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INFORMATION FLOW ALONG THE MARITIME TRANSPORT CHAIN – A SIMULATION BASED APPROACH TO DETERMINE IMPACTS OF ESTIMATED TIME OF ARRIVAL MESSAGES ON THE CAPACITY UTILIZATION

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ABSTRACT

Various actors are involved in hinterland transportation of incoming rail containers along the maritime transport chain. To coordinate each actor's logistics processes, and therefore to improve utilization of existing transport capacity, the early provision of information, e.g. in form of estimated time of arrival (ETA), is inevitable. The objective of this paper is to determine impacts of these information flows on capacity utilization via a simulation based approach. To simulate the effect of ETA container from vessel to hinterland transport mode rail, a system dynamic simulation model is developed based on a case study about input containers at the port of Hamburg. As result the container output on rail is compared with and without ETA for different container input volumes. It will be shown; managing provision of information in supply chains – such as maritime transport chains – is a valuable approach for increasing existing utilization.

1 INTRODUCTION

Various actors are involved in transportation of incoming containers along the maritime transport chain. In the area of hinterland transportation by rail these are especially the deep sea carrier, the terminal operator, the railway operator and the railway company. To coordinate each actor's logistics processes, and therefore to improve utilization of existing transport capacity, the early provision of information, e.g. in form of estimated time of arrival (ETA), is inevitable (Almotairi et al. 2011). A container vessel's delay entails delayed containers unloaded in the terminal and thus leads to delayed or even not transshipped ready containers on the hinterland side. This is especially relevant for the hinterland transport mode rail, as there are strictly limit time slots and schedules for clocked transportation services. The lack of ETA could result in full container storages and reshuffling of containers as well as a utilization of possible containers on rail at a lower level as possible, as containers can only be handled in an operational way without any further information. In analogy to these effects – similar to the bullwhip-effect (Forrester 1961) – production industry already implemented planning and information concepts such as advanced planning systems (APS) (Meyr et al. 2008) and supply chain management (SCM) (Rönkkö et al. 2007). Trade companies implemented concepts like efficient consumer-response (ECR) and collaborative planning, forecasting and replenishment (CPFR) to use information at the point of sale in real time for performance improvements (Christiansen et al. 2007). In all these concepts the flow of goods is directly connected with the information flow.

The heterogeneous structure in the maritime transport chain with different actors involved – each actor organized in different business models which have to be coordinated without interfering with their target self-interest (Roorda et al. 2010) – shows that the possession of information is as important as the possession of the goods itself. In topic research literature, Talley (2014) indicates further research need in maritime transport chains. Therefore, the effect of containerized ETA on capacity utilization for actors within a maritime transport chain is proofed and quantified for selected maritime transport chain actors within our paper. The effect multiplies in maritime transport chains with increasing container vessel sizes. A vessel delay consequently means delay of each unloaded container. As storage operations within terminal may capture larger amounts of containers within a certain time, the trains in hinterland mode rail are strictly scheduled in time slots. Furthermore dispatcher does not exactly know, whether the planned container will be available for transshipment on the intended wagon. If not, the wagon space will stay unused. Containerized ETA enables a better disposition of containers on the one hand, and a substitution of planned but not available containers, by a transshipment ready container, on the other. This problem increases on container vessel size, as nowadays modern container vessels can carry more than twice as much container as the generations before. The berthing window for unloading and loading these vessels extends from 24 to 72 hours, and unloading is not prioritized.

The objective of this paper is to determine impacts of the information flow – especially containerized ETA – on the utilization of overall existing capacity of the maritime transport chain actors. Therefore, a simulation based system dynamic approach is used. Focus is set to the hinterland transport mode rail and variation of import container volumes. We use a case study within the maritime transport chain including the rail-bound import containers of the automated container terminal in port of Hamburg. The remainder is structured as follows: First an overview of simulation in container terminals is given in form of a literature review. Then the case study in the maritime transport chain with the derived real data including measures and distributions of containers for further system dynamic simulation will be presented. Finally the experimental results of simulation with and without ETA effect for different container volumes will be discussed.

