IMPROVING ON-TIME DELIVERY PERFORMANCE IN DISTRIBUTION NETWORKS - A SIMULATION APPROACH

KEYWORDS

Distribution process, discrete event simulation, on-time delivery performance

INTRODUCTION

Uncertainties in the process of oversea delivery, for example like late delivery to the port of departure or variation in shipping times, may cause problems in on-time delivery performance at the customer. These uncertainties result from the fact that oversea delivery covers long distances and consists of several process steps, demanding transshipment processes in between. Changing weather conditions lead to uncertain vessel shipping times (Halvorsen-Weare, Fagerholt, and Rönnqvist 2013). Therefore, processing times must be modelled stochastically, considering the interdependencies of consecutive process steps. A delay in the transport to the port of departure may have the consequence that the planned ship cannot be reached. This risk increases with the number of transshipments. However, customers need to receive the ordered products on time to be satisfied, which makes on-time delivery an indicator of high importance.

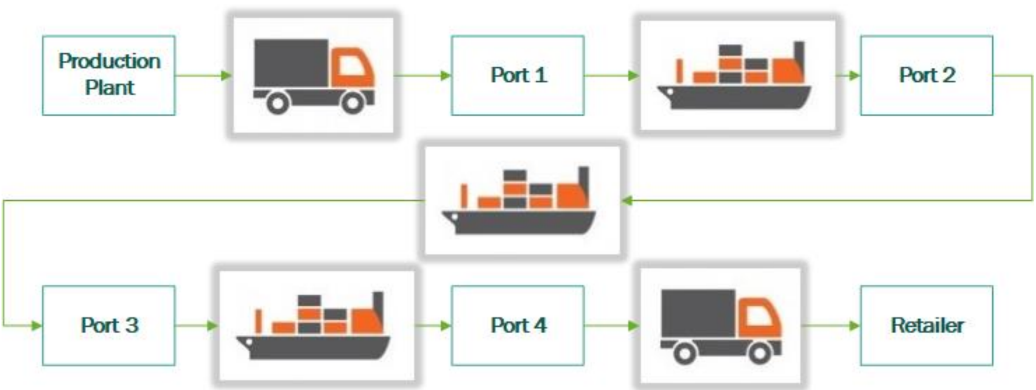

Figure 1: Model of the distribution network under investigation

The purpose of this paper is to get more information on how to improve the on-time delivery performance. This is done by building a simulation model of a car manufacturer’s delivery process, based on real data. Figure 1 pictures the distribution network considered. We simulate different scenarios and evaluate which scenario leads to the best on-time delivery performance.

LITERATURE REVIEW

On-time delivery has been studied in various contexts. For example, Karim et al. (2010) improved the on-time delivery performance of make-to-order productions. Forslund and Jonsson (2010) investigate issues with on-time delivery of suppliers, based on a large survey in Sweden. An intermodal delivery network was investigated by Gillen and Hasheminia (2016). They considered a network including transportation by railway from port of arrival to final destination in North America and used data including name and time of the departure in Asia. They estimated operational parameters for a queueing modelling approach, as for example the distribution of vessel arrivals, container inter-arrival time, number of servers, flow time, service time and others. They further simulated the transportation network in order to identify sources of variability and evaluate its reaction under disruptions.

In production management and traffic modelling, queueing theory has proven to be a good theory to model various processes (Papadopoulos and Heavey 1996). The field of queueing theory investigates processes, where entities arrive in random distances, wait in line for service and have stochastic service time (Ibe 2011). It is common to use discrete event simulation to analyze complex queueing systems (Gillen and Hasheminia 2016).

This research exposes new aspects of oversea transportation. What agreements need to be made with shippers, to improve the on-time delivery performance? In other words, what conventions of shippers lead to suboptimal performance?

METHODOLOGY

For the purpose of this research, a big data set is available, including 15 production plants and more than two thousand retailers, covering the worldwide market of a car manufacturer. The data of six month are available, recording the delivery of about one million cars up to retailers in all continents of the world. At the beginning and end of each process step, there are time stamps for each car delivered.

We chose queueing theory as a basis to model our distribution network, since queues operationalize waiting times, service times (i.e. transportation times), as well as capacity constraints of transportation. To decide which entity should be transported next, queueing theory incorporates different policies, including first in first out and last in first out (FIFO, LIFO). We simulated the queueing systems via discrete event simulation (Ivanov 2017), using AnyLogic Software, which is common for simulation purposes of many kinds. To this end, a descriptive analysis was necessary to determine the operational parameters (see table 1 below) of the individual queueing systems (Gillen and Hasheminia 2016).

