Proceedings of the 2017 Winter Simulation Conference
W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, eds.

SIMULATION OF THE ORDER PROCESS IN MARITIME HINTERLAND TRANSPORTATION: THE IMPACT OF ORDER RELEASE TIMES

Ralf Elbert
Katrin Scharf
Daniel Reinhardt

Chair of Management and Logistics
Technische Universität Darmstadt
Hochschulstraße 1
Darmstadt, D-64289 Darmstadt, GERMANY

ABSTRACT

The integration of information systems between the various actors organizing and executing the transport of containers to seaports is slowly progressing. Transport orders are frequently characterized by high change rates causing high manual revision effort for dispatchers. Therefore, these order changes, often received shortly before the day of departure, raise the question regarding the immediate transmission of transport orders to the subsequent actors in the transport chain. This paper analyzes the impact of different order release times, which define the timing of order transmission, on order process efficiency (processing times and costs) using a multi-method simulation approach. In a case study, four actors, two focusing on transport planning and two on operative transport execution, are considered. The simulation experiments with varying order release times and change rates reveal: A late release of orders from planning to operative actors and a reduction of order changes can significantly increase order process efficiency.

1 INTRODUCTION

Maritime transportation is the backbone of the worldwide economic development with a share of over 80 % of global trade volume (Lam 2011). Over the last two decades (except in 2009) the global demand, especially for containerized transport, expanded continuously with yearly growth rates above 2 % (UNCTAD 2016). Therefore, the maritime transport chain (MTC) is a vital part of global supply networks over which actors, e.g., carriers, forwarders, and other logistics service providers, offer services for the movement of freight (Talley and Ng 2013).

The involvement of multiple actors planning and executing container transports in the MTC leads to a highly heterogeneous and fragmented structure making inter-organizational coordination challenging (Roorda et al. 2010). From a technical perspective, these challenges are addressed by the steady improvement of information and communication technology (ICT). By enhancing digital information exchange manual effort (caused by information exchange via e-mail, fax, or phone) can be reduced (Giannopoulos 2004). Additionally, real-time information technologies (e.g., tracking and tracing via GPS) offer opportunities to streamline intra- and inter-organizational processes (Harris, Wang, and Wang 2015). Thus, on the one hand ICT enables actors to differentiate in the competitive transport market (Khalid et al. 2007). On the other hand further standardization and open access to relevant information challenges established routines and services making actors more interchangeable (Inkinen, Tapaninen, and Pulli 2009). Hence, the high number of interfaces along with the risk of being interchangeable might explain the slow penetration of ICT within the transport sector. Especially the maritime sector is lagging behind and thus a great potential to improve process efficiency exists (Tapaninen, Ojala, and Menachof 2010; Almotairi et al. 2011).

Recently, the hinterland has become a focus of maritime research because hinterland transportation costs account for 40 to 80 % of total shipping costs (Notteboom 2008) and the increase of port throughput is highly dependent on efficient hinterland connections (Van Der Horst and De Lange 2008). Due to the increasing demand for container transports not only efficient operative transport processes (material flow) are necessary (Ruiz-Aguilar et al. 2016). An efficient information flow is also required to deal with the increasing demand and complexity of the transport operations (Perego, Perotti, and Mangiaracina 2011).

Orders are the basis of the information flow in logistics systems and are hereby defined as container transport requests from the shipper which can be an industrial or retail company or a logistics service provider itself. Nowadays, orders are usually transmitted via electronic data interchange (EDI) between actors, but when it comes to small actors or order changes, information is often still sent via e-mail, fax, or by phone (Saldanha 2006; Inkinen, Tapaninen, and Pulli 2009; Almotairi et al. 2011). This leads to high manual effort for dispatchers, who plan and coordinate the transport related activities based on order information and corresponding order changes. Order changes hereby comprise all relevant modifications of an order caused and transmitted by the shipper between the day of order placement and the day of departure. High rates of order changes can be explained by the competitive character of the maritime transport chain. Hence, shippers are usually not penalized (e.g., rebooking fees) for frequent order adjustments and thus have no obligation to fulfill the original order. These change rates and the corresponding high revision effort for dispatchers raise the question, if orders should be immediately transmitted to the following actors in the transport chain. In case order transmission is postponed, order changes only have to be incorporated into the original order by the actors at the beginning of the transport chain. Hence, manual effort for succeeding actors in the chain can be reduced. However, if orders are transmitted too late, there might not be sufficient time to coordinate the corresponding transport activities.

Despite the high relevance, the challenges of the order and change processes as well as the potential to improve process efficiency in terms of processing times and costs are not sufficiently analyzed in research. Although the advantages of ICT for managing information across company boundaries are acknowledged (Li et al. 2006), the appropriate timing of information exchange between actors considering the high degree of order changes remains untapped. To address this research gap the concept of order review and release (ORR) dealing with the identification of an order review point and the corresponding order release times between planning and operative systems (e.g., Bergamaschi et al. 1997; Lu, Huang, and Yang 2011) is applied for maritime hinterland transportation. In other words, when is order information reliable enough meaning that most order changes are incorporated into the original order before orders should be transmitted to the operative actors? Therefore, the first research question investigates the proper timing of order transmission between planning and operative actors to improve order process efficiency in terms of reduced processing times and costs per order. Additionally, the suitable timing with regard to process efficiency might be dependent on the magnitude of order changes. Hence, the second research question addresses the impact of a reduced order change rate.