2 MARITIME TRANSPORT CHAIN IN A SYSTEM DYNAMICS SIMULATION MODEL

2.1 Simulation in Container Terminals

For positioning of our paper within current research, we followed the literature review on maritime transport by Ng et al. (2013). We conducted an additional literature review for understanding history in simulation approaches on maritime transport chains. Papers within our review must connect to the context of maritime transport chain. Focus was set to papers in international journals with more than five publications within the selected focus (Ng et al. 2013). The selected papers represent the most important approaches within identified papers. Papers from operations research and reviews were explicitly allowed. Additional papers from conferences were added, if suitable, to support understanding of historical development in research within the last ten years. It is shown; system dynamics is a novelty in maritime transport – and in maritime transport chains. Literature review furthermore shows, topic simulation with focus on maritime transport chain perspective concentrates on the nodes of maritime transport chains instead of the transport chain itself. A strong impact on operations research could be identified. The used system dynamic approach helps to understand maritime transport chain overarching effects by combining actors in a maritime transport chain. The endogenous effects within this system would be exogenous effects in a singular viewpoint of e.g. a container terminal within a seaport. Thus feedback mechanisms relating to early provision of information can be understood when maritime transport chain is considered.

Simulation models concerning container transport or transshipment in literature are often depending on the pure examination of transshipment capacities or operative reshuffling, and storage of containers within the sea port terminal itself. Thus, the interorganizational processes in the maritime transportation chain are not considered. Table 1 shows the literature review with focus on simulation and management in container terminals. Literature is concentrating on the development of better operative algorithms for e.g. gantry cranes (e.g. Petering et al. 2009, Choe et al. 2013), storage (e.g. Vis 2006; Van Asperen et al. 2013), automated guided vehicles and trucks (e.g. Petering 2009). Acciaro and McKinnon (2013) pronounce the importance of understanding the whole container supply chain – which the authors understand as maritime transport chain (Talley 2014). Furthermore, data is usually given by existing values based on literature or data generators for simulations.

Table 1: Literature review on container terminal simulation with maritime focus

Author (Year)	Focus	Problem	Solution
Steenken et al (2004).	Operations	Classification of logistics processes, operations and optimization	Literature Review and recommendation for further research
Murty et al. (2005)	Operations	Decision support system for minimizing the berthing time of vessels, resources needed for handling the workload, waiting time of customer trucks, road congestion and storage utilization	Decision support models and algorithms
Jung and Kim (2006)	Operations	Loading scheduling methods of yard crane	Numerical experiment performance comparison of used algorithms
Vis (2006)	Storage	Performance of straddle carriers and automated stacking cranes	Simulation study
Froyland et al. (2007)	Landside operations	Container exchange with multiple RMG	Three stage integer programming-based heuristic
Chen et al. (2007)	Operations	Coordination of terminal equipment	Mixed-integer programming model
Stahlbock and Voß (2007)	Operations	Current state of the art in terminal operations	Literature Review
Han et al. (2008)	Storage	Traffic congestion especially in major transshipment hubs with focus on export containers	Tool based on model for storing export and transshipment containers
Petering et al. (2009)	Storage	Real-time yard crane control	Experiments based on algorithms for stacks, cranes and trucks
Wan et al. (2009)	Storage	Minimizing reshuffles in container yard	Integer program for optimum reshuffle sequence
Meisel and Wichmann (2009)	Operations	Internal reshuffling of containers on vessel	Optimization model and greedy randomized adaptive search procedure (GRASP)
Petering (2009)	Operations	Yard truck control system and dynamical vehicle routing	Discrete event simulation and experiments using multiple 3-week simulation runs
Petering and Murty (2009)	Storage	Length of storage blocks and controlling yard cranes among blocks in the same zone	Discrete event simulation and experiments varying block length for crane rates
Lee and Kim (2009)	Storage	Parallel and vertical arranged layout of storage blocks	Numerical experiment for determination of optimal number of bays in blocks
Park et al. (2010)	Storage	Stacking locations of containers in yard	Multi-objective evolutionary algorithm (MOEA) for the containers in the stacking yard of an automated container terminal
Petering (2010)	Management	Strategic and tactical management	Discrete event simulation model of non-automated container terminal
Park et al. (2011)	Storage	Container stacking policies for incoming containers in automated terminals	Online search algorithm, dynamic policy adjustment (DPA)
Sun et al. (2011)	Simulation platform	General simulation platform for terminals	MicroPort simulation tool including different software layers using multi-agent system
Clausen and Kaffka (2012)	Operations	Improvement of crane control strategies	Shortest path calculation
Jang et al. (2012)	Storage	Computational costs in simulation and noisy evaluation for deriving stacking policies	Noise-tolerant genetic algorithm (NTGA) for policy for container stacking at an automated container terminal
Petering (2013)	Storage	Real-time selection of storage location in yard for export containers	Discrete event simulation and scenario building
Rashidi and Tsang (2013)	Operations	Modeling of decisions and scheduling	Literature review for evaluation of Constraint Satisfaction and Optimization Problem (CSOP)
Acciaro and McKinnon (2013)	Hinterland service	State of the art hinterland transport management	Literature review
Choe et al. (2013)	Storage	Remarshalling of containers and automated stacking cranes	Comparison of different remarshalling schedules
Van Asperen et al. (2013)	Storage	Container stacking rules and truck anouncement for expected import container departure time for pre-emptive remarshaling	Stacking algorithms
Exposito-Izquierdo et al. (2013)	Integrated problems	Integrated approaches for interrelated terminal problems	Literature review