For simplicity, we choose a linear process in this paper, starting at one plant and leading to only one retailer. In between, the first port is reached by trucking, followed by three sea shipping sections and another trucking section to the retailer (figure 1). In front of each transportation section, there is a waiting queue, representing the area, where the cars wait to be loaded on the next vessel.

PRELIMINARY FINDINGS

Let us first discuss the findings of the descriptive analysis, which we listed in table 1. We took the arrivals of the cars, i.e. the starting times of the delivery orders directly from the data. The same holds for the departure times of the vessels at the three ports of departure. The arrivals for the second to the last queueing systems are determined by the completions of the previous system. We modeled the service times to be triangular distributed, determined by the averages, minima and maxima of the respective times in the real data. For simplicity, we assumed the trucks always available, which approximates the real situation good enough. At the ports, the cars have to wait for transport and are loaded at time of departure according to FIFO or LIFO discipline. If the service capacity is reached, the loading stops. In the FIFO scenario, all queues follow this discipline. In the LIFO scenario, we set the disciplines at the three ports of departure to LIFO. This is comparable to the stacking of containers, where the first containers are at the bottom and can thus be loaded last.

Table 1: Operational parameters of the queueing model

Queueing System	**Mode**	**Arrival of cars**	**Service Time**	**Service Discipline**	**Service Availability**	**Service Capacity**
Production Plant – Port 1	Truck	According to data	50h	FIFO	Promptly	Unbounded
Port 1 – Port 2	Vessel	As released by prev. step	250h	FIFO/ LIFO	According to data	130 per vessel
Port 2 – Port 3	Vessel	As released by prev. step	33h	FIFO/ LIFO	According to data	140 per vessel
Port 3 – Port 4	Vessel	As released by prev. step	170h	FIFO/ LIFO	According to data	150 per vessel
Port 4 – Retailer	Truck	As released by prev. step	37h	FIFO	Promptly	Unbounded

We simulated the two scenarios and compared the overall lead times for the individual delivery orders. Figure 2 shows their distributions for the two scenarios compared to the distribution of the lead times in the real data.

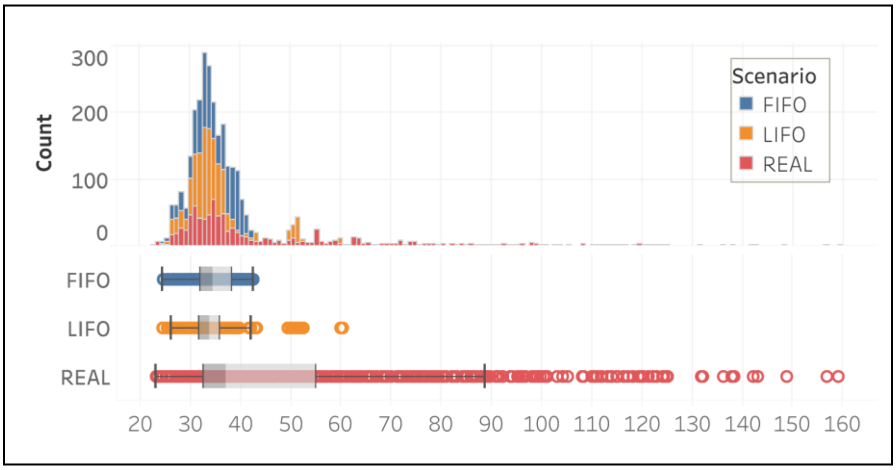

Figure 2: Distribution of the lead-time for the scenarios FIFO and LIFO

We can see that in the FIFO scenario, the cars are delivered simply one after the other, leading to an approximately normal distribution. The variation stems from different waiting times at the ports for the next vessel departure. In the LIFO scenario, there are some outliers, accounting for the fact that if some cars reach a port before the preceding ones are loaded, they are prioritized. Therefore, the other cars, already waiting for some time, have to wait even longer and resulting in outliers in terms of lead time. However, the median of the lead times is slightly lower in this scenario. In the real data, we found that the distribution of the delivery times is even more right-tailed than in the LIFO scenario but has a larger median.

CONCLUSION

While the FIFO scenario seems very unrealistic but has constant performance, the LIFO scenario comes a bit closer to the real delivery times, having a right-tailed distribution. This indicates that LIFO is used at the ports, whereas FIFO would lead to a more constant performance and should therefore recommended. Further development of the model will be necessary to find more suggestions for improvement. Moreover, since the real delivery process is carried out in a network, rather than in a chain, one next step will be to extend the delivery chain to a network. The simulation approach allows for testing several scenarios, even in very complex networks.

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