RQ1 What is the impact of different order release times on the process efficiency of the individual actors and the transport chain in total?

RQ2 What is the impact of a reduced order change rate on the process efficiency of the individual actors and the transport chain in total?

These research questions are analyzed based on simulation modeling. It allows to incorporate the dynamic and stochastic nature of the order and change processes as well as their interdependencies. Additionally, simulation modeling can be used to quantify the impact of different process designs (order release times). The simulation model is applied in a case study of an export-oriented container transport chain in Germany. In the case study the order and change processes of four actors, two focusing on transport planning and two on operative transport execution, are considered.

The remainder of this paper is structured as follows. In the next section the research background regarding the MTC and the integration of ICT as well as the concept of ORR are briefly reviewed. The developed simulation model is presented in section 3. In section 4 the case study is introduced giving an overview of the generated input data, the conducted simulation experiments, and the corresponding numerical results. Subsequently the paper ends with conclusions.

2 RESEARCH BACKGROUND

2.1 Maritime Transport Chain

In general, the MTC can be separated into pre-, main-, and on-carriage. In the main-carriage containers are moved from an origin to a destination seaport terminal by container vessels, whereas the hinterland transport consists of pre-carriage (from the shipper to the origin seaport terminal) and on-carriage (from the destination seaport terminal to the receiver of the goods) (Elbert and Walter 2010). The pre-carriage considering an intermodal transport is usually carried out by road and rail or road and barge. The container transport starts at the day of departure at the shipper's site with the provision of a loaded container. Loaded containers are usually transported by truck to the hinterland terminal. From the hinterland terminal containers are transported by rail or barge towards the seaport terminal. At the seaport terminal, containers are transshipped onto the planned container vessel. Furthermore, merchant's and carrier's haulage can be differentiated. In the merchant's haulage the shipper instructs a freight forwarder to coordinate and negotiate all terms of sea and hinterland transport, whereas in the carrier's haulage the deep sea carrier receives orders directly from the shipper and provides a door-to-door transport service on behalf of the shipper (Lam 2011; UIC 2012). In this case the deep sea carrier is not only in charge of the oversea transport but also coordinates the hinterland transport. For the hinterland usually an intermodal operator plans and assigns transport requests to hinterland transport capacities. Additional logistics service providers related to the transport execution are e.g., agencies monitoring the road transport and rail transport companies responsible for rail haulage as well as other actors (e.g., terminal or barge operators), which are not focused in this investigation.

2.2 ICT in the Maritime Transport Chain

Over the past two decades, ICT systems have experienced a vast development to further improve information flows in transport chains (Giannopoulos 2004; Perego, Perotti, and Mangiaracina 2011; Harris, Wang, and Wang 2015). Key applications include intra- and inter-organizational ICT systems like enterprise resource planning (ERP) systems and EDI, online freight information and booking systems, integrated route planning systems, or Internet-based portals (Giannopoulos 2004; Alt, Gizanis, and Legner 2005; Inkinen, Tapaninen, and Pulli 2009; Almotairi et al. 2011). Giannopoulos (2004) highlights that some of these ICT applications enable 30 % reduction of delays due to fewer mistakes in order processing. Additionally, Corsi and Boyson (2003) conclude that real-time information exchange using an inter-organizational platform can result in reduced inventories, lower lead and cycle times, fewer mistakes in orders, and better resource utilization across actors. According to Dovbischuk (2016) the positive economic impact of ICT with regard to time and cost reduction has been thoroughly investigated on a qualitative basis, but quantitative analyses based on empirical numbers using mathematical or simulation models are scarce. Research agrees that ICT-based transport operations have a major influence on costs, facilitate transport processes, and serve as a significant source of competitive advantage (Wong, Lai, and Ngai 2009). Additionally, Almotairi et al. (2011) emphasize the importance of inter-organizational ICT for maritime hinterland transportation to increase the efficiency of transport operations and to offer improved services. As mentioned before, transport orders are prone to late incoming updates and all kinds of modifications, e.g., due to production delays. It has to be mentioned that ICT cannot completely replace manual effort for dispatchers due to the complexity and interdependencies of order changes (Saldanha 2006). Hence, the design of the order process must account for the high number of changes.

2.3 Order Review and Release

The concept of order review and release in general deals with definition of suitable release times of orders between planning and operative systems (Melnyk, Ragatz, and Fredendall 1991; Bergamaschi et al. 1997; Lu, Huang, and Yang 2011). For manufacturing systems, production orders arriving continuously are backlogged and released according to a predefined ORR mechanism to the shop floor. ORR mechanisms can be separated in load limited and time phased methodologies (Bergamaschi et al. 1997). While load limited approaches consider distinctive features of the orders and the workload in the shop floor, time phased order approaches calculate a release time for each order which is independent of the workload in the shop floor at that time (Bergamaschi et al. 1997).

This concept is used to ensure that orders are processed and transferred to the shop floor according to their individual due dates. There are mainly two general advantages of applying ORR mechanisms (Lu, Huang, and Yang 2011): On the one hand, by keeping production orders with due dates far away from the present time in the backlog pool and releasing them at an appropriate time, earlier completion and thus finished stock inventory can be reduced. On the other hand, appropriate ORR mechanisms can control the work-in-process inventory to allow predictable lead times.