Additional container based information, e.g. departure time, is not always improving stacking algorithm itself (Van Asperen et al. 2013). Here, more real context is claimed to be researched (Expósito-Izquierdo et al. 2013). However, categorization of containers as basic information is seen a good influencing factor for e.g. reshuffling (Dekker et al. 2006). This paper contributes to the lack of missing real data by involving real actors' operational container data as an interconnected data set on container ID level. Furthermore improvement of rail-bound container operations and disposition based on these data is complemented by additional information in form of a containerized ETA and evaluated on an abstract level.

2.2 Case Study of port of Hamburg in maritime transport chain

The port of Hamburg is selected for two main reasons. First, this port belongs to those ports that are historically based in urbanized areas. Therefore, its capacity is not expendable due to shortages in space with the consequence that utilization of capacity is particularly important (Cullinane and Wilmsmeier 2011). Second, the port of Hamburg is part of the Le Havre – Hamburg Northrange and its hinterland connection by rail is important location factors for German and European economies. Our investigation covers all relevant transportation and information processes as well as interfaces between a deep sea carrier, a terminal operator, a railway operator and a railway company in the case of the port of Hamburg (Yin, 2009). In expert interviews with representatives of each actor, the business processes and respective data for rail-bound import containers were gathered. Within round-table discussions and workshops with all actors, the container and information flow was brought together in one business model. Here, relevant measuring scales for process performance were derived, too. Plausibility of results was again discussed in following workshops. With this research design result – for the first time – a complete process containing information flow between the involved actors in maritime transport chain is depicted. It contains all processes from vessel to hinterland including transshipment, warehousing and on-going railway transport until leaving the terminal boundaries. Interviews and process modelling lead to over one hundred activities for a total number of four container movements as depicted in Figure 1: from ship to land, warehousing, swapping from warehouse to rail side and transshipment of the container to railway wagon.

The data implicates e.g. container dwell time on terminal area, restacking rate and utilization of trains. Container dwell time on terminal area and restacking rate of containers are used to determine non-productive processes on terminal area. This means that a lower container dwell time on terminal area causes a higher flow rate of containers and therefore a better utilization of existing terminal capacity. A decreasing restacking rate of containers causes an increasing fraction of removals from block storage yard per yard crane move, which is providing clear evidence that existing crane capacity can be used more efficiently. The higher the utilization of trains, the higher the utilization of existing railway tracks, which causes an improved utilization of existing capacity of the railway company.

