2004), while the second category models the whole container terminal (see Gambardella et al. 1966; Lee et al. 2003; Parola and Sciomachen 2004). This last category is rather comparable with our approach (Benna and Gronalt 2008). 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 suitable for our purpose. In fact, in BCTs activities and goals are rather centered on container shipment by railway. To summarize our literature review, it should be mentioned that only few research is done on the special nature of binnenland container terminals.

3. SIMCONT – ELEMENTS

We have both developed a simulation system (SimConT) and a procedure how to stepwise evaluate

the capacity of a particular BCT. The approaches are interdependent and we will now first present the SimConT elements and further show how we are using them on a detailed simulation case study. SimConT is both a concept and a simulation tool completely coded with Java Classes and supplemented by AnyLogic statecharts functions.

3.1. Terminal Configuration

The terminal configuration prepares the detailed layout of the terminal, the gates, parking areas inside and outside the terminal, loading and storage areas and all the distance and time related data. This is completed by opening and operating hours of the terminal.

For the terminal equipment it is necessary to define its operations modes and ranges. For this an assignment of tracks and storage areas has to be defined and detailed operation plan for each of the various equipment is applied.

The terminal is dominated by the train schedule and the flow attributes of the ITEs. The daily arrival distribution of trains, their lengths and ITE-mix must be defined clearly and flexible for further adjustments. Also the operation mode (floating or fixed) for the trains generally and/or in particular effects the terminal capacity and must be provided as a system's input. Figure 3 shows the activity diagram of exporting containers with trucks.



Figure 3: Modelling of daily truck arrival

For particular ITEs the in- and outflow in the system, planned storage time, dedicated storage areas, stacking attributes and required handling equipment must be defined.

The above presented data and dependencies are stored and provided in a database outside the simulation. It used as a generic input for the simulation and is application driven adapted. For example, it is necessary to work with a variable portion of non stackable trailers in BCT due to an increase of intraeuropean freight traffic.

Figure 4 shows some selected configuration parameter the corresponding simulation logic and attributes.



Figure 4: Configuration parameter and attributes of simulation entities

3.2. Simulation model

The simulation model for conducting various experiments is coded with Any Logic, where the main control processes are implemented in state chart logic.



Figure 2 the first phase of the simulation is generating input data for the simulation model. This iteration makes the simulation application specific. According to the terminal configuration database the main elements of the simulation logic can be divided in

- Flow control,
- Handover control,
- Track control,
- Equipment control and
- Storage control.

Figure 5 provides the storage control state chart. It selects the next possible storage spot for the specific ITE at hand. Clearly, the simulation model provides spots classes for controlling the storage areas.



Figure 5: Storage state chart

In the following figure we show the state chart for the equipment class. It displays the state transitions of cranes in the terminal. The supporting evaluation functions like pickTime(), dropTime(), chooseNext() which are responsible for the efficient movement of the cranes are not shown here.



Figure 6: Crane state chart

We have validated our approach during the conceptual phase with three different BCTs. One further essential element is the simulation output generation which is presented in the next section.

3.3. Simulation Report

The simulation report puts together the simulation expertise with the BCT process knowledge to extract the most relevant performance figures. For SimConT we decided on the following concept on report generation.

Basic Indicators describe the BCT in general. Regarding the terminal infrastructure we focus on the following data:

- storage capacity of loaded containers, empty container, trailers and swap bodies,
- total storage capacity,
- number and length of tracks,
- number of cranes per terminal unit,
- number of stackers,
- number of gates and
- number of container handover places.

For the infrastructure related indicators usually utilization measures are evaluated in the reports. These can be defined both static and over the time. Especially for the cranes the portion of service lifts are reported.

In addition the terminal operation and container flow are also considered in the standard report. Basic set of indicators contain the number of import and export container per time unit and the portion of train and truck deliveries. According to these data, flow time indicators for containers, trucks and trains are reported. The set of basis indicators may be extended according to the specific requirements of the application. For example for new terminals the truck queue in front of the gates are important to estimate the traffic jams caused by the terminal.

