TRUCK GATE SIMULATION FOR INLAND TERMINALS

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1. INTRODUCTION

Inland terminals are often characterized by the dominance of rail and road based freight and transhipment between those modes. While various other authors have looked in detail on processes of terminal operation, including terminals at sea ports as well as inland rail-road terminals, the stage just before trucks which are delivering or picking up intermodal transport units (ITUs) such as containers, swap bodies or reefer containers, enter the terminal is commonly ignored. This is especially true for inland rail-road terminals. In practice, however, carriers sending their trucks to a terminal have to wait before they can pick up and/or drop of ITUs. This waiting time is costly for costumers and not desired. Additionally, truck waiting is often linked to exhaust emissions as trucks are idling while waiting. Thus, long waiting times for carriers, which often result from poor gate operations and transfer point assignment, are causing problems for operators of inland terminals as well as for the local and global environment.

Therefore, in this ongoing research, we focus on the possibilities to organize trucks waiting for empty transhipment points in different ways using real data from several Austrian terminals. We develop an agent based discrete event simulation model, which investigates alternative options to organize truck arrivals and gate policies. The simulation aims to find alternatives which reduce the dwell time of trucks, transhipping goods at the terminal, especially focusing on the waiting time before those vehicles enter the terminal. After a literature review we present the problem description, the tentative structure of the simulation model (incl. simulation input and output data) and a short conclusion.

2. RELATED LITERATURE

There is a lack of interest in the interface between road traffic and terminals, especially regarding inland terminals but also concerning port terminals. This is surprising as there is already some research pointing to the importance of this topic. For example, Benna and Gronalt (2008) investigate hinterland terminals by presenting a simulation based tool for the planning and design of these terminals. They show that the reduction of total waiting times for trucks is a key goal for rail-road terminals and that the average waiting time of truck delivering and picking up containers is a critical factor for customer satisfaction. Similarly, Rizzoli, Fornara, and Gambardella (2002) who present a simulation model which represents the flow of ITUs within and between intermodal inland terminals based on the discrete event simulation paradigm, point out the importance of modelling the processes of arrival and departure of trucks and trains at the terminal gate in rail/road terminals as ITU dwell time is shorter in this terminals. However, they clearly state that they are not researching processes or activities beyond the terminal gates, although they do explicitly model the gate itself. Instead they are referring the reader to both traffic simulation and simulation/optimization of the rail network to be used to "model the 'interfaces' of the terminal with the external world".

Huynh and Vidal (2010) focus on truck turn times, and thus the inner workings of the terminal, to reduce waiting time for trucks at the gate. The authors point out the high costs for drayage trucks in proportion to total transport costs which according to them make up 25% to 40% of total transportation costs. These authors, however, also argue in an additional vein as they discuss the emissions produced by idling trucks which are waiting for entrance into the terminal.

This focus on related environmental issues can also be found in Longo et al. (2015). The work considers green initiatives for port terminals. The authors develop a decision support system which simulates various green practices with several configurations in order to evaluate the different solution scenarios. In addition, they list and categorize green practices in ports. One category is named "practices for the reduction of emission by parked vehicles", under this heading the authors list "Gate policies for incoming trucks" as best practice example for this category which impacts direct and indirect emissions as well as fuel and electrical consumption. Gate processes are further classified as Process-centric practices as opposed to technological-centric and relationship-centric practices.

Suggestions regarding the economic and environmental importance of gate processes and congestion can, e.g., be found in the work of Iwasaki et al. (2003), Simpson and Gamette (2010) or Motono et al. (2016).

Simpson and Gamette (2010) present the design of the first terminal which is planned after the Port of Long Beach has committed itself to a strict Green Port Policy.

The authors present a number of environmentally friendly design elements such as shore-to-ship power for container ships. However, it is worth highlighting that one of the elements of the newly planned container terminal is the implementation of efficient gate systems and effective truck circulation. This is done in order to reduce truck idling and thus, emissions as well as waiting time.
Iwasaki et al. (2003) present a non-stop terminal gate system for Japanese container terminals which eliminates the need for paperwork by using ITS Technology. Their work shows that this system improves efficiency and reduces environmental impacts when it was tested at the Shimizu port container terminal.
Motono et al. (2016) consider the reasons for landside gate congestion as well as different measures to decrease this problem. They find three categories of measures to decrease congestion; First: controlling the arrival rate of trucks, e.g., by shifting arrivals to other modes or using an appointment system, or by extending the opening hours, Second: increasing the number of the gate lanes dynamically; Third: improve gate service rate by increasing the automatization or by eliminating trucks which have documents that are not correct.
A very different solution to the issue of truck congestion in container terminals is provided by Dekker et al. (2012) which is especially designed to mitigate peak hour gate congestion. They introduce a chassis exchange terminal. This is an additional terminal, where trucks do not have to load or unload ITUs but rather switch their chassis (trailer) against another one. The chassis are then loaded or unloaded during off peak times at the required container terminal. These authors again argue that gate congestion has more than one problem, they point to the emission problem caused by idling trucks while waiting as well as to the problem of waiting time itself, stating that this can amount to more than two hours. Their idea for a chassis exchange terminal is that turnaround time is much shorter as switching chassis faster than loading and/or unloading, additionally smoothing out the demand on traditional terminals and thus, reducing waiting times there as well. This is, however, also a problem for the idea of a chassis terminal, as transport companies might not be willing to bear additional costs for the terminal and the chassis respectively the rental system behind them as well as the transfers to and from the chassis terminal when waiting times at traditional terminals are reduced.