By comparison of the status quo within a process analysis, together with the actors it was derived, that an ETA of the vessel is not sufficient enough for hinterland disposition and transportation orders. Moreover the exact notification when the specific container, which is on the arriving vessel, will be ready for hinterland transportation is needed. The ETA of containers (containerized ETA) touching the sea port's quay represents the minimum useful ETA. Within the case study, the bi-lateral provision of this container specific information was established as technical improvement regarding to economical expenses.

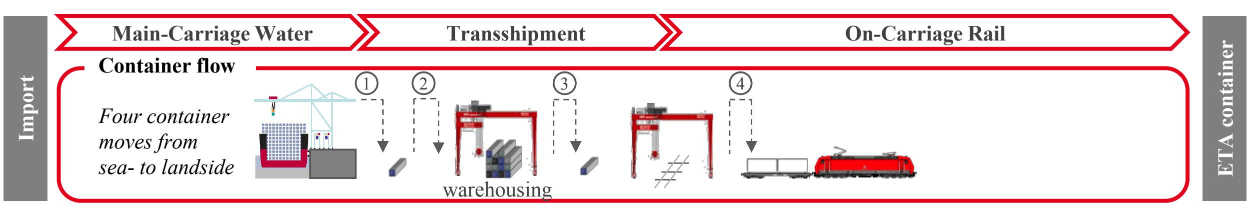

Figure 1: Import direction of maritime transport chain for hinterland transport mode rail.

2.3 System Dynamic Modeling

System Dynamics is an approach to understand complex processes and Systems including feedback loops (Hussain and Drake 2011; Forrester 1958 and 1961). The modelling and simulation techniques were developed by Forrester (1958) within his book Industrial Dynamics and further developed (Forrester 1961; Schieritz and Milling 2003; Borshchev 2013). Forrester (1961) illustrates the bullwhip-effect which bears his name by modelling this supply chain. He modelled and analyzed a four-tiered supply chain including interacting information flows, money, orders, materials, personnel, and capital equipment (Forrester 1961). In System Dynamics concepts of servo-mechanisms and social science are combined (Richardson 1991; Richardson 2011). This is used to understand dynamic behavior of information feedback and delays within industry (Vennix 1996; Angerhofer and Angelides 2000). Experiments and simulations help to understand system structures with non-linear relations (Angerhofer and Angelides 2000, Richardson and Pugh 1981). From mathematical perspective stock variables are integrations of their depending flow variable. Here, net flow is the rate of change for the stock variable between initial time t_0 and current time t (Forrester 1961; Sterman 2000; Teimoury et al. 2013).

Schieritz and Milling (2003) are separating the characteristics from agent-based simulation by basic building block, unit of analysis, level of modeling, perspective, adaption, handling of time, mathematical formulation, and origin of dynamics. In applying these criteria, in this paper the simulation problem can be clearly assigned to system dynamics. Not containers or the sea port are modelled as individual agents, but the macroscopic structure of container import in the maritime transport chain is combined with additional ETA information. In order to build a realistic simulation model and to determine impacts on containerized ETA messages on utilization of existing capacity, a system dynamic simulation model was developed. It was combined with real actors' data distributions for two periods, with and without the establishment of bi-lateral early provision of information in form of ETA of import rail containers. Both periods cover data for ninety days and were confirmed as representative and sufficient by the actors' experts.

The individual data was gathered from the involved actors to create parameters and distribution functions. To be able to connect the operational data of one actor with the others' each dataset is supplemented with container ID and a timestamp. The data for building the parameters include planned vessel arrivals (days and daytime), ETA of vessels (days and daytime), ETA of containers (days and daytime), transshipment (day and daytime), storage utilization, multiple restacking (day and daytime), multiple transport orders per container (day and daytime), traffic days for hinterland transshipment, trains, train-types, train utilization, as well as gate-out day and daytime. The distribution functions were built by frequency and time of occurrence of individual container-based data. Building categories, such as hour or day, the frequencies were accumulated.