In this paper, this concept is transferred to the context of maritime hinterland transport chains. According to the manufacturing systems, the order review point is located between the planning and operative actors in the chain. While for manufacturing systems, the advantage of introducing an ORR mechanism refers to efficiency gains in the material flow (lower inventory levels and predictable lead times), the advantage regarding the investigated transport chain results from an improved information flow. High order change rates cause high revision effort for dispatchers in the chain and thus the backlog and controlled release of orders can be beneficial to increase process efficiency by reducing processing times of the dispatchers in the MTC. However, releasing the orders too late for processing to the operative actors can result in transport delays. Hence, an appropriate timing has to be found for the release of orders between planning and operative actors in the chain.

3 SIMULATION MODEL

3.1 Simulation Model Development

The simulation model focuses on the pre-carriage of a MTC in a carrier's haulage in Germany, which comprises the largest share of export containers. For this configuration, the shipper assigns the orders to a deep sea carrier. Besides the deep sea carrier, an intermodal operator is responsible for the transport planning. Relevant actors for the execution of the transport order are in this case an intermodal agency as well as a rail transport company. Orders and order changes are sent from one actor to another handled by the dispatchers of each actor. The order and change processes (in accordance to Croxton 2003; Lambert, Garcia-Dastugue, and Croxton 2005) are derived from the literature and validated with experts from the actors. To consider actors with a high joint order volume, a highly frequented hinterland relation in Germany from the Rhine-Main region through Frankfurt to the seaport of Hamburg is selected. The relevant shippers for this relation are located in the Rhine-Main region. Containers are transshipped at the hinterland terminal in Frankfurt which is the central transshipment point for intermodal traffic in the Rhine-Main region. The transport continues towards the seaport of Hamburg which is the third largest container seaport in Europe and under the top 20 worldwide (UNCTAD 2016). The considered deep sea carrier is under the top five of the worldwide largest liner shipping companies in terms of market share (UNCTAD 2016). The intermodal operator with the contracted agency is one of the leading actors providing intermodal transport services and the rail transport company has the highest market share in Germany.

The process mappings and validation procedure was conducted in focus workshops on management level and semi-structured expert interviews with the dispatchers on operating level. In total, three focus workshops on management level (senior process and business development managers/head of operations) were conducted. The managers' knowledge of the overall process was valuable to validate the plausibility of the process mappings (conceptual model) and the implementation in the computer-based model. In the first focus workshop the specifications of the order and change processes of the MTC were reviewed. Within the second focus workshop the gathered data from the expert interviews and the conceptual model were validated. In the third workshop a structured walk-through of the computer-based model was performed to ensure model credibility and the plausibility of the simulation output was checked.

The interviews with the dispatchers on operating level were used to fix parameter values and to collect input data for the model. The dispatchers are the knowledge owners executing the order and change processes on a daily basis. Therefore, these experts can give reliable assessments of working efforts (processing times and magnitude of order changes). The data gathering took place between the first and the second focus workshop. The semi-structured expert interviews with at least one dispatcher of each actor were recorded and transcribed. The resulting documentation of the interviews was validated by the experts to prevent misinterpretations and to ensure internal validity of the assumptions. These verification and validation procedures are inevitable within the simulation model development and ensure that the model is an adequate representation of the investigated system with a satisfactory range of accuracy for the particular objectives (Manuj, Mentzer, and Bowers 2009; Law 2013).

3.2 Conceptual Model

Based on the described development approach the order and change processes are depicted in Figure 1. The shipper initializes the order process and sends a transport order to the deep sea carrier. After the dispatcher of the deep sea carrier has checked the preferences of the shipper as well as the available shipping capacities, the intermodal operator is selected. The intermodal operator reviews the hinterland rail and road capacities and has either to accept or decline the order. Afterwards the intermodal agency receives the order and is in charge of organizing the execution of the container road and rail transport. Finally, the rail transport company carries out the rail transport towards the seaport. Hence, the deep sea carrier and the intermodal operator cover the planning of the transport activities (planning actors), while the agency coordinates the container handling and transport operations close to or on the day of departure and the rail transport company is responsible for rail haulage (operative actors). Hereafter usually no more order changes from the shipper can be expected and order information can be considered as final. Further changes might arise during transport (e.g., delays), but are not considered in this case. The change process comprises similar steps. The major difference is that if orders are not yet transmitted to the next actor, the change is included into the order information and only the completed order is transmitted. The process for the specific change ends at this point. However, when the order is already transmitted, then the order has to be updated and the change is transmitted to the next actor. Consequently, the following actors also have to update the order causing additional effort.

The objective regarding the order and change processes is to increase the overall process efficiency by reducing processing times and costs per order. Therefore, the manual effort (order and change processing times) for all the dispatchers in the chain is regarded. The order review point is located between the planning and operative actors (between the intermodal operator and agency). Timing of order transmission and start of order processing at the next actor are not separated by a time delay meaning that order processing starts immediately after transmission. The ORR mechanism applied in the model takes the difference between the time the order arrives at the order review point and the time remaining until the day of departure (due date of the order) into account. If this time difference is smaller than the predefined order release time, the order gets transmitted to the operative actors immediately. Otherwise it is backlogged until the time difference equals the predefined order release time. This mechanism can be classified as a time phased ORR approach. It does not consider the workload of the operative actors because only one relation is considered and the workload of dispatchers in total cannot be derived from it.

