Optimization of Inland Container Transportation with and without Container Sharing

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Abstract: In this contribution we optimize the transportation of containers in the hinterland of a local area with one terminal and one depot for empty containers and trucks. There are several customers who want to receive goods by inbound containers and several customers who want to ship goods by outbound containers. Additionally, there are empty inbound containers and empty outbound containers. We present two different models corresponding to different scenarios for the transportation processes performed by a homogeneous and limited set of available trucks. In the first scenario (distinct container problem) empty containers are exclusively used by their owners and therefore must be sent to their predefined destinations. In the second scenario (shared container problem) empty containers can be interchanged among several owners and therefore can be arbitrarily used. By comparing the model for the distinct container problem with the model representing the shared container problem the benefit of container sharing can be analyzed.

1. INTRODUCTION

We present a truck and container scheduling problem and we model this problem for a hinterland transportation scenario with full and empty containers which are transported in a local area. A trucking company with a set of homogeneous trucks and a pool of empty containers is considered. We assume that there is a depot in which empty containers can be stacked and where the trucks are stationed. Additionally, it is assumed that there is a terminal in the area which can be a maritime port or a railway hub station to which trucks transport full and empty containers from customers' places and vice versa. In general, it would be possible to model the above situation for several depots and several terminals in the local area. But in order to keep the problem formulation simple we only present models for the *Inland Container Transportation Problem* (ICT problem) with one depot and one terminal. For further simplification we restrict our considerations to 40-foot containers. The ICT problem has been presented in Zhang *et al.* (2010). In contrast to Zhang *et al.* (2010) we consider in this paper two different versions of the ICT problem, one first version without allowing container sharing and a second version with the permission of container sharing. In the first version containers must be used for their predefined transportation task. In the second version containers can be arbitrarily interchanged in order to achieve improved solutions.

There are two types of containers, *inbound* and *outbound* containers. The containers located at the terminal that need to be moved to their destination (to the depots or their receivers) are called *inbound* containers. Reversely, the containers located at the depot or customers' places that need to be delivered to the terminal are called *outbound* containers. Moreover, each type of containers can be divided into full and empty containers. Thus, there are four types of containers demanding for transportation tasks that the company should carry out: inbound full, outbound full, inbound empty and outbound empty containers. First, an inbound full container has arrived from outside to the local area and is initially located at the terminal. It must be picked up by a truck at the terminal during a given terminal time window, must be delivered to its receiver (customer), and must be dropped off there. After being dropped off, the container is available at the customer location and is ready for being unpacked by the customer. When the inbound full container is completely handled at its destination, we obtain an empty container and a time window given for picking up the container at its current location. We have to move it to a depot or another alternative location by a truck. Secondly, an outbound full container is actually some freight that has to be transported in a container and is located at a customer's place. Thus, we should transport an empty container to the customer's location and deliver it during a given customer delivery time window which has been agreed on with the customer before. This empty container will be packed with freight by the customer. When the container is ready for shipment it can be picked up during a predefined customer pick up time window. It then has to be delivered to the specified terminal during a predefined terminal time window. Of course, the before mentioned customer pick up time window must be consistent with the terminal time window for this container. Thirdly, an inbound empty container is also initially located at a terminal and is available to be picked up during its specific terminal time window. We should pick it up at the terminal and transport it to a depot or another alternative location regarding the time window of the chosen location. Finally, an outbound empty container means that we should pick up an empty container at the depot and deliver it to the specified terminal during the specified terminal time window. The topic of this paper is the optimization of the container flows in the local area for a given time period as well as the resource planning and scheduling for a set of vehicles used for the needed container movements. For the analysis of the ICT we use an objective function which minimizes the total operating times of all trucks.