The used simulation software had to be able to combine system dynamics simulations with an event management system, including libraries and allowing manual programming. Here 19 simulation tools were identified: Analytica, AnyLogic, Consideo, DYNAMO, Forio Simulations, Insight Maker, JDynSim, MapleSim, NetLogo, OptiSim, Powersim Studio, Pyndamics, Simantics System Dynamics, Simile, Sphinx SD Tools, Stella iThink, Sysdea, Vensim and VisSim. Next to conditional programming, a continuous time system with support of distribution functions, a discrete event management and the possibility for sensitivity analysis and monte carlo experiments was required for simulation. Covering all of these requirements, the software multi-method tool AnyLogic 6.9.0 (AnyLogic 2013) was used for simulation (Ivanov et al. 2010; Brailsford et al. 2013; Borshchev 2014). The data, which are used by the simulation model, are real-world data of each actor and contains the import container flow for hinterland transportation by rail.

The basic simulation framework is based on table functions representing a data set, linked on container ID level. The data set connects the container import data of the involved actors with referential integrity within a database system for the two different periods – with and without early provision of information in form of containers' ETA. The first period represents data from September to November 2012 and the second from January to March 2013. All involved experts from deep sea carrier, the terminal operator, the railway operator and the railway company confirmed the data of both representative periods in round-table discussions. The involved amount of containers by deep sea carriers was 13,656 import containers for the rail operator. On terminal side 74,293 containers with 271 storage specific datasets were added. On rail-side the operator data contained 55,275 containers on 866 trains as well as 113,340 order data. In total 261,361 data tuples represent the transformation of actor specific data sets into a database with referential integrity. Here, structured query language and a logic check within the database system for connected data sets were used to prevent inconsistency or double values. Computational time for generating the connected data set was 92.7 seconds using a four core intelCore i5 vPro processor on a 64bit system. As result 788 cross-actors interorganizational data sets were computed. In a further logic check this was reduced to a total of 597 suitable datasets for both simulation periods.

Based on this step the container based distribution function was built and adjusted to simulation time and a total probability of occurrence of 1.0. A further deductive evaluation of the data led to outlier stable triangular representation of the functions by using interquartile range. The three values first quartile (Q1), median (M), and third quartile (Q3) represent the middle fifty percent of all containers. Within triangular representation of the container based distribution functions, Q1 is the left and Q3 the right ends of triangular function. The median M represents the top value. This function now can be used for simulation of a general period with and without ETA container by randomized function access at each simulation run as depicted in Figure 2.

For verification and validation of the simulation model two methods were used. First, six iterative steps from problem to the improved model by Forrester (1994) and steps for successful dynamic modelling by Sterman (2000) were passed through. Second, before, within and after these steps, face-validity with experts from involved actors and simulation expert of the terminal was conducted in round-table discussions. We used this validation and verification procedure following the concerns of Sterman (2000, p. 846). Due to simplification of the reality within models, Sterman (2000, p. 890) argues, the purpose of a model is used for, has to be clearly understood.