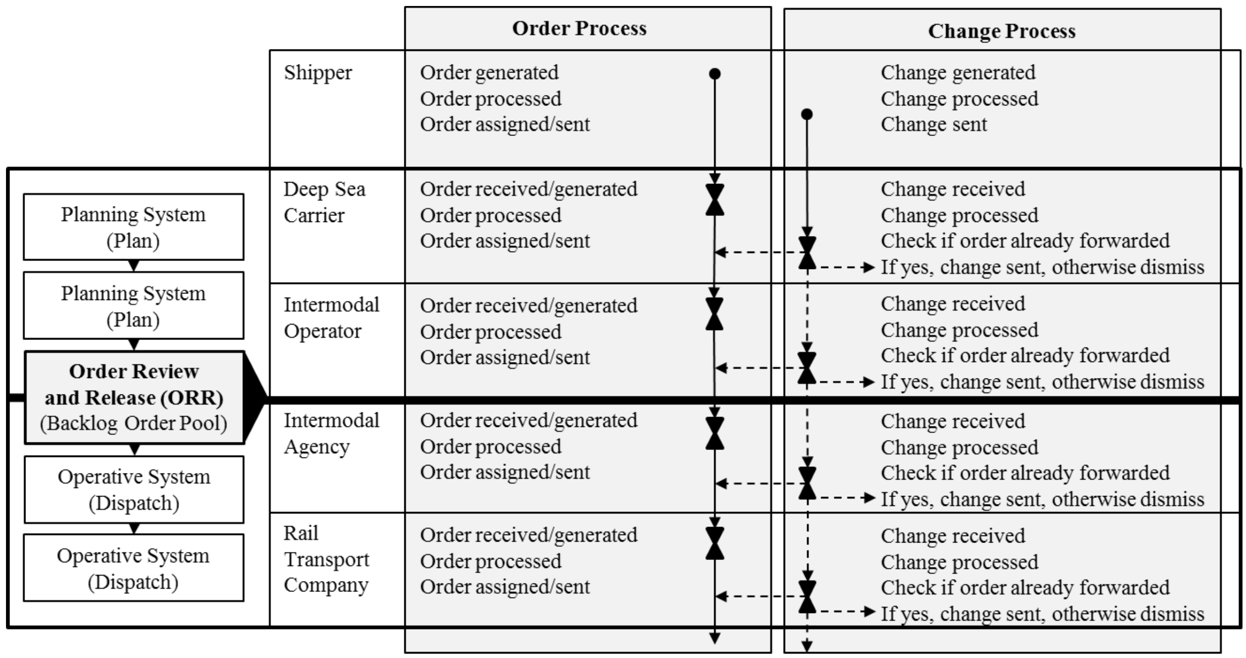

Figure 1: The order and change processes of the MTC incorporating ORR.

3.3 Computer-Based Model

To transfer the conceptual model into a computer-based model a multi-method simulation approach is applied using agent-based and discrete event modeling features included in the simulation software AnyLogic 7.2. While agent-based modeling is used for the interaction between actors through orders and order changes, discrete event modeling is applied for sequencing the events inside the different actors. The advantage of agent-based modeling is the great degree of detail which can be implemented. Entity behavior and characteristics such as autonomy, mobility, and reactiveness can be modeled in detail (Owen et al., 2010). In this case the different actors as well as orders and order changes are modeled as agents. The generated order changes are linked to specific orders since the information, if an order is already processed and transmitted to the following actor in the chain or not, is crucial for the processing of the change. Furthermore, discrete event modeling is well suited for problems where the detailed sequencing of entities in a process is the main focus and where stochastic effects are important (Owen et al., 2010).

Complexity was added stepwise to the computer-based model. At every step, the code was checked by the researchers in order to debug individual elements concurrently with model development (Sargent 2013). To ensure model verification, operational and data validity (Sargent 2013), the actors (deep sea carrier, intermodal operator and agency, and rail transport company) were involved in various stages of the verification and validation process (see section 3.1). Through this intense consultation practical relevance and correctness of the process mappings within and between actors was ensured and the input data was validated. Based on a sensitivity analysis the output behavior of the model was examined (Sargent 2013).

4 CASE STUDY

4.1 Simulation Input Data

The data set for the selected transport relation comprises 786 transport orders (one order can contain several containers) of seven months (from November 2014 to May 2015). This order data set is provided by the deep sea carrier and covers its export-oriented orders from shippers of the Rhine-Main region during that time period. According to the available data set the run length of the simulation was set to eight months to ensure that all orders are processed. The provided data sets, the focus workshops, and the transcription of the expert interviews formed the data basis for the simulation model. In Table 1 the relevant assumptions regarding the processing times are summarized. To keep privacy rights of employees recording of detailed processing times was restricted. However, the triangular probability distribution is adequate and commonly used in research as an approximation for the distribution of processing times (Robinson 2003). The range of the triangular distribution T (min., max., mode) is defined by the minimum and maximum value as well as the most-likely value which is the mode of the distribution (Law 2013). Multiple real orders and corresponding order changes considering average and extreme cases were discussed with the dispatchers to derive appropriate values for the triangular distributions. The reason for the two different distributions for the order changing time for the deep sea carrier can be attributed to the differentiation of minor and major changes. Additionally, the dominance of the order processing and changing times of the deep sea carrier are remarkable. These values can be explained by the high effort of the deep sea carrier in the carrier's haulage being the direct contact to the shipper and in charge of coordination along the MTC.