2. PROBLEM DESCRIPTION

For all full containers the origin (pickup location) and the destination (delivery location) is fixed by the problem data since these locations are defined by the required flows of goods carried in these containers. In the first scenario considered in this paper we assume that empty containers cannot be interchanged, maybe, since they have different owners and have to be used for their specific purpose or, maybe, since they have to reach their specific destination. This scenario is called *distinct container problem* during this paper. In the scenario of the distinct container problem the usage of empty containers being available at some location is determined in advance. That is why the origins and the destinations of all containers (empty containers as well as full containers) are fixed by the given data of a problem instance. In this case the optimization model related to the ICT problem comes up to a pickup-and-delivery problem with time windows (PDPTW) with each container movement representing a full truckload request for the PDPTW. The only difference to a usual PDPTW is that each customer has two time windows, one first time window for the delivery of a (full or empty) container in order to make the container available for the customer's loading or unloading operation and another second time window for picking up the container after the container has completely been handled by the customer.

But if it is allowed to interchange empty containers then we will have more flexibility. In this case, we can use any available empty container for any transportation. Throughout this paper this scenario will be called *shared container problem*. For the shared container problem, the decision which empty container will be assigned to the usage of which freight transportation task constitutes an optimization problem of its own. There are three types of empty containers which are available for the assignment to upcoming transportation tasks. The first type of available empty containers originates from the company's depot. The second type consists of all inbound empty containers located at the terminal. Finally, the third type of available empty containers is constituted by all containers that have been emptied at a customer location and that are currently disposable for a new task. Available empty containers can be used for two types of tasks. They can either be used as an empty outbound container (to be delivered to the terminal) or as a container which will be used to fulfill a customer's request for an empty container in the local area (i.e. the container will be packed with freight by this customer before it is transported to the terminal). Moreover, there is the opportunity for the trucking company to move the available empty containers to its depot. When empty containers can be interchanged, the origin of outbound empty containers and the destination of inbound empty containers are not defined by the problem data. The determination of these locations (i.e. a part of the input data of a PDPTW) is part of an optimization process itself. That is why the shared container problem cannot be modeled and solved as a usual PDPTW.

In this paper we discuss three approaches for modeling, describing and solving the ICT problem. The first approach refers to the distinct container problem, i.e. the model of the first approach describes the ICT problem without the possibility of container sharing. It turns out to be a PDPTW with a set of given container movements between customers, the terminal, and the depot. At the depot there are no time windows. For each container passing the terminal we have to respect its specific terminal time window. Each full container (inbound as well as outbound) has two time windows at its customer location (one for delivery and one for pickup).

The second and third approaches discussed in this paper refer to the shared container problem. The second approach is based on a sequential process for solving the two sub-problems of the ICT. The third approach pursues a simultaneous procedure for the solution of the ICT.

The second approach consists in the following two steps for solving the ICT. In the first step an optimal decision on the assignment of available empty containers to upcoming transportation tasks is aspired, i.e. in the first step it is tried to install minimum flows of empty containers in the local area in order to keep the total transportation demand of containers in the area as low as possible. The objective function used for the determination of the container flows is the minimization of the sum of the length of all distances that containers have to be transported. Of course, the determination of the container flows fixes an origin and a destination for each empty container which has to be transported. I.e., at the end of the first step, we have to solve the same type of problem as we have in the situation for the distinct container problem. That is why the model for the distinct container problem could also be used for the second step of the second approach. Since the flow of containers has to be performed by transportation processes fulfilled by the own fleet of the trucking company, the container flows have to be installed in that way that the given maximum number of coevally used trucks is not exceeded. The problem of minimum container flow with the important restriction of a limited resource capacity for transporting these containers is very interesting in general but it is not easy to solve. Since the problem in the first step of the second approach needs further investigation, this approach will not be pursued in the remainder of this paper.

Following the third approach we will solve the two sub-problems of the second approach in one single step, i.e. solving the assignment problem of empty containers simultaneously with the vehicle routing and scheduling problem induced by the originally given problem data and the compulsory assignment decisions. Using the model for solving the problem determines: a) where to deliver the empty containers released after inbound full/empty loads, b) where to pick up the empty containers for outbound full/empty loads, and c) in which order and by which truck the loads should be carried out.