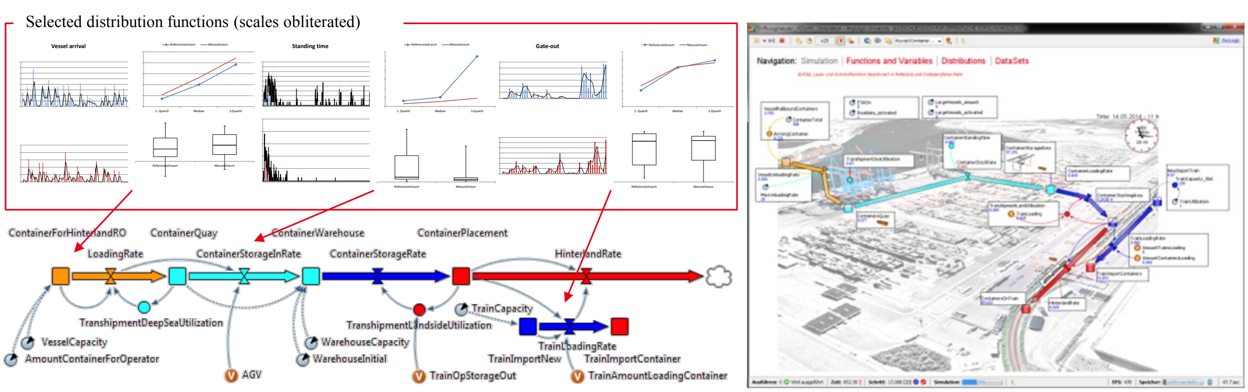

Figure 2: Basic simulation model using System Dynamics (bottom left) with a selection of interpolated distribution functions (top left) and illustration of final simulation view (right).

3 EXPERIMENTS BY SIMULATION

3.1 Simulation Cockpit

Simulation parameters are adjusted by a central cockpit and will by passed to the system dynamic simulation itself. To determine impacts of information flows on utilization of existing capacity main parameter of our simulation model is ETA and can be set to 0 (ETA_{Off}) or 1 (ETA_{On}). This allows to set the influence of ETA on container dwell time on terminal area, restacking rate of containers, train processing time, and utilization of trains and therefore on utilization of existing capacity. The possible parameter settings are depicted in Table 2. As a maximum total input container the amount of deep sea shipper import rail containers from real actor's data for both periods is used for a more lifelike discussion. For a restriction of the system dynamic model the transshipment on the seaside can be varied. On the hinterland side transshipment on rail is limited by a maximum amount of trains with a maximum amount of container spaces on the wagons.

The discrete parameters are influencing the continuous behavior on simulation time of the system. This leads to continuous feedbacks. Hence, multiple experimental runs using the same simulation parameters within a monte-carlo experiment are leading to different outputs (Vis and de Koster 2003). The results of the multiple runs then can be compared in a sensitivity analysis for deriving whether ETA container has an effect on input container volumes and the hinterland output on rail.

Table 2: Parameter settings of system dynamic simulation.

Parameter	Type	Minimum	Maximum	Step
ETA enabled	discrete	0	1	1
Total input containers	discrete	1	14,000	250
Transshipment seaside	discrete	1	350	1
Maximal amount trains in rail slot	discrete	1	12	1
Maximum amount container space on train	discrete	1	70	1

3.2 Experimental results

The experiment is conducted as follows: For both periods with and without containerized ETA information one experiment is run. Each with experiment has five simulation runs containing ascending container input volumes. The output of containers on train in relation to the varying input of import containers will be saved in a two-dimensional array at the end of each simulation run. Each simulation run within the experiment represents a period of ninety days. The runs are executed without further variation of other parameters. As experiments shall represent a general time period, the triangular representation of real distributions are used. Each experiment runs multiple simulations with increasing container input amounts. For statistically robust results, monte carlo is used for a five time replication of all simulation runs (Stahlbock and Voß 2007). Additional computational time is only justified if reduction of variance is given (van Asperen et al. 2013). Multiple reproductions of simulation runs with same input parameters are conducted. The input and output volumes are compared. Thus, sensitivity of the model, relating to the parameters and the interpolated triangular distributions in behind, can be analyzed (Vis 2006). Sensitivity analysis compares the parameters and their trustworthy influence on the model output and their standard deviations for both ETA_{Off} and ETA_{On}. Each simulation of five replication runs for 28 different input container amounts, which equals a total of 140 simulation runs per experiment, lasts about 1,940 seconds. An unpaired t-test is used to analyze, whether a significant difference of the aggregated means of monte carlo replications exists – with and without the early provision of information in form of ETA. As shown in Table 3, the mean results are tested using an unpaired t-test with 95 percent confidence intervals of the means. The results support a significant effect of ETA_{On}.

