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SIMULATION-BASED ANALYSIS OF A CROSS-ACTOR PALLET EXCHANGE PLATFORM

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ABSTRACT

Pallets are returnable transport items and of great importance for supply chains. They ensure efficient storage, transport, and handling processes. The pallet cycle, however, is associated with a substantial effort. In addition to administrative costs, extra trips and detours must often be taken by forwarders to retrieve pallets or buy new pallets. In this paper, a fictitious cross-actor pallet exchange platform is analyzed, which manages pallet debts and receivables between the different actors of a supply chain. A claim transfer is performed, and the actors no longer owe pallets to each other, but to the system. This provides greater flexibility, as actors with open claims can collect pallets from all actors that have a negative balance according to the system. Our analysis shows that with such a system, additional trips can be reduced by 70 %, thus making the management of pallets more efficient.

1 INTRODUCTION

Road freight transport has a high contribution to CO_2 emissions (Demir et al. 2019). Therefore, it is the goal in the field of logistics to reduce transports in order to achieve climate goals and save costs at the same time. Besides the forward flows from the production to end-users, there is also a backward directed flow. This is known as reverse logistics and is currently becoming increasingly important (Kazemi et al. 2019). An example are returnable transport items (RTI), which ensure efficient material flows in the supply chain. Since RTIs are used several times depending on treatment and transported goods (Carrano et al. 2015), they must be returned to an upstream location in the supply chain after they have completed the delivery (customer receives goods on pallets). When arriving at the starting point, the cycle restarts again. For that reason, this is also referred to as a closed-loop supply chain (Kazemi et al. 2019). RTIs have to be managed efficiently in order to draw environmental and operational benefits from their use (Bottani et al. 2015). It is, therefore, not surprising that RTI management has gained importance in the scientific literature (Glock 2017). Pallets are the most widely used RTIs (Roy et al. 2016). The current scientific interest is focused on an actor-specific view of pallet management. Research questions in the spotlight explore which system an actor should use (e.g., Menesatti et al. 2012), which organizational structures companies should use (e.g., Elia and Gnoni 2015), or how the tracking of RTIs via RFID can lead to improvements (e.g., Hellström and Johansson 2010). Although logistics service providers play a decisive role in the handling of RTIs (Gnoni et al. 2011), they have hardly been investigated so far (Glock 2017). In a pallet exchange system, where the actors bring in their own pallets and exchange them with each other (Bottani et al. 2015), forwarders are important (Gnoni et al. 2011). They supply the manufacturers with empty pallets and receive empty pallets in return from the receivers of the goods. They, thus, take over the supply and return of the pallets. Since deferred exchange often takes place, the forwarder has to make detours to collect empty pallets on additional tours or to purchase new pallets.

In order to reduce the administrative effort, the first digital logistics platforms are already available, in which the players can manage their pallet accounts (receivables and debts) via a common system. In Germany, examples of this are swoplo as a RTI management platform (Hector 2017; sennder 2018) and the "pallet exchange using blockchain" project launched by GS1 (GS1 2018). Furthermore, there are already examples of networks of partner companies that collect and aggregate the balances in order to carry out as few bilateral compensation trips as possible (EUROLOG 2016; Wild 2015). There are also examples of logistics service providers with whom customers exchange pallets at various depot locations. Here, the incoming and outgoing flows of the individual depots are collected and calculated as a balance against the overall system (AMETRAS; IDS 2013). This means that customers do not have to go to different depots, but only to one that handles the aggregated exchange of empty pallets. Our focus is on the combination of both approaches. The central question of the paper is how to reduce the transports by consolidating debts and receivables on digital platforms. In this approach, the bilateral pallet debts between individual, independent actors are converted directly into debts to a digital platform. Such a claim transfer has the advantage that pallets do not necessarily have to be requested from the original exchange partner, but can also be collected from other network participants who have debts to the system. For the forwarder, this has the effect that pallets could be taken along on regular stops at the customers' sites instead of having to drive to specific actors and possibly having to cover long distances to collect the empty pallets owed. In practice, round trips are often made just to collect empty pallets. The system, in which a claim transfer is possible, therefore offers the potential to save transport distances traveled for the RTIs.

In this paper, we investigate the potential of such a cross-actor pallet exchange platform compared to the current system without such a platform. Since the potential of networks always depends on the number of participants, we also want to investigate from which participation rate the system with claim transfer becomes advantageous. This leads to the following two research questions:

RQ1: How high are potential transport savings in RTI management for the freight forwarder when using a cross-actor pallet exchange platform?

RQ2: What is the minimum participation rate of consignees for a freight forwarder in order to implement transport savings?