Table 1: Distributions of order processing and changing times for each actor.

		Deep Sea Carrier	**Intermodal Operator**	**Intermodal Agency**	**Rail Transport Company**
Order processing time [in minutes]	Min.	0.5	0.5	0.5	0.5
	Max.	15	2	1	1
	Mode	5	1	0.75	0.75
Order changing time [in minutes]	Min.	0.5 / 5	1	0.5	0.5
	Max.	5 / 45	5	2	2
	Mode	2.5 / 20	1	1.25	1.25

Further parameter specifications for the simulation model are summarized in Table 2. Four dispatchers in total handle the orders and corresponding changes for the regarded transport relation. The orders are dedicated to direct trains which are operated from the hinterland terminal to the seaport twice a week. An order is assigned to a train in accordance to the day of departure (latest train before or on the day of departure). The day of departure of an order is determined by the closing time at the seaport which is the relevant time limit to be considered for the stowage plan of the vessel. However, if the order is processed too late, the train and thus the vessel can be missed and penalty costs can arise. Penalty costs result from higher transport rates due to short term bookings on alternative transport modes, production or sales losses as a consequence of missed transport connections.

Table 2: Configuration of parameters.

Parameters	**Configuration**
Dispatcher	1 Worker / Actor
Working hours of dispatchers	8 Hours / Day from Monday to Friday
Day of order placement	T (2, 31, 15) Days before day of departure
Number of incoming orders	Real monthly data (uniformly distributed within months)
Timing of incoming changes	T (day of order placement, day of departure, day of departure)
Direct trains	2 Trains / Week
Processing costs	50 Euro / Hour
Penalty costs	500 Euro / Order

4.2 Simulation Experiments

For the simulation experiments a full factorial design was chosen. The parameter variations are summarized in Table 3 resulting in 26 scenarios (13 x 2). The order release time varies from 2 to 14 days before the day of departure. 14 days can be referred to as early order transmission and 2 days as late order transmission. Less than 2 days are not realistic to handle all orders on time and more than 14 days are not considered because most of the orders are not placed earlier than that. The distribution of order changes is varied between the current change rate and a 10 % reduction of the change rate. According to the current change rate 50 % of the orders have no change, 30 % of the orders have one change, and so on (see Table 3). A fixed sample size procedure with 50 replications for each scenario was selected. To receive independent replications a different random number stream was used for each simulation run (Law 2013).

Table 3: Investigated scenarios.

Independent variables	**Variation of the independent variables**
Order release time (days before day of departure)	2, …, 14 days
Order change rate (probabilities of order changes per order)	Current order change rate (0 – 50%, 1 – 30%, 2 – 10%, 3 – 7%, 4 – 3%) Reduced order change rate -10 % (0 – 55%, 1 – 27%, 2 – 7%, 3 – 6.3%, 4 – 2.7%)

4.3 Numerical Results

To analyze the output behavior for each scenario the mean, variance, standard deviation, and confidence interval (95 % confidence level) of the dependent variable (total processing time per order) was calculated for the transport chain and for each actor individually. The output for each scenario can be considered as normally distributed. An analysis of variance (ANOVA) was performed to analyze, if the independent variables (main effects and interaction effect) have a significant influence on the dependent variable. Results are presented in Figures 2-4. Each figure shows the total processing time per order for all evaluated release times and the current as well as the reduced change rate.

As shown in Figure 2 the total processing time per order is increasing with a higher order release time for the transport chain. That means the earlier the order is released to the operative actors the higher the total processing time per order. When the change rate is reduced by 10 %, the total processing times for the transport chain reduce by 5.1 % on average. According to the results of the ANOVA the impact of the order release time and the change rate are statistically significant (with $p < \alpha = 0.05$). The interaction effect of the two independent variables is not statistically significant, which means that the impact of the order release time is not dependent on the level of the change rate and vice versa.

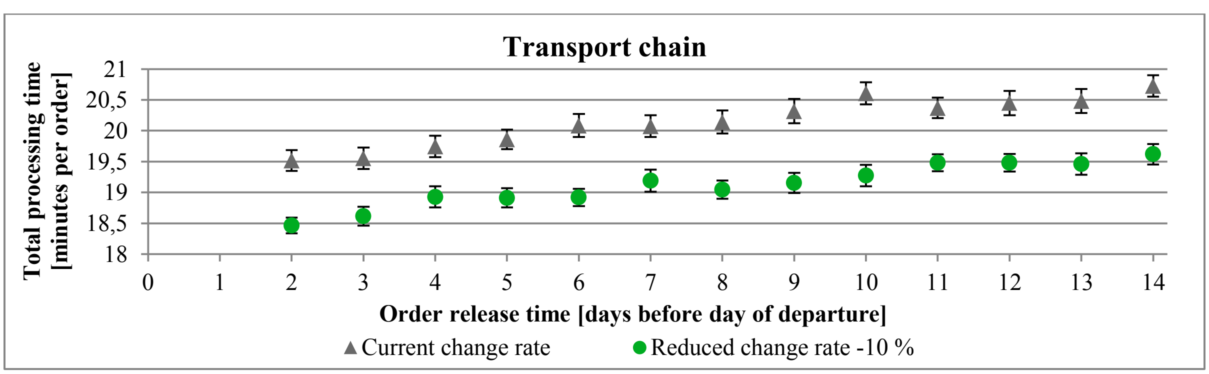

Figure 2: Total processing time per order of the transport chain.