The mean values by monte carlo indicate, the output is depending on the input and the feedback of capacity restrictions. An increase of container volume does not lead to an improved output of the system. The results without containerized ETA are constantly on a lower level and oscillate around 57.91 percent of input containers. When containerized ETA is established by early provision of information, the oscillation of values increases, but the mean level raises on 77.37 percent. This significant change means on an input of 14,000 containers, that 10,831 instead of 8,107 are transshipped into hinterland. A train usually carries about 66 containers in hinterland, thus, virtually summed up 164 instead of 122 trains are fully loaded within the same time period using the same infrastructures and capacities.

Table 3: Unpaired two-tailed t-test results.

N=28	Mean	Standard deviation	Standard error of the mean	Degrees of freedom	Standard error of difference	T-test	Significance
ETA_{Off}	0.5791	0.0386	0.0070	54	0.015	t(0.95, 54) = 12.7696	t > 3.29, p < 0.001 ***
ETA_{On}	0.7737	0.0708	0.0133				

Leveraging effects within the model are already included within the distributions. So limiting factors for transshipment can be varied to compare different additional ETA effects. Within this paper two additional ETA effects will be introduced as experimental setup. First, in strategy 1 ETA will be enhanced by the knowledge about more containers' ETA for disposition on trains. The larger the amount of containers is the more dispositions of wagons on train with ETA containers are possible. Second, in strategy 2 the availability of other surrogating ETA containers is tested, by an additional stock. This stock has a certain amount of ETA containers, which can be used instead of a planned container, if the planned container is not ready for loading on a train wagon on traffic day. The rail operator's experts confirmed, this leads to less unused container spaces on the wagon, because usually disposition on rail side is not capable to plan short-term replacement if no ETA container is available and the wagon keeps unused. When considering the simulation model, it becomes clear that the intermodal operator has two additional strategies for his disposition of containers. First, the intermodal operator may have information about more containers of different carriers. The intermodal operator might then use all information for containers for his disposition. But here the problem of containers, which are not ready for transshipment still prevails (strategy 1). To solve this problem, the intermodal operator might use a second strategy, as information about ETA can be combined with information about containers ready for transshipment. If now a planned container is not available, an already available container will be used for transshipment. This virtually creates a second stock and increases capacity utilization of the train (strategy 2). Of course to achieve this second strategy the intermodal operator has to change his hinterland disposition of containers, too, which is not part of this simulation and will be assumed.

Figure 3 shows the utilization of hinterland mode rail for the different import container volumes adjusted to the provided amount of rail-bound containers by the deep sea shipper for a more realistic view. The other parameters were set on a the upper levels to show the potential of ETA, as e.g. a vessel or train may always appear at the end of the simulation period for a container volume and would not completely influence the output. The measure for utilization of hinterland transport mode rail is used, as the given distributions are based on a consistent data set. Within the experiments, now an interconnected transport chain and their input-related output behavior can be analyzed. This enriches multiple single problems designs.

It is proofed, if early provision of information in form of ETA_{On} is enabled, especially for smaller input container volumes within a period the output is stabilized on a higher level than for ETA_{Off}. On increasing container volumes restrictions in terminal and hinterland are triggering. The ETA container effect is not increasing on higher container amounts. The effect shifts the bottleneck from the terminal transshipment on the sea side and yard storage operations to the hinterland transportation mode rail. This means a further increase of output containers is now possible, e.g. by an increased amount of trains. These trains could now transport containers to other landside terminals, such as dry port or extended gate concepts – for capabilities of these concepts, e.g. see Roso et al. (2008). In practice indirect connections via another marshalling yard, or direct shuttle train connections into the hinterland would be used more extensively.

The results connect to the research of Sun et al. (2012) by establishing a general simulation based on case study data. Instead of detailed simulations, as used by e.g. Petering (2010, 2011 and 2013), in the experimental setup the positive effect of an additional information – here in form of containerized ETA – instead to van Asperen et al. (2013) could be determined. The paper supports the topic research by including maritime transport chain information on containerized ETA with real actors' data on a general level.