These research questions are analyzed based on simulation modeling. This methodology is suitable for investigations in RTI management (Glock 2017). In the proposed approach, the focus is on a network of different actors interacting with each other. Stochastic influences play an important role since the random ordering of consignees and the assignment of different carriers by the shipper leads to different pallet flows, which have to be balanced.

The remainder of the paper is structured as follows: Section 2 presents the relevant literature on simulation-based analysis in RTI management and a brief overview of platforms. Section 3 presents the conceptual model leading to section 4 with a description of examined scenarios. In Section 5, the results of the simulation experiments are presented. Finally, the findings are summarized in Section 6 and an outlook on future research is given.

2 RELATED LITERATURE

According to Glock (2017), there are four main research streams in the RTI research. In the first stream, different packaging systems are compared, such as using their own RTIs or rental RTIs (e.g., Cheng and Yang 2005). In the second stream, the focus is on inventory management of RTIs, where topics such as optimal time of ordering and order quantity of RTIs are investigated (Buchanan and Abad 1998). The third stream focuses on the forecasting of RTI returns, since these are characterized by high uncertainty (e.g., Bojkow 1991). The fourth and last stream is the management of RTIs, where, for example, different organizational structures are compared (e.g., Elia and Gnoni 2015). In these research streams, mainly analytical methods and optimization are being used. Only in a few papers the method of simulation was used in the area of RTI management, whereas Glock (2017) recommends gaining new insights using simulation modeling in the future. Simulation modeling is used in the first and second research stream. These simulation studies are discussed in further detail below.

Simulation modeling is used to decide whether an RTI management system could be profitable and, consequently, which system should be used. Under certain conditions, the use of single-use packaging material can be economically more reasonable. Mollenkopf et al. (2005) have shown with their simulation model that the container cost factor ratio (which represents container costs in one factor calculated by reusable unit costs divided by expendable unit costs) and average daily volume are the main driving factors for the decision between reusable and non-reusable or recyclable containers. The delivery distance plays a less important role and the cycle time of the RTI (total time for completing a loop between supplier and customer) even proved to be relatively insignificant. Cheng and Yang (2005) also compared three container systems (disposable containers, recyclable containers, and reusable containers) in a case study in the automotive sector using simulation modeling. Disposal containers are disposed after a single use, the materials of the recyclable container are sold, and the reusable containers can be used for further transportation processes. They concluded that reusable containers are economically more reasonable in the long term in their considered case. Menesatti et al. (2012) came to the same conclusion in their simulation-based analysis of a case study in the floricultural sector. In addition to the decision between reusable and non-reusable RTIs, companies can still decide whether to buy or rent the RTIs. In the case of rented RTIs, service providers assume the responsibility of the allocation of RTIs, the return as well as maintenance and repair. As a result, the degree of utilization can be increased (Cheng and Yang 2005). While in the case study of Cheng and Yang (2005) the costs between rental and purchased RTIs were almost identical, Ray et al. (2006) show in their case study that the rental option was more expensive.

Once an RTI system is chosen, the RTIs must be managed. In research, simulation-based studies are carried out with a focus on a specific actor and usually for a concrete case study. For example, Bottani et al. (2015) examine a manufacturer in a real network with one pallet provider and seven retailers in their simulation study. With the help of multi-objective optimization, they analyzed the best configurations for individual scenarios to minimize the costs of purchasing new pallets or collecting empty pallets from the receivers. The time of order and the minimum stock for the order placed from the manufacturer at an RTI service provider are defined as decision variables. A follow-up study (Bottani and Casella 2018) was conducted based on this research. Here, the environmental impact was minimized by means of optimization. It was shown that the kilometers driven have a significant influence on the environmental impact, while the purchase of new pallets (taking into account emissions of pallet manufacturing, maintenance, and end-of-life processes) plays a secondary role. The study for a food company by Hellström and Johansson (2010) examined the impact of a tracking system and the option of setting up pools for different consumers. Both options were more efficient than the actual reference scenario, with RTI tracking proving to be the more cost-efficient option.

In their simulation model, Accorsi et al. (2019) investigated a pallet pool service provider that designs its processes according to the retailer's network configuration. Various scenarios with the combination of selling pallets and integrating the retailer network into the pool service provider network were examined. It was shown that scenarios with a pool service provider and a central hub, through which the flows of goods and empty pallets pass, lead to a reduction in traffic and, thus, to a lower environmental impact in the considered supply chain.

Elia and Gnoni (2015) examine a logistics service provider that maintains a distribution center as an interface between a manufacturer and a retailer. The effects of different organizational structures on RTI management were analyzed. A distinction was made between two pallet flows. The upstream flow, in which the logistics service provider receives pallets from the manufacturer and must return them, and the downstream flow, in which the logistics service provider transfers pallets (with goods) to the retailer and receives empty pallets in return. Depending on the organizational variant, the exchange can be postponed. In the variant without postponed pallet exchange, the manufacturer has to bear the lowest costs, but the scenarios with postponement were more cost-efficient for the logistics service provider and retailer as well as for the entire supply chain.