To gain a detailed insight into the results for each actor the ordinate of the following figures have been adjusted. In Figure 3 the results for the planning actors (deep sea carrier and intermodal operator) are depicted. The results of the ANOVA show no significant influence of the order release time on the total processing time per order. Also, the interaction effect is not statistically significant. However, the change rate has a statistically significant impact on both actors. For the deep sea carrier the mean total processing time per order is 14.2 minutes for the current change rate (3.1 minutes for the intermodal operator) and 13.5 minutes for the reduced change rate (2.9 minutes for the intermodal operator). Thus, on average for the reduced change rate the total processing time per order can be reduced by 5.0 % for the deep sea carrier and by 6.2 % for the intermodal operator. The non-existing influence of the order release time on the total processing times of the planning actors is not surprising. Changes have to be processed by the planning actors regardless of the value of the order release time.

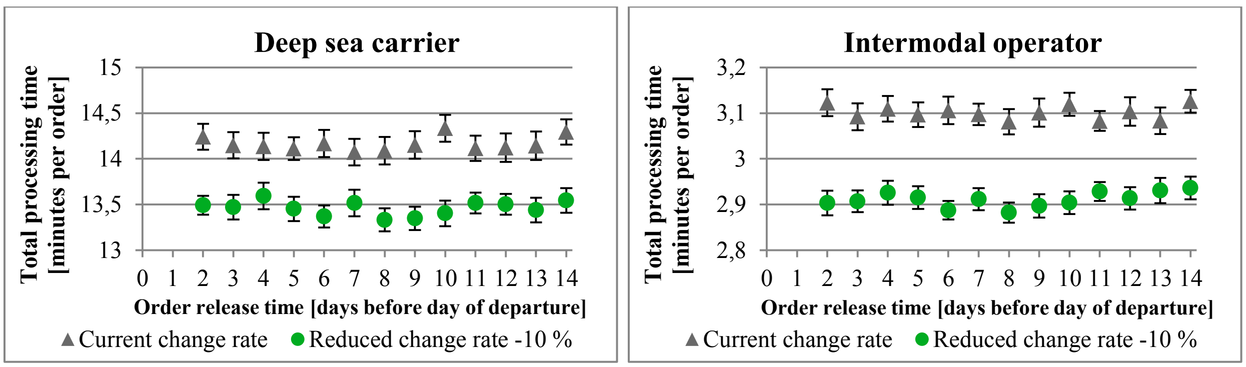

Figure 3: Total processing time per order for the planning actors.

The results for the operative actors are presented in Figure 4. The total processing time per order increases with higher values of the order release time. For an order release time of 14 days the total processing times reach their highest values and setting the order release time to 2 days results in the lowest total processing times. Comparing an order release time of 14 days and 2 days, the total processing times can be reduced by 35.6 % for the intermodal agency and by 34.8 % for the rail transport company on average. According to the ANOVA the impact of the order release time and the change rate as well as the interaction effect are significant (with $p < \alpha = 0.05$) for the operative actors (intermodal agency and rail transport company). Comparing both change rate scenarios, the average reduction is 5.0 % for the intermodal agency and 4.2 % for the rail transport company. The higher the value of the order release time, the higher is the increased process efficiency gained from a reduced change rate. However, the results of the main effects should not be interpreted isolated because of the significant interaction effect.

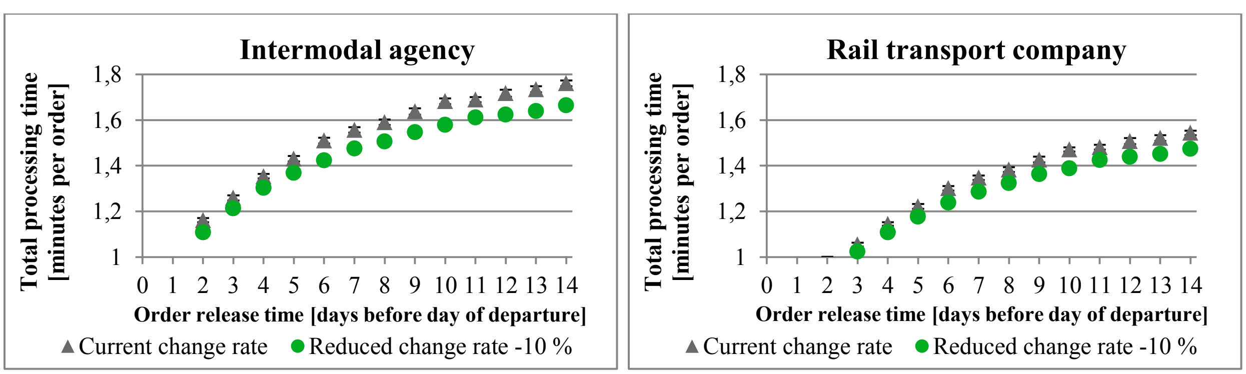

Figure 4: Total processing time per order for the operative actors.