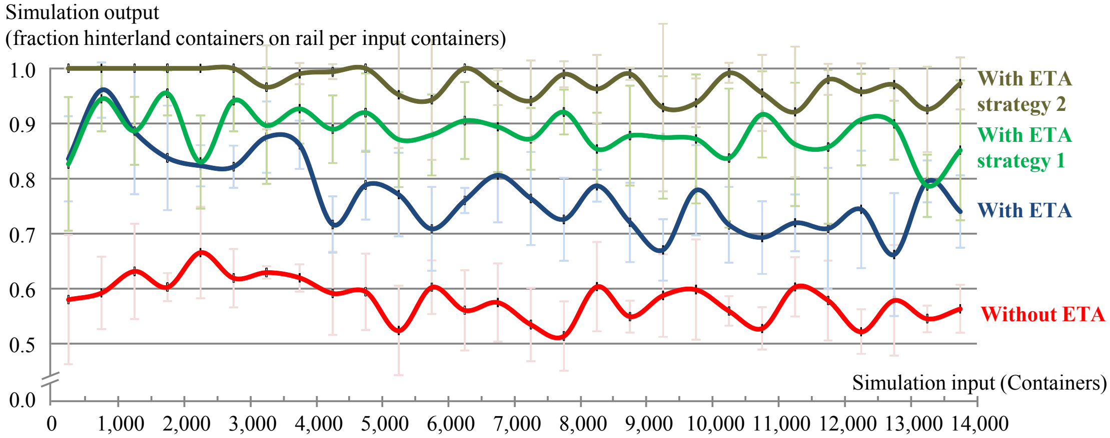

Figure 3: Sensitivity analysis with means and standard deviations of monte carlo simulation output with triangular distributions for high use of existing transshipment capacities and ETA optimizations.

4 CONCLUSION

Infra- and supra-structure cannot be easily changed in developed ports, such as the port of Hamburg. The paper presents the first research findings of our comprehensive simulation approach to determine impacts of containerized ETA on utilization of existing capacity of import containers for hinterland transportation mode rail in the maritime transport chain on an abstract level. For simulation a system dynamic approach, including deep sea shippers, sea-port terminal, hinterland rail operator, and railway company combined with real actors' operational container handling distributions, was built. We proofed the positive effect of early provision of containerized ETA and potential for an even higher output in maritime transport chain. In consequence with the increased utilization of train capacity, rail infrastructure utilization is increased, too. We proofed, managing early provision of information in maritime transport chains is a valuable approach for increasing existing utilization especially in volatile times. Deep sea shippers can now fulfill container transport with hinterland mode rail more reliable for their customers' needs. Terminals may decrease their reshuffling times per container and the time for loading trains. Hinterland railway operators profit most. They now can adjust their disposition strategies with increased containerized information. Furthermore they perform higher utilization of containers per train, by e.g. changing the transport order for containers. If an ETA container will not be in time for transshipment, this effect increases.

The simulation model and its output are not without limitations. First container terminals and the disposition of containers is complex and in the case study only bi-lateral communication was established for the selected actors. The real actors' data only cover a part of the total container volume in Hamburg. Furthermore it is not possible to factor out global economic changes during data gaining. The used restrictions are on a high abstraction level and do not include special events, such as accidents, weather or customs.

System dynamics enables a general overview especially capacity shifts in transport chains without going into details. A memory for the continuous streams is missing. Here – for further research – agent-based modelling should be concerned to capture complete container based information set. This set should including movements and delays on vessel, terminal as well as rail and combine it with the specific order data. Next to interrelating effects and tracking of containers, it then is possible to characterize more precisely the effect of an additional provision of early container information in further research on maritime transport chain for the involved actors at different points in time. A combination of system dynamic and agent-based modeling in an intermediate step and even in a final simulation should be considered, too, as this enables the researcher to combine the strengths of both simulation techniques. Based on our paper further research should examine routines and governance structures for establishing containerized ETA throughout maritime transport chains (Talley 2014). By including complete maritime hinterland and export directions, the effect of ETA on capacity utilization of restricted hinterland infrastructure should be determined closer.

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