On the subject of RTI management via a cross-actor platform, no scientific work could be found. However, there are many digital logistical platforms. They can basically be divided into multi-sided platforms and innovation platforms (Parker et al. 2017). The multi-sided platforms bring together different actors and enable an exchange of information, goods, and services (Reuver et al. 2018). An example of this is Uber Freight, which brings together carriers and customers (Hofmann and Osterwalder 2017), or cargo community systems, in which different players can post and retrieve information on goods (e.g., Wallbach et al. 2019). Innovation platforms offer specific services for the participants of the network. In the field of logistics, for example, there are time window management platforms that organize the allocation of time windows for their customers (Elbert et al. 2016).

3 METHODOLOGY

Simulation is a well-established methodology in the scientific field of logistics and transport. An agent-based simulation is used, which is ideally suited for use in RTI management: various actors with individual interaction among each other and the environment are considered (Law 2013). The simulation modeling method is suitable in the context of RTI management, because different concepts such as organizational structures can be compared with each other easily, quickly, and without large investments for implementing real-world systems (e.g., pallet exchange platforms). The systematic procedure for the development of the simulation model is based on the development model according to Manuj et al. (2009).

3.1 Conceptual Model of Modeled Agents and Interactions

The investigation is based on the concept of pallet exchange, in which all actors (shipper, forwarder, consignee) bring in their own pallets and exchange them with each other (Gnoni et al. 2011; Hector et al. 2015). The main actors of the simulation model, which are modeled as agents, and their interactions are shown in Figure 1. The consignees order goods from the shipper (step 1). The shipper then commissions a forwarder to transport the goods to the consignee (step 2). A truck modeled as an agent carries out the transport of the pallets and palletized goods for the forwarder. The shipper provides the goods on pallets. When the forwarder picks up the palletized goods, they hand over empty pallets to the shipper in the corresponding number (step 3). The forwarder then transports the goods to the consignees(s) and delivers the goods there (step 4). For this purpose, delivery tours are planned and executed. The forwarder demands the corresponding number of empty pallets back from the consignee (step 5). If the consignee cannot hand over the appropriate number of empty pallets to the forwarder, it is recorded in pallet accounts, which list the respective pallet debts and pallet receivables. The forwarder can then claim the pallet debts at a later time. Another actor is the pallet shop. If the forwarder needs new pallets, the pallets can be purchased and collected from a pallet shop (step 6). This happens either when the forwarder no longer has enough empty pallets to carry out the next order or when the quality of the pallets in stock falls below a critical value. The pallets, which are also modeled as agents, wear out during the transportation processes. According to Carrano et al. (2015), pallets with medium-weight goods and average handling and treatment last for an average of 15 cycles. The quality of the pallet during the exchange is not taken into account, but pallets are taken at random from the stock.

3.2 Concept

There are already first platforms for pallets that offer network participants a system in which they can uniformly record their pallet debts and receivables via a jointly used platform. For the concept of this paper, it is assumed that the debts and receivables are completely transferred to this system. The platform, thus, acts as an independent third party similar to a bank. As a result, the network participants have debts and receivables only against the system and no longer among themselves. The actors, who have pallet receivables from the system, claim their receivables from all actors, who in turn have debts to the system. Therefore, a forwarder with pallet receivables outstanding from the system can collect the pallets from other consignees who have outstanding debts, even if these were originally owed to another forwarder. In Figure 2, the system with the platform as a mediator (right) is compared with the current system in which bilateral exchanges between actors are made and cleared (left). In the current system, the receivables and debts, as well as the pallet flows, are settled bilaterally between the actors. In the concept with a platform model (right), all liabilities and receivables are transferred to the platform. This gives the forwarder more flexibility in collecting pallets from various actors and enables the forwarder to avoid additional trips to collect empty pallets. A forwarder can make claims during regular stops at consignees and pick up additional empty pallets (provided the consignee has a negative pallet balance and, thus, owes pallets to the system). For example, forwarder F1 can pick up empty pallets from consignee C2 in the system with the cross-actor platform, although both have no bilateral receivables and debts.