3. EXAMPLE FOR CONTAINER INLAND TRANSPORTATION

Figures 1 and 2 show a very small example for the ICT problem. Customers are illustrated by circles; the depot is illustrated by a rectangle and the terminal by a triangle. The flow of goods is shown in Figure 1. There are two customers represented by the nodes 1 and 2. The flow of goods from customer 1 to the terminal is demonstrated by the arc g_1 and the flow from the terminal to customer 2 is demonstrated by g_2. The flow of goods is made possible by means of containers. The time window for the availability of a container at the customer's location i is given by $[s_i,e_i]$. Additionally, there are terminal delivery time windows for outbound containers and terminal pickup time windows for inbound containers. Customer 1 will have to pack the container provided to him during the time window $[s_1,e_1]$. The container of customer 1 has to reach the terminal respecting the terminal delivery time window for this container and will then leave the local area via the terminal. Customer 2 will receive a container carrying a flow of goods shown by the arc g_2. For this customer the time window for unloading the container is $[s_2,e_2]$.

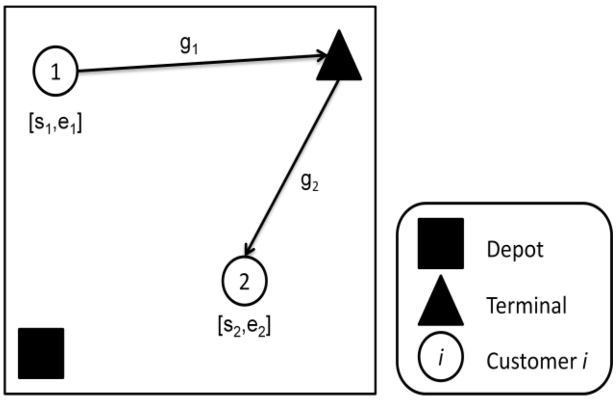

Figure 1: Flow of goods in the local area

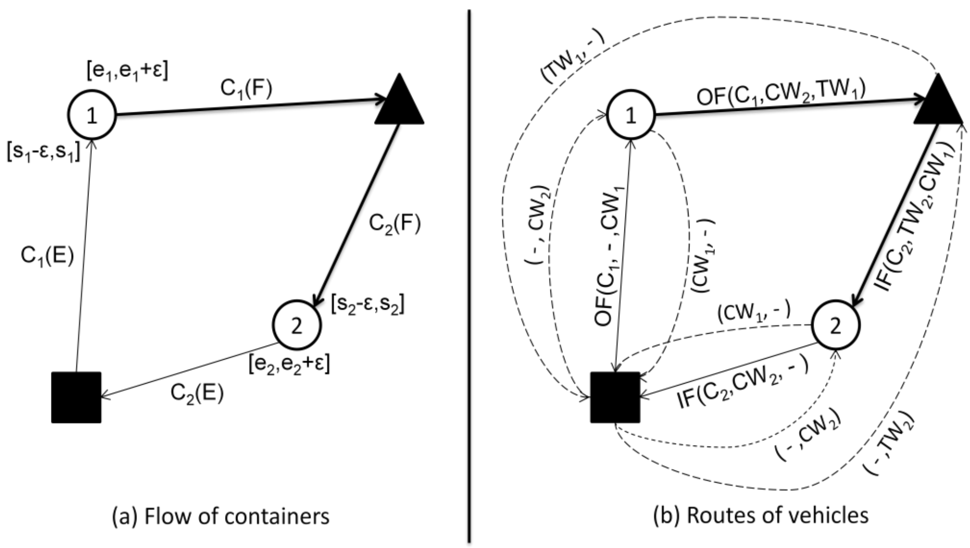

Figure 2: Distinct container problem

The flow of goods induces a flow of containers. Figure 2(a) shows the flow of containers for the case that the containers used for customer 1 and 2 cannot be interchanged (i.e. the situation of the distinct container problem). The container C_1 respectively C_2 will be used for the realization of the flow of goods g_1 respectively g_2. The flow of the empty container C_1 is denoted by $C_1(E)$ and afterwards when this container is loaded at customer site 1 its flow as a full container is denoted by $C_1(F)$. The flow of the full container C_2 from the terminal to the customer 2 is shown as arc $C_2(F)$ and after this container is unloaded by customer 2 its flow continues as an empty container to the depot on the arc denoted as $C_2(E)$. As mentioned above there is an availability time window for containers at each customer's site. We assume that the customer delivery time window for a container to be delivered to customer i will be $[s_i–\varepsilon,s_i]$ and the customer pickup time window will be $[e_i,e_i+\varepsilon]$, respectively, with ε denoting the amount of time that a container may arrive earlier at a customer's site than necessary or the amount of time that the container is allowed to remain at a customer's site after the availability time window is over.