Nevertheless, few have tackled “the interfaces of the terminal with the external world” as described by Fornara and Gambardella (2002) so far. While this is especially true for inland rail-road terminals, it also applies for port terminals. This is reflected for example in a recent review paper on ports and container terminals including more than 200 publications by Dragovic, Tzannatos, and Park (2017). The authors visualize the port system and its main subsystems and although they do mention the shore-side link, it is, unlike the anchorage-ship-berth link, not regarded as one of the main subsystems of the port system. However, there are some papers on the gate congestion problem for ports existing. Most of this work is focusing on systems for booking appointments or time windows which are often referred to as truck appointment systems (e.g., Gracia, González-Ramírez, and Mar-Ortiz 2016; Chen and Jiang 2016; Guan and Liu 2009).
Guan and Liu (2009) use a multiserver queuing model for the analysis of gate congestion at marine container terminals. They additionally develop an optimization model to minimize total gate waiting costs, from which they derive different measures to mitigate gate congestion, from which a truck appointment system is seen as most suitable.
These results are confirmed by Gracia, González-Ramírez, and Mar-Ortiz (2016) who address gate congestion and how it can be reduced by truck appointment systems by analysing a case study of a Chilean port terminal using a simulation model. The results of this work indicate benefits of implementing a truck appointment system with regard to gate congestion reduction.
Chen and Jiang (2016) use optimization to tackle the problem of gate congestion at marine terminals. They present a framework to assign time windows to manage truck arrivals, which are dependent on vessels, as well as three strategies for optimizing these time windows.
To the best of our knowledge only Zeng, Cheng, and Guo (2014) look at gate congestion of railway container terminals, using queueing modelling. Additionally, Ballis and Golias (2002) include truck dwell times into their criteria for acceptance of a rail-road terminal design. They evaluate different designs and only accept those which serve 95% of arriving trucks within 20 minutes (Ballis and Golias 2002).
Thus, so far there is little research done on the interfaces pointed out by Rizzoli, Fornara, and Gambardella in 2002.

3. PROBLEM DESCRIPTION

Trucks delivering or collecting ITUs from rail-road terminals usually enter the terminal via truck gates where export ITUs are checked regarding possible damages on the outside, this can be done manually by a checker or (partly) automated, e.g., by using a ‘fotogate’ where pictures are taken of the ITUs when the vehicle carrying it passes. These pictures can then be interpreted either by personnel or in future possibly fully automated by software applications. In addition, labels, seals and temperature might need to be checked. Before entering the terminal all vehicles whether they are delivering or picking up an ITU also have to provide data to the terminal, e.g., which ITU they are picking up and the associated documents. This process differs and might also be (partly) automated, e.g., through prior document provision via an online platform. In a next step the transfer point is determined. This process might start after all checks have been completed successfully. However, because the process of determining the transfer point can take some time it often starts as soon as possible, i.e. the driver has registered its vehicle and provided the relevant data. The exact process varies from terminal to terminal. It depends among other things on the local circumstances, e.g., the availability of space. In addition to variations in the sequence, delays might occur at any given point in the process. For example a delay might be caused by wrong or incomplete documents as described in Motono et al. (2016), by mistakes made by the driver (user) when self-service check in counters are used. When the transfer point is determined, its location is given to the truck driver. This can be done manually by a staff member but also via a computer gate where the driver receives his or her transfer point after typing in a specific number. The driver then moves his or her vehicle there and waits for the transfer to take place as soon as the transfer point is idle. After the truck arrives at the transfer point the transhipment takes place, e.g., a crane puts an ITU onto or picks up an ITU from the truck. The crane or other terminal equipment can only tranship a given number of ITUs at a time. Its capacity therefore limits the throughput of ITUs and affects the trucks dwell time, delays at the gate also occur due to limited capacity within the gate itself. The process described above is illustrated in a simplified way in Figure 1. Poor organization at the gates and transfer point assignment causes congestion before and at rail-road terminals and thus, long dwell times for trucks.