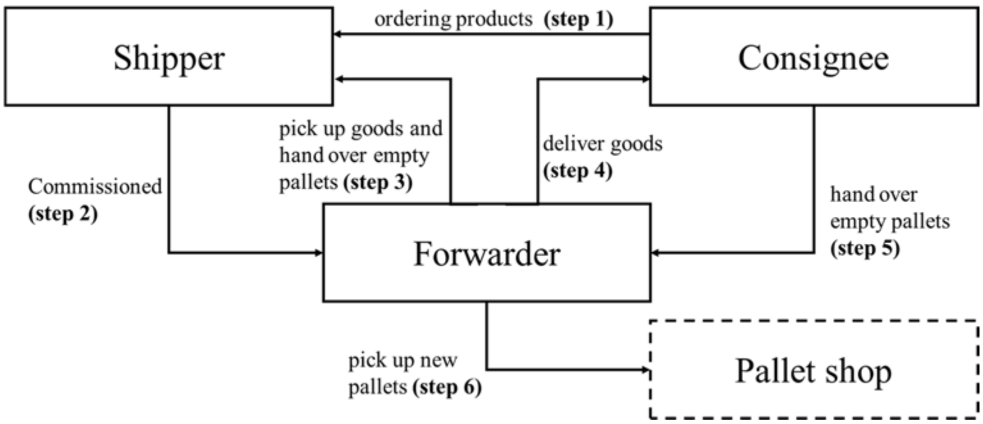

Figure 1: Main actors and their interactions.

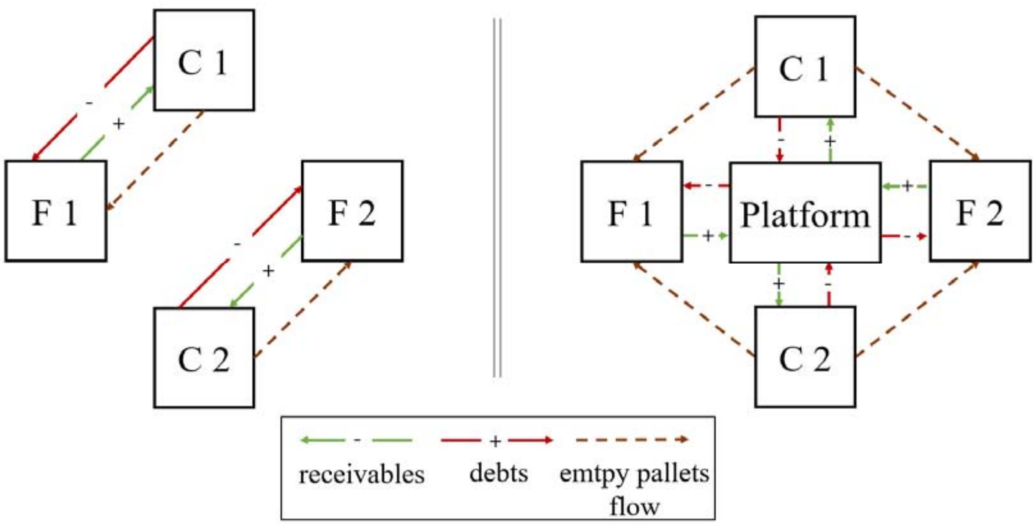

Figure 2: Comparison of bilateral balancing (left) and balancing over the platform (right) with two forwarders and two consignees.

3.3 Evaluation Criteria

In order to examine the concept of a cross-actor RTI management platform, the length of the detours made for the supply of pallets s^D is recorded as a central evaluation criterion. The costs are not a major evaluation criterion. The detours driven could be evaluated with costs, but there is no added value because costs for driven kilometers depend on factors such as use of a special truck and current fuel prices, which are not considered in the simulation model. The meaningfulness of the number of purchased new pallets is limited as well. This is due to the fact that the purchase of new pallets does incur costs, but the forwarder receives the equivalent value of a pallet, whereas costs for storage or ordering processes are not recorded.

The length of the detours s^D is calculated from the sum of the detours made by the individual forwarders i with $i \in I$, where I represents the set of all forwarders. On the one hand, these are calculated from trips to the pallet shop for purchasing new pallets, which are determined from twice the distance s_i^{PS} between the respective forwarder i and the nearest pallet shop, multiplied by the number of trips x_i made by the respective forwarder to the nearest pallet shop in the simulated period. On the other hand, the number of kilometers driven on round trips to collect empty pallets is added. Here, various consignees who have a pallet debt to the forwarder are approached in extra tours in order to collect empty pallets. These are calculated on the basis of the total distances traveled by the individual forwarder on the round trips for collecting empty pallets $s_{iz_i}^{REP}$. Here, z_i represents the respective round tour and Z_i is the set of all round trips driven by the forwarder i in the simulation run.

$$s^D = \sum_{i \in I} (2 s_i^{PS} x_i + \sum_{z_i \in Z_i} s_{iz_i}^{REP})$$

The route planning, which is largely responsible for the length of the tours, is based on optimization algorithms developed by Schrimpf et al. (2000) and Pisinger and Ropke (2007). For this purpose, the open-source toolkit jsprit was integrated, which has already been used for various scientific contributions (e.g., Elbert and Friedrich 2018). With the help of route planning, the tours are planned efficiently, so that the transport steps can be realistically evaluated and compared using a cross-actor exchange pallet platform.