Overall, the lower the value of the order release time, which reflects a late order transmission from the planning to the operative actors, the better. However, the later orders are processed and the later changes are prevalent, the greater the probability that the planned train is missed. Therefore, orders missing the assigned train are tracked for all scenarios. Considering the resulting costs per order a slightly adjusted conclusion can be drawn. For an order release time equal to 2 days, the costs are boosted (approx. by a factor of five) because the probability that an order misses the train increases dramatically (from two to more than 100 orders on average). Therefore, to find the best order release time for the MTC, an order release time of 2 days is excluded from consideration. Altogether, the best results in terms of total processing times and costs for this case-specific analysis can be generated with an order release time equal to 3 days before the day of departure.

5 CONCLUSIONS

Research has shown that ICT integration can generate a competitive advantage and increases the process efficiency in transport chains. However, the maritime hinterland transport sector is lagging behind due to the highly fragmented structure of the chain. To improve process efficiency special constraints prevalent in this sector have to be taken into account. In the MTC the order processes exhibit high manual efforts for dispatchers due to high change rates. Efficient inter-organizational processes can only be designed by considering these order characteristics. The simulation model shows that in areas with a great share of manual work, it is worthwhile to analyze the (negative) effects of early information exchange.

Regarding the first research question the simulation-based case study reveals that late order transmission is reasonable between the planning and operative actors to reduce the total processing time per order for the entire MTC. The deep sea carrier as the actor with the highest effort in the order process in the carrier's haulage accounts for the major share of the total processing time in the chain. Altogether the planning actors (deep sea carrier and intermodal operator) are not significantly influenced by different values of the order release time. On the contrary, the operative actors (intermodal agency and rail transport company) are highly influenced by different values of the order release time. According to the total processing time per order as well as the costs, the best order release time for the regarded MTC to improve process efficiency is 3 days before the day of departure. Regarding the second research question the simulation-based case study reveals a significant impact for the planning as well as operative actors. Overall this means that the processing time per order can be reduced by more than 5 % on average in case the change rate is reduced by 10 %. Regarding the high amount of orders and changes per day, this implies a huge potential of improvement. However, for the operative actors a significant interaction effect between the order release time and the change rate exists according to the ANOVA. For them the process efficiency gains due to lower order change rates decrease in case of late order transmission (short order release times).

The investigation has shown that early information exchange is not always reasonable but fundamentally dependent on the characteristics and constraints of the respective transport chain. Practitioners in maritime transportation should therefore be encouraged to integrate ICT conscientiously and to evaluate the improvement potential for the regarded order processes holistically. A limitation of this research is that the findings of the simulation are case specific and rely on the input data of the selected actors. Therefore, more actors of the MTC should be investigated in further research considering additional real data to adjust the arrival distributions of orders as well as to generalize the results. Furthermore, orders and changes are considered on an aggregated level and not further differentiated according to their contents. Further research should also analyze if the arrival time distribution of order changes, which is constant in this paper, has an influence on the process efficiency. It might be worthwhile to apply the simulation model to a setup in other countries where order change rates can have a different magnitude. Altogether, the reasons for the high change rates should be further investigated to improve order process efficiency in maritime hinterland transportation.

REFERENCES

Almotairi, B., J. Flodén, G. Stefansson, and J. Woxenius. 2011. "Information Flows Supporting Hinterland Transportation by Rail: Applications in Sweden". *Research in Transportation Economics* 33:15–24.

Alt, R., D. Gizanis, and C. Legner. 2005. "Collaborative Order Management: Toward Standard Solutions for Interorganisational Order Management". *International Journal of Technology Management* 31:78–97.

Bergamaschi, D., R. Cigolini, M. Perona, and A. Portioli. 1997. "Order Review and Release Strategies in a Job Shop Environment: A Review and a Classification". *International Journal of Production Research* 35:399–420.

Corsi, T. M., and S. Boyson. 2003. "Real-Time E-Supply Chain Management: Diffusion of New Technologies and Business Practices". *Transportation Research Part E: Logistics and Transportation Review 39:*79–82.

Croxton, K. L. 2003. "The Order Fulfillment Process". *International Journal of Logistics Management* 14:19–32.

Dovbischuk, I. 2016. "Information and Communication Technologies in Freight Transport: A Taxonomy of Applications and Key Barriers". In *Proceedings of the Annual Conference of the International Association of Maritime Economists (IAME) 2016*, Hamburg.

Elbert, R. and F. Walter. 2010. "Behavioral Logistics – Analysis of Behavioral Routines and Governance Structures in the Interorganizational Maritime Transport Chain". *Electronic Scientific Journal of Logistics* 6:11–19.

Giannopoulos, G. A. 2004. "The Application of Information and Communication Technologies in Transport". *European Journal of Operational Research* 152:302–320.

Inkinen, T., U. Tapaninen, and H. Pulli. 2009. "Electronic Information Transfer in a Transport Chain". *Industrial Management & Data Systems* 109:809–824.

Khalid, N., A. S. Zamil, F. Farid, and B. Unit. 2007. "Leveraging the Application of Information Technology to Gain Competitive Advantage in the Maritime Sector". Paper presented at Maritime Science & Technology Seminar (MARSTEC 2007), Kuala Lumpur, February 22.