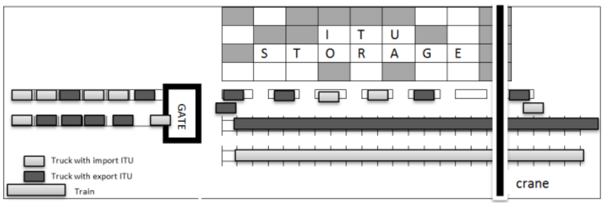

Figure 1: Terminal system

4. THE SIMULATION

4.1. Developing the simulation model

The goal of the simulation is to support terminals and carriers by researching different possibilities how truck movement respectively operations into the terminal is organized. In contrast to existing models, we have widened the scope to include not only the trucks that are entering but also those waiting for entrance (or are still to arrive). As this is a first attempt to include this at an inland rail-road terminal, we decided not to focus on the inner works of the terminal (Benna and Gronalt 2008) as this has been modelled before, but to keep this part of the simulation as simple as possible. This simplicity is also an advantage as in so doing it is easier to adapt the simulation model to different terminal situations.

4.2. Simulation components

The simulation is set up as an agent based discrete event simulation. An individual agent-based model may be defined as a model "in which the agents in the model are represented individually and have diverse characteristics" (Macal 2016) while the term discrete event simulation is according to Borshchev (2013) "used for the modelling method that represents the system as a process" and is therefore also referred to as process simulation in which entities are traversed through queue and delays. Thus, the entities (vehicles, ITUs, cranes) in our simulation are modelled as agents with diverse characteristics (e.g., capacities or types) waiting in queues and traversing through delays. The presented simulation model consists of two main parts. The first one is the part we want to focus our research on, this is the journey of a truck from before the terminal gate, waiting for a transfer point to transhipment and exiting the terminal under different pre-gate regimes. The second part is necessary to simulate adjacent processes at the terminal; it contains the transhipment of ITUs (rail-rail, rail-truck, truck-rail, storage-rail/truck, and rail/truck-storage) by terminal equipment (e.g., a crane) as well as the arrival and departure of trains.

4.2.1. Set up of part 1: truck arrival and lane assignment

In a first attempt, we look at different numbers of First in First-Out (FIFO) queues for arriving trucks which are assigned randomly and according to the truck's import/export status (picking up or delivering ITUs). This strategy is used due to the reason that the work of Gracia, González-Ramírez, and Mar-Ortiz (2016) who, in addition to looking at the implementation of a truck booking system, also implement a variety of lane segmentation strategies in their model for their Chilenian case study port, i.e. five lanes for all vehicles, five lanes split up into two lanes for refer, two lanes for empty and dry containers and one lane without segmentation indicates that an appropriate approach for lane segmentation can be sufficient to reduce congestion at terminal gates. The development of alternative options, i.e. regarding the number of lanes (and gates) and lane segmentation but also the sequence of processes, is a key part of this ongoing research. However, in our first setting trucks wait in queues until one transfer point is idle. We especially focus on these transfer points for trucks which have to be empty for the next truck to use it as they directly influence the waiting and therefore the total dwell times of trucks. When transhipment has been completed the truck leaves the transfer point and subsequently the terminal, thereby freeing the transfer point for following trucks.

4.2.2. Set up of part 2: terminal process interactions

As soon as a truck is assigned an idle transfer point it also interacts with other terminal processes. These have to be modelled to make sure waiting times for and at transfer points are reasonable. This is important as they are the basis for experiments on part 1 components. A simplified overview of the processes is presented in Figure 2 and Figure 3.

In case of export trucks the ITU (to be delivered) claims a spot in the terminals equipment's job list. To start with, we consider one and two cranes with a list of transhipment-jobs, as terminal equipment. When the ITUs request is at the top of the cranes job list, the crane tranships it either to a train (if available) or to storage.

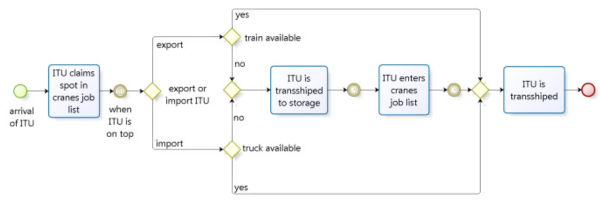

Figure 2: ITU process

In case of an import truck (picking up an ITU) the vehicle informs the terminal equipment (crane) that transhipment is now possible and requested. The next available container on the cranes job list needing pick up by a truck is now assigned to the waiting truck. In case the trucks pick-up capacity is greater than one, i.e. the vehicle needs to pick up more than one ITU, the process is repeated until the truck is loaded with the requested number of ITUs.
Import trucks may be loaded from storage or directly from trains. To include this we also model arriving trains in a very simple form. Trains arrive according to a given arrival pattern. Each train has a given number of spaces for ITUs (capacity) of which a given number are occupied by export ITUs. ITUs on arriving trains proceed as ITUs on arriving trucks, placing a request for transhipment in the job list of the terminal equipment. In a first step this list is FIFO, we do, however, also consider priority based approaches.