4 SIMULATION STUDY

The simulation model is created using AnyLogic 8.5.2, a software from the AnyLogic Company. AnyLogic is widely used for studies in the field of logistics, transportation, supply chains, and RTI management (e.g., Elbert and Friedrich 2018; Elia and Gnoni 2015). AnyLogic is based on Java and provides high modeling flexibility (Borshchev 2013).

4.1 Network Design

Since there is currently no exchange network platform with pallet claim transfers in practice, experiments were carried out in a generic environment in order to be able to make statements that are as generally acceptable as possible. For the investigation, a randomly generated network of 50 nodes in a field measuring 100 km by 100 km was created (Figure 3), using the algorithm developed by Leyton-Brown et al. (2000). This algorithm has already been used in the logistics context for the simulation of road networks (Elbert et al. 2020). The nodes represent the locations of 50 actors: 5 forwarders, 5 shippers, 37 consignees, and 3 pallet shops. The edges between the actors correspond to road links that the trucks use to reach the different actors. The trucks use the shortest route between start and destination via the different edges. A matrix, which lists the shortest distances over the different edges from all nodes to all nodes, is used for the route planning algorithm.

4.2 Analyzed Scenarios

For the investigation of a cross-actor pallet exchange network concept, two scenarios are created to answer the first research question. Scenario 1 represents the reference scenario without a pallet exchange platform and Scenario 2 represents the situation including an exchange platform. In both scenarios, the 37 consignees randomly order a number of 1 to 30 full pallet loads (following a uniform distribution) of products daily from the various shippers. The shippers have a daily contingent with a maximum of 30 full pallets (one full truckload). The consignees order daily at different times from randomly selected shippers for the next day. Here, first-come-first-served applies until the shipper's contingent is exhausted. If the requested order quantity of the consignees exceeds the available contingent, the maximum order possible is ordered. As soon as all consignees' orders are received, the shipper instructs one of the forwarders randomly for the next day to pick up the full pallets from the shipper and distribute them to the consignees. Due to the randomly generated orders and the random allocation of the carriers, there are constantly varying interactions between the different actors.

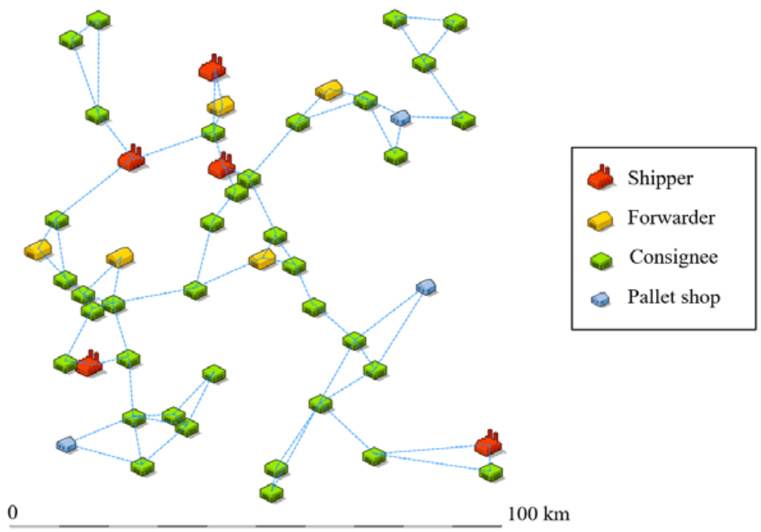

Figure 3: Generic network consisting of shippers, forwarders, consignees, and pallet shops.