The flow of container requires corresponding truck operations. Figure 2(b) shows the transportation processes needed to implement the intended container flows. The solid lines illustrate the transport of containers by a truck and the dotted lines illustrate truck movements without any container. The bold solid lines indicate the transportation of a full container while the semi-bold lines indicate the transportation of empty containers. The solid lines are marked by a denotation, for instance $OF(C_1,CW_2,TW_1)$. This denotation is used for describing the type of container, the identity of the container, and the relevant time windows. The first two characters denote the type of the container transported on that line: OE for Outbound Empty, OF for Outbound Full, IE for Inbound Empty, IF for Inbound Full. The first parameter within brackets identifies the container to be transported, e.g. C_1 for Container 1. The second parameter identifies the time window to be met when picking up the container. The values of that parameter might be CW_1 respectively CW_2 for the first respectively the second time window of the customer location where the container has to be picked up. Alternatively the value of the second parameter might be TW_j for the time window which is relevant for container j at the terminal. Finally, the value of the second parameter might be "-" indicating that no time window is relevant for the pickup operation. The third parameter identifies the time window to be met for the delivery of the container at its destination. The possible values of the third parameter are the same as the ones for the second parameter. The dotted lines used for the illustration of empty container movements are marked by a denotation which describes the time windows for the locations at the origin and destination of that movement, for instance $(-,CW_2)$ for a truck movement from the depot to a customer who has to be reached at his second time window. The first parameter identifies the time window at the starting point of that empty truck movement and the second parameter identifies the time window at the endpoint of that movement. The values for the time windows of empty movements can be the same as for the time windows for container movements on the solid lines. Figure 2(b) demonstrates the case that the time windows and the limitation of available trucks do not allow any bundling or concatenation of transport processes to common tours. For this case Figure 2(b) shows all transportation processes which are necessary in the local area to fulfill the container flows shown in Figure 2(a). There are 10 transportation processes needed for the transportation of the two containers. For each move of a container to or from the depot there will be needed a pendulum tour (i.e. 4 truck movements for the two containers). And for each move of a container between a customer location and the terminal there will be a tour with three transportation legs (i.e. 6 truck movements for 2 containers).