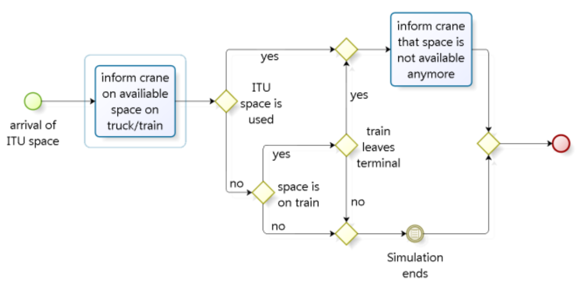

Figure 3: ITU space process (empty trucks and trains)

In accordance with the process for import trucks, empty ITU spaces on trains inform the terminal equipment that they are ready to receive ITUs which need to be transferred onto trains. In order to stop ITUs from being re-shipped to their arrival train from storage this is forbidden in the model. The terminal equipment tries to tranship ITUs from trains and trucks onto trucks or trains, depending on the vehicle type requested by the ITU. If this is not possible ITUs are transhipped to storage. Once stored ITUs are looked in storage for a given time and can only be transhipped to a vehicle after this time has passed.
Regarding the assumptions of the presented simulation, an average time is assumed for each transhipment regardless of the destination, i.e. storage, train or truck of the ITU. We further assume a given distribution of dwell times of ITUs in storage, thus, in case an ITU is not directly transhipped onto a vehicle (train or truck) it stays in storage for a given time until it is again allowed to be transhipped. The storage area itself is, in the first setting, assumed to be unlimited and ITUs are not stored according to any system. Additionally, as the presented model focusses on gate congestion by trucks, no gate processes are modelled for arriving trains, as they are assumed to be non-existent. The same approach is used for gate out processes of leaving trains or trucks.

4.3. Simulation input data

We use two kinds of input data. Input data for part 1 defines the alternative "pre-gate" regimes. These input scenarios are developed by the authors building, e.g., on the work of Gracia, González-Ramírez, and Mar-Ortiz (2016). They include variations of the number of truck waiting lanes and thus gates, the priority system and the segmentation of these lanes including the use of priority lanes, as well as the information available to the (waiting) trucks and the availability of an online booking system. Input data for part 1 also includes truck arrival patterns and the number of available transfer points, here real data from several Austrian terminals is used.
Input data for part 2 are parameters regarding the operation of the modelled terminal and the arrival of the ITUs at the terminal by train. For this input we mainly use available data from Austrian terminals, this includes average dwell times of ITUs in storage, average times for transhipment of single ITUs, arrival patterns of trains as well as numbers of and probabilities for (occupied) ITU spaces on trains, probabilities of ITUs being transhipped from rail to rail, from rail to road and from road to rail while transhipment to storage is an intermediate step in case direct transhipment is not possible. Except for the number of transfer points terminal layout is not included, this could, however, be part of future research.

4.4. Simulation Output

The performance indicator we are interested in primarily is the total dwell time of trucks from arriving at/close to the terminal until exiting the terminal depending on the "pre-gate" regime. We additionally, measure the time the trucks in the simulation model wait until they enter the terminal, and how this time is distributed between different types of trucks, i.e. export and import trucks. However, a simulation model also allows for a greater understanding of the modelled system. Thus, in line with a renowned quote by Huntington, Weyant and Sweeney (1982) the aim of the presented simulation model is also the "modelling for insights, not numbers".

5. CONCLUSION

The goal of the agent-based discrete event simulation model presented in this paper is to provide a starting point in the research of the interface between the road system and the rail-road terminal. We compare different pre-gate regimes regarding their influence on total truck dwell times as well as pre-gate waiting times at inland rail-road terminals. These dwell and waiting times present an important cost factor for carriers and thus terminal customers and are also relevant regarding resource and space management at terminals. In addition, especially pre-gate truck waiting times, which are often times when trucks are idling, present not only an economical but also an environmental burden due to the locally and globally harmful emissions produced by the vehicles engines. As this is research in progress a conclusion cannot yet be drawn. It is clear however, that, this research promises interesting results especially because the topic has been mostly neglected so far or rather the issue was researched separately; before and after the terminal gate.

Further work might focus on the extension of the presented simulation framework. It can therefore include, various additional characteristics such as differentiations between types of ITUs or between regular customers of the terminal and those arriving for the first time. In addition, terminal design could be included to a greater extend within the simulation model. Greater detail could also be added to the assignment of ITUs to vehicles and on entrance processes of trains.

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