The orders of the consignee are handed over to the forwarder as transport requests, which contain information about the shipper, the consignee, the forwarder, and the quantity of palletized goods ordered. These transport requests are transmitted to the route planning algorithm. Using a distance matrix (lists all distances between the actors), the algorithm calculates the number of kilometers to be driven in a round trip for different sequences. The shipper is always the first stop, as the goods are initially loaded there. As a result, the route planning algorithm sends the transport requests to the trucks in an order that enables an efficient round-tour. After the route planning, the forwarder loads the appropriate number of empty pallets into the truck. In the simulation model, the pallets are stored at the individual agents (trucks, shippers, forwarders, and consignees) in collections. After loading the empty pallets, the truck starts its tour and drives to the shipper. There, the truck of the forwarder hands over the empty pallets (corresponding to the number of full pallets to be transported). From the shipper, the truck drives to all consignees in a round trip and delivers the palletized goods there. When the goods arrive at the consignee's premises, they are handed over, and the forwarder receives empty pallets back from the consignee in return. Since a direct exchange does not always take place in reality, e.g., due to a lack of time or insufficient empty pallets at the consignee's premises, the forwarder does not always receive pallets back. In the simulation model, a variable is set to true or false for each consignee daily with a probability of 50 %, which indicates whether empty pallets are available on that day. In Scenario 1, the pallet debts between the actors are posted bilaterally. In Scenario 2, the receivables and debts are added to or subtracted from the current balance of the participants, i.e., for each participant the total number that is owed to the system or that the system owes the actor is stored. If the current consignee has empty pallets available, the forwarder checks whether the truck can pick up additional empty pallets. Here, the two scenarios differ considerably from each other. In Scenario 1, additional empty pallets are only taken along if the forwarder still has receivables from the specific consignee. In Scenario 2, however, additional empty pallets can always be taken along if the forwarder has receivables from the system, and at the same time the consignee has debts to the system, regardless of whether the forwarder has previously interacted with this consignee. In both cases, the maximum number of additional pallets that can be taken along is limited to 18. This is based on the assumption that the supply of empty pallets plays a subordinate role in the delivery runs. A number of 18 pallets can easily be loaded into the truck at once with a forklift truck. Loading more pallets would take more time, which could be problematic, e. g., due to the time window that needs to be reached. Furthermore, it would also take up more space in the truck, which could hinder the unloading of the palletized goods.

The truck then drives to the next consignee. After all consignees have been supplied, the truck drives back to the home depot of the forwarder.

In both scenarios, the freight forwarders must ensure that there are always enough empty pallets available to be able to hand over the corresponding number to the shipper in the next delivery tour. As soon as the number of pallets in stock of the forwarder falls below a value of 30 pallets (number required for the next day's tour), the forwarder must obtain additional pallets. There are two options available to the forwarder in Scenario 1 (reference scenario). The preferred option here is to collect empty pallets from consignees who still owe the forwarder pallets. For this purpose, additional round trips are planned in which the forwarder collects empty pallets from various consignees. Round trips are typical for collecting RTIs (Glock 2017). A maximum of eight consignees will be approached (in order not to exceed the driving limit of eight hours per driver and day). It is checked whether the variable for pallet availability of the particular consignee is set to true. The variable is independent of the pallet stock from the consignee. The consignees have a stock of 60 pallets at the start. If the stock falls below this level, 30 new pallets are created and added directly to the stock. This procedure is simplified since the focus is on the RTI management of the forwarders and the processes of the consignee are not considered in further detail. The consignees with the highest debts to the forwarder are approached. It is also checked that the consignees are not on the next delivery tour. Here, too, the route planning is done using the jsprit tool. If less than 30 pallets would be collected in a round trip, this is not carried out. Instead, a truck from the forwarder drives to the nearest pallet shop and buys 30 new pallets there. In the scenario with a cross-actor pallet exchange platform, no round trips for empty pallets are carried out. It is assumed that the consignees are more willing to hand over empty pallets in addition to those that they must hand over anyway than to organize additional pick-ups with forwarders they may not have worked with before. Thus, open pallet claims are only collected in regular delivery runs. In Scenario 2, forwarders can also buy new pallets from the pallet shop.

In both scenarios, new pallets are only purchased if the other measures do not allow the forwarder to organize enough empty pallets following Bottani et al. (2015). The reason for this is to keep the costs of capital for the pallet stock as low as possible. There is one exception to this: If the quality of the pallets in stock is too low (as pallets wear out by going through a high number of exchange cycles), new pallets are purchased. At the start of the simulation, the forwarders have a stock of 60 pallets, which covers the demand for two days and ensures that the model quickly reaches a steady-state status. The two scenarios described above represent extreme points of a continuum, respectively discrete set of various solutions. Either the cross-actor exchange platform is used by all participants or none. However, it is also interesting to examine the effects of only certain consignees participating in the cross-actor pallet exchange network. For this reason, the participation rate of consignees in the cross-actor exchange platform was varied for further analysis. This results in two consignee groups for the forwarder. Firstly, the group that participates in the network and from which pallets can be collected more flexibly from another consignee, and a group of which owed pallets are still collected via round trips.

Table 1 summarizes the input parameters for the simulation. The parameters used as well as the modeling of the current system without a pallet exchange platform were presented and validated in a focus group interview. This group consisted of people who deal with the topic of pallet exchange daily (forwarder, manufacturing industry, trading industry). The interview took place on May 8th, 2020.

Table 1: Simulation parameters.