4. SIMULATION STUDIES

Simulation experiments are used to evaluate system's performance over time. Beside statistical issues like simulation run length, warm-up periods and number of replication and others it is further essential to consider specific terminal requirements. These may be related to the role of the terminal in the freight network (gateway, feeder, hinterland, industry supply) or the portion of empty container for exchange with industry or development possibilities of the terminal like additional terminal units. According to the role of the terminal we found different procedures on how to improve terminal's performance.

In the first step of the simulation study we use the generic SimConT models as shown in Figure 2 in order to simulate a Basis Scenario. Before we conduct the simulation experiments we apply the configuration steps in order to generate the data for terminal infrastructure, layout and operations strategies. For these it is especially important to build reliable train schedules. The data generated were validated with terminal operator and it also assists in defining the goals and varying parameters to guide the simulation experiments. For these the standard reports are extended to fit the simulation application. Usually we use order data for one month as model input and generate the simulation data for the simulation period (e.g. one year).

The second step usually consists of the first simulation experiments for a new or existing terminal to calibrate the simulation to application specific restrictions. The simulation results (report) are analyzed for critical or near critical performance values. If the model is calibrated we can now define future simulation scenarios. Some elements which may be used to define scenarios are listed below:

- train length,
- arrival frequency of trains,
- relation of direct exchange containers,
- dedicated storage for containers/swap bodies/trailers,
- number of terminal tractors and
- portion of liftable trailers.

This iteration - definition of scenario parameters and simulation - is run again and again until the performance shows stable results and no further infrastructure options should be considered. In the last section we will now present the results of a real life case. We show the results with modified data.

5. CASE STUDY - TERMINAL A

The starting point for this was the renewal of the BCT network in Austria (see Gronalt et al 2010). For this, a performance analysis of existing and new terminals is required. We discuss now the procedure to support the infrastructure investment decisions for a specific industry supply terminal. The terminal handles a large amount of empty containers.

The current configuration of the terminal was used as a baseline and compared to two improved terminal layouts. By doing this we defined some scenarios with increased transshipment volumes in order to figure out the marginal capacity of the terminal. The key figures of the starting configuration and the simulated layout variants are summarized in Table 1.

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	Current Layout	Layout 1	Layout 2
storage capacity loaded container (TEU)	570	479	1277
storage capacity empty container (TEU)	1450	2773	3582
total storage capacity (TEU)	2020	3252	4858
number of tracks	6	4	4
track length	1310	2000	2240
cranes	1	2	2
stacker	2	2	2
truck parking area	9	15	20
gates	1	2	2



Figure 7 displays the layout and storage blocks for terminal layout 2. Handover spots are located near the tracks for direct rail-truck transshipment. The number of transshipment points is restricted and also the number of trucks inside the terminals was controlled in order to prevent jams in the terminal.



Figure 7: Case study - Terminal Layout 2

For terminal layout 2 an increase in transshipment volume was simulated in order to determine the marginal capacity of this layout. The volume increase was modeled by a higher train arrival rate and by the number of container per train. The consolidated figures are given in **Table 2**.

	Table	2:	Increasing	transshipment	t volumes
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	increase	+ increase	
Scenario 2	arrival rate	volume	increase
2.1	(+ 5%)	(+ 16%)	21%
2.2	(+ 10%)	(+ 18%)	28%
2.3	(+ 15%)	(+ 20%)	35%
2.4	(+ 20%)	(+ 22%)	42%
2.5	(+ 25%)	(+ 24%)	49%

For each scenario a simulation was made with a run period of one year for smoothing seasonal fluctuations in the results. The simulation runs were replicated 20 times to eliminate stochastic disturbances.

Figure 8 shows the crane utilization rates for these different volume increase scenarios. It can be seen that for the current volume which is at the limit of the existing terminal's capacity, the new layout will be able to handle these volume very easily. But a 42% increase or above leads to near critical crane average utilization of about 70%. We also can notice that we may have some opportunities to raise the capacity if we can change train schedules. Further improvements are possible by new crane movement strategies.

6. CONCLUSIONS

In this paper we provided our point of view in conducting simulation studies with the generic BCT simulation tool SimConT. We can conclude that this approach is very suitable for analyzing the performance of binnenland container terminals.



Figure 8: daily development of crane utilization and volume increase scenarios

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