Lam, J. S. L. 2011. "Patterns of Maritime Supply Chains: Slot Capacity Analysis". *Journal of Transport Geography* 19:366–374.

Lambert, D. M., S. J. Garcia-Dastugue, and K. L. Croxton. 2005. "An Evaluation of Process-Oriented Supply Chain Management Frameworks". *Journal of Business Logistics* 26:25–51.

Law, A. M. 2013. *Simulation Modeling and Analysis.* 5th ed. New York: McGraw-Hill.

Li, J., R. Sikora, M. J. Shaw, and G.W. Tan. 2006. "A Strategic Analysis of Inter Organizational Information Sharing". *Decision Support Systems* 42:251–266.

Lu, H. L., G. Q. Huang, and H. D. Yang. 2011. "Integrating Order Review/Release and Dispatching Rules for Assembly Job Shop Scheduling Using a Simulation Approach". *International Journal of Production Research* 49:647–669.

Harris, I., Y. Wang, and H. Wang. 2015. "ICT in Multimodal Transport and Technological Trends: Unleashing Potential for the Future". *International Journal of Production Economics* 159:88–103.

Manuj, I., J. T. Mentzer, and M. R. Bowers. 2009. "Improving the Rigor of Discrete-Event Simulation in Logistics and Supply Chain Research". *International Journal of Physical Distribution & Logistics Management* 39:172–201

Melnyk, S. A., G. L. Ragatz, and L. D. Fredendall. 1991. "Load Smoothing by the Planning and Order Review/Release Systems: A Simulation Experiment". *Journal of Operations Management* 10:512–523.

Notteboom T. 2008. "The Relationship between Seaports and the Intermodal Hinterland in the Light of Global Supply Chains: European Challenges." *OECD/ITF Joint Transport Research Centre Discussion Papers* 10:25–75.

Owen, C., P. Albores, A. Greasley, and D. Love. 2010. "Simulation in the Supply Chain Context: Matching the Simulation Tool to the Problem". In: *Proceedings of the 2010 Operational Research Society Simulation Workshop, SW 2010*, 229–242.

Perego, A., S. Perotti, and R. Mangiaracina. 2011. "ICT for Logistics and Freight Transportation: A Literature Review and Research Agenda". *International Journal of Physical Distribution Logistics Management* 41:457–483.

Robinson, S. 2003. *Simulation: The Practice of Model Development and Use.* 1st ed. West Sussex, England: John Wiley & Sons, Ltd.

Roorda, M. J., R. Cavalcante, S. McCabe and H. Kwan. 2010. "A Conceptual Framework for Agent-Based Modelling of Logistics Services". *Transportation Research Part E: Logistics and Transportation Review* 46:18–31.

Ruiz-Aguilar, J. J., I. J. Turias, M. Cerbán, M. J. Jiménez-Come, M. J. González, and A. Pulido 2016. "Time Analysis of the Containerized Cargo Flow in the Logistic Chain Using Simulation Tools: The Case of the Port of Seville (Spain)". *Transportation Research Procedia* 18: 19–26.

Saldanha, J. P. 2006. "Choosing the Right Information Coordinating Mechanism for the International Ocean Shipping Process". Ph.D. thesis. College of Business Administration, Pennsylvania State University, State College, Pennsylvania.

Sargent, R. G. 2013. "Verification and Validation of Simulation Models". *Journal of Simulation* 7:12–24.

Talley, W. K., and M. Ng. 2013. "Maritime Transport Chain Choice by Carriers, Ports and Shippers". *International Journal of Production Economics* 142:311–316.

Tapaninen, U., L. Ojala, and D. Menachof. 2010. "IT in Logistics and Maritime Business". In *The Handbook of Maritime Economics and Business.* edited by C. T. Grammenos, 1017–1032. London: Taylor & Francis.

UIC, International Union of Railways. 2012. *Combined Transport in Europe.* Report December. Paris.

UNCTAD, United Nations Conference on Trade and Development. 2016. *Review of Maritime Transport 2016.* Accessed on March 15, 2017. http://unctad.org/en/PublicationsLibrary/rmt2016_en.pdf.

Van Der Horst, M. R. and P. W. De Langen. 2008. "Coordination in Hinterland Transport Chains: A Major Challenge for the Seaport Community". *Maritime Economics & Logistics* 10:108–129.

Wong, C. W. Y., K. H. Lai, and E. W. T. Ngai. 2009. "The Role of Supplier Operational Adaptation on the Performance of IT-Enabled Transport Logistics under Environmental Uncertainty". *International Journal of Production Economics* 122:47–55.

AUTHOR BIOGRAPHIES

RALF ELBERT is full professor at the chair of Management and Logistics at Technische Universität Darmstadt with a strong focus on simulation modeling in the context of logistics and transport service engineering. His email address is elbert@log.tu-darmstadt.de.

KATRIN SCHARF is research assistant at the chair of Management and Logistics at Technische Universität Darmstadt. Her email address is scharf@log.tu-darmstadt.de. Her research focuses on information technologies for maritime and air cargo transport chains.

DANIEL REINHARDT is research assistant at the chair of Management and Logistics at Technische Universität Darmstadt. His email address is reinhardt@log.tu-darmstadt.de. His research centers around the simulation-based investigation of the efficient usage of transport capacities.