Parameter	Value
Participation rate	0 % - 100 %
Number of pallets at start	60
Purchased pallets at pallet shop	30
Probability no direct pallet exchange	50 %
Max. stops for empty pallet run	8
Max. additional pallets per stop	18
Order size consignee	1-30
Contingent shipper per day	30

5 RESULTS AND DISCUSSION

In this section, the results of the scenarios described were examined. First, the two scenarios with a participation rate of 0 % and 100 % are examined. Since no seasonality was implemented, each simulation run is simulated over a month so that the time of simulation runs is limited and at the same time it is long enough that all other events (accumulating debts, compensating debts, and broken pallets) occur in evaluable numbers.

Table 2: Detours for RTIs.

Variable	Scenario 1 (Participation rate 0 %)	Scenario 2 (Participation rate 100 %)
Detours to pallet shop (mean)	1,885.1 km	2,563.5 km
Detours empty pallet run (mean)	7,109.6 km	-
Detours overall (mean)	**8,994.7 km**	**2,563.5 km**
Sample Variance	307.9954,6	106.006,8
95 %-confidence interval	[8,134.2 , 9,854.2]	[2,403.5 , 2,772.5]

Here, two systems are compared, which were simulated independently. The number of replications (16) was determined by using the method described in Goldsman and Nelson (1998). It can be seen that the total number of detours made to ensure the supply of pallets is significantly higher in Scenario 1 than in Scenario 2. In Scenario 1, freight forwarders have to drive to the pallet shop more often and buy new pallets there. In Scenario 1, an average of 1,211 new pallets are purchased by all forwarders, whereas in Scenario 2 1,635 new pallets are purchased. In Scenario 1, however, the forwarders have to make long detours for round trips to collect the empty pallets. In Scenario 2, in which all actors participate in the cross-actor pallet exchange network, the total number of tours driven specifically for pallets is reduced in average by almost 71.5 % from 8,994.7 to 2,563.5 km. The simulation did not consider any detailed operational planning, in which, for example, trips to pallet shops or other consignees are integrated, if, for example, waiting for time windows for the next consignee is necessary. Thus, the additional kilometers driven for empty pallets would still be reduced. Even though, the savings of over 70 % show the advantages of a cross-actor pallet exchange network.

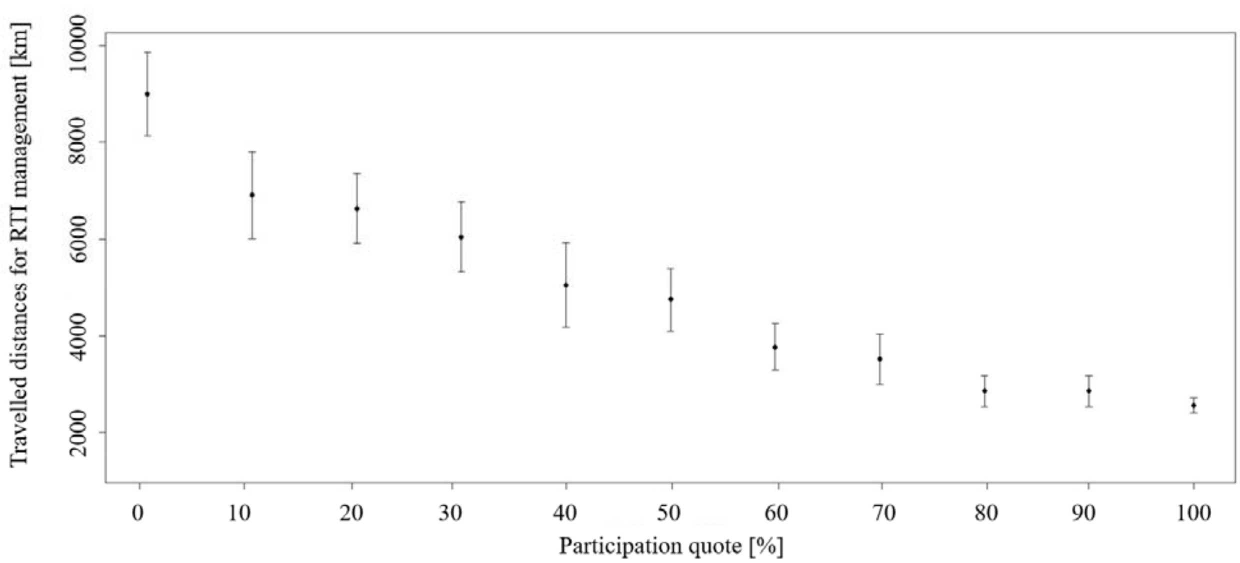

Figure 4: Travelled distances for RTI management (mean and 95 % confidence intervals).