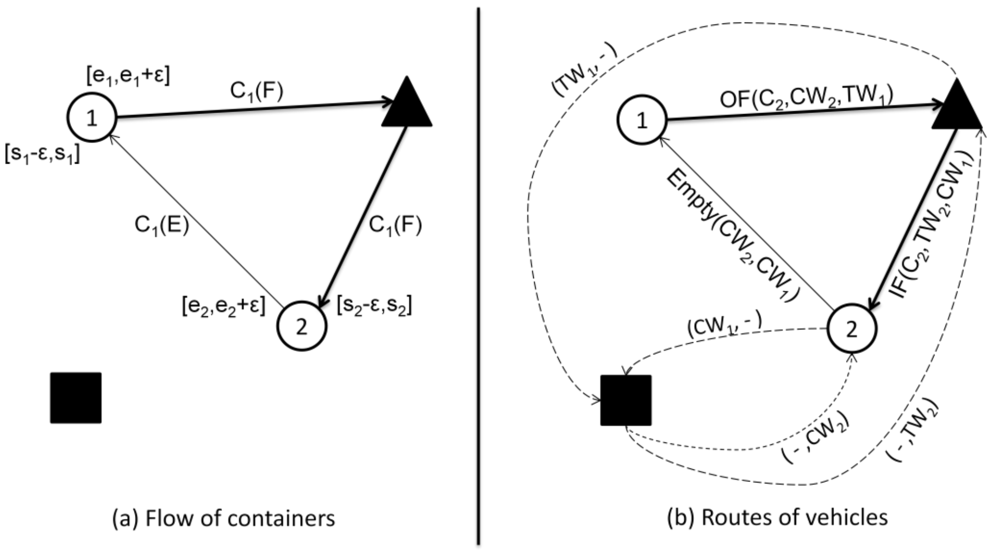

Figure 3: Shared container problem

The optimization model for the distinct container problem will minimize the transportation effort (in driving distances or operating times of the available trucks) for a given set of container movements. The two approaches for the shared container problem try additionally to minimize the container flows. Provided that the availability time windows [s_1,e_1] and [s_2,e_2] of the customers 1 and 2 allow that the same container can be used for both customers, the container flow illustrated in Figure 2(a) can be reduced to the container flow shown in Figure 3(a). As shown in Figure 3(b) the set of needed transportation processes will also be reduced.

4. MODELING THE CONTAINER INLAND TRANSPORTATION PROBLEM

The two models for the first and second approach use the following variables, parameters and constants.

$s(0) = \{0\}$	Start node (Depot)
$e(0) = \{3d + e + f + 1\}$	End node (Depot)
$P^i = (1, \dots, p)$	Pickup nodes (outbound full customers, first time window)
$P^o = (d + 1, \dots, d + p)$	Pickup nodes (outbound full customers, second time window)
$P = P^i \cup P^o$	
$D^i = (p + 1, \dots, d)$	Delivery nodes (inbound full customers, first time window)
$D^o = (d + p + 1, \dots, 2d)$	Delivery nodes (inbound full, second time window)
$D = D^i \cup D^o$	
$H^{OF} = 2\mathrm{d} + 1, \dots, 2\mathrm{d} + \mathrm{p}$	Terminal nodes (belonging to the number of outbound full customers)
$H^{IF} = 2d + p + 1, \dots, 3d$	Terminal nodes (belonging to the number of inbound full customers)
$H^{IE} = 3d + 1, \dots, 3d + e$	Terminal nodes (belonging to the number of inbound empty containers)
$H^{IF} = 3d + e + 1, \dots, 3d + e + f$	Terminal nodes (belonging to the number of outbound empty containers)
$H = H^{OF} \cup H^{OE} \cup H^{IF} \cup H^{IE}$	
$V = (s(0) \cup P \cup D \cup H \cup e(0))$	All nodes
$K = 1, \dots, m$	Vehicles
$C^{IF} = d - p$	Inbound full containers
$C^{IE} = d - p + 1, \dots, d - p + e$	Inbound empty containers
$C^a = d - p + e + 1, \dots, d - p + e + 1 + z$	Additional empty containers (originating from the depot)
$C = C^{IF} \cup C^{IE} \cup C^a$	
e	Number of inbound empty containers
f	Number of outbound empty containers
z	Number of additional empty containers
m	Number of trucks
W	Waiting time for the loading/unloading operation at a pickup/delivery node
M	Sufficiently big constant
t_{ij}	Required time for a truck to drive from node i to j
s_i/e_i	Time window of node i (i.e. TW_i for terminal time window of container i and CW_1 respectively CW_2 for the first respectively second customer time window)

Decision variables:	x_{ijk}	1, if truck k drives from node i to j; 0 otherwise
	y_{ijc}	1, if container c is moved from node i to j; 0 otherwise
	T_{ik}	Represents the starting time of truck k from node i
	L_{ic}	Represents the starting time of container c from node i

For a comprehensive survey of the different types of node sets Figure 4 illustrates their interrelations within the distinct and the shared container problem. Customers $i \in P$ providing outbound full containers are defined as pickup customers. Additionally, customers $j \in D$ who receive inbound full containers from the terminal are declared as delivery customers. To constitute the first and the second time window of the customer locations each customer is represented by two vertices ($P^i \wedge P^o; D^i \wedge D^o$). The terminal has to handle all types of containers and thus is split into four node sets ($H^{OF} \cup H^{OE} \cup H^{IF} \cup H^{IE}$). The additional possibilities of the shared container problem to allocate the container between the node sets are illustrated through the arrows and lay the basis for the following mathematical models.