Since not all actors will participate in such a platform from the beginning, the participation rate of consignees was gradually increased from 0 % (Scenario 1) for the next study. This shows that already from 0 % (mean=8,994.7 km ± 860) to 10 % (mean=6,911.15 km ± 891.5) considerably less needs to be driven for empty pallets (Figure 4). At a participation rate of 60 % (mean=3,772.75 km ± 475), the kilometers driven are only slightly reduced up to a participation rate of 100 % (mean=2,533.5 km ± 159.5). Overall, it can be seen that with low participation rates, the fluctuations vary significantly (Figure 5). The fluctuations can be explained by the round trips carried out for collecting empty pallets. Depending on which actors owe pallets to the forwarders, the length of the tours varies.

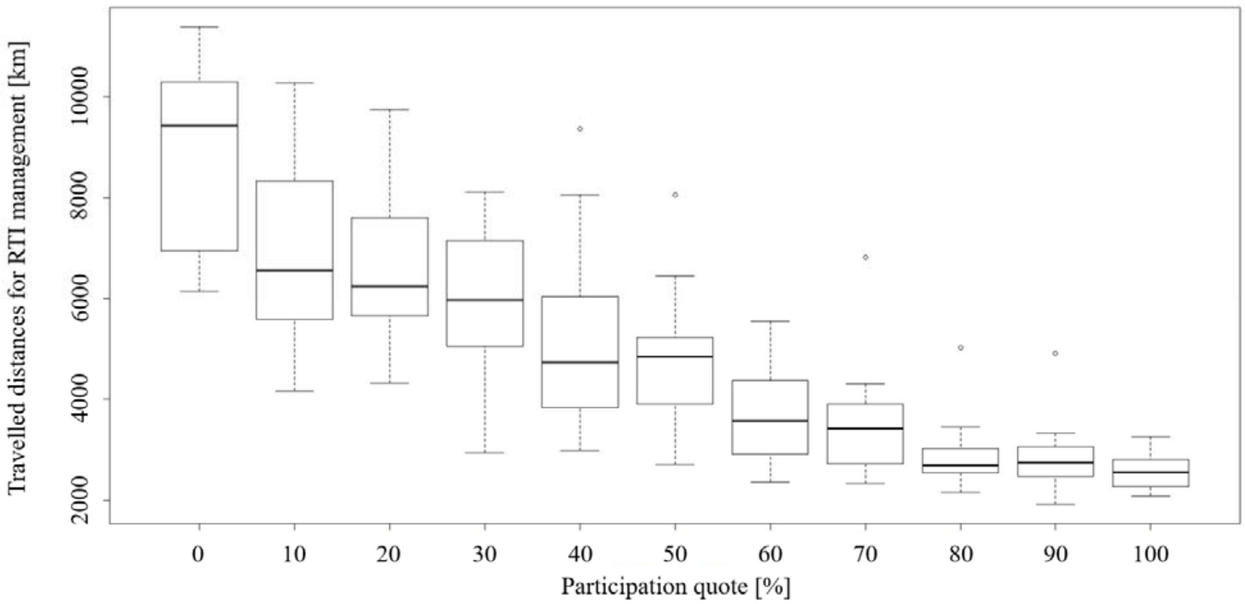

Figure 5: Travelled distances for RTI management (boxplot of data).

6 CONCLUSION

In this paper, we have shown that the actor pallet exchange network, where pallet debts and receivables are aggregated in a common system, leads to fewer detours for the forwarder to supply empty pallets. Such a system, therefore, has great potential to improve the management of pallets or other shared RTIs. As a result, the distances traveled for managing RTIs have been significantly reduced, thus saving both costs and emissions. Even a network with only a few participants can achieve significant transport savings, i.e., platforms and systems with claim transfer also make sense in small collaborations.

We looked at a system with 37 consignees, five forwarders, and five shippers in a limited space, where the pallet debts have only incurred between consignee and forwarder. It makes sense to consider other systems in the future, such as the fact that the forwarders do not bring in their own RTIs, but the pallet exchange only takes place between shippers and consignees. This also results in debts and receivables between these two actors. Furthermore, the shipper and consignees were defined, because in reality the companies both receive and send goods. For further investigations, mutual supply relationships should be taken into account.

In this study, the focus was on the shippers and the possible transport savings. However, it has to be taken into account that consignees also have to take advantage of the system in order to have an incentive to participate (e.g., Wallbach et al. 2019). In the future, motivations and barriers must be identified as with other collaborations in the logistics area (e.g., Rabe et al. 2016). In this context, it makes sense to consider the issue of trust in such a system. The platform would be a new actor in the pallet exchange system in which the network members must be able to trust. In cross-company platforms, data-related problems often arise, such as data protection and data security. These problems must first be solved so that competitors in the market use common structures and have an interest in sharing their data. A possible digital, implementable solution could be the blockchain technology (Meyer et al. 2019).

In addition to the advantages described here, which are mainly aimed at making the collection location for empty pallets more flexible, further control options can be implemented with a central pallet system. Such a system could be used to organize flows of empty pallets between the different actors via the central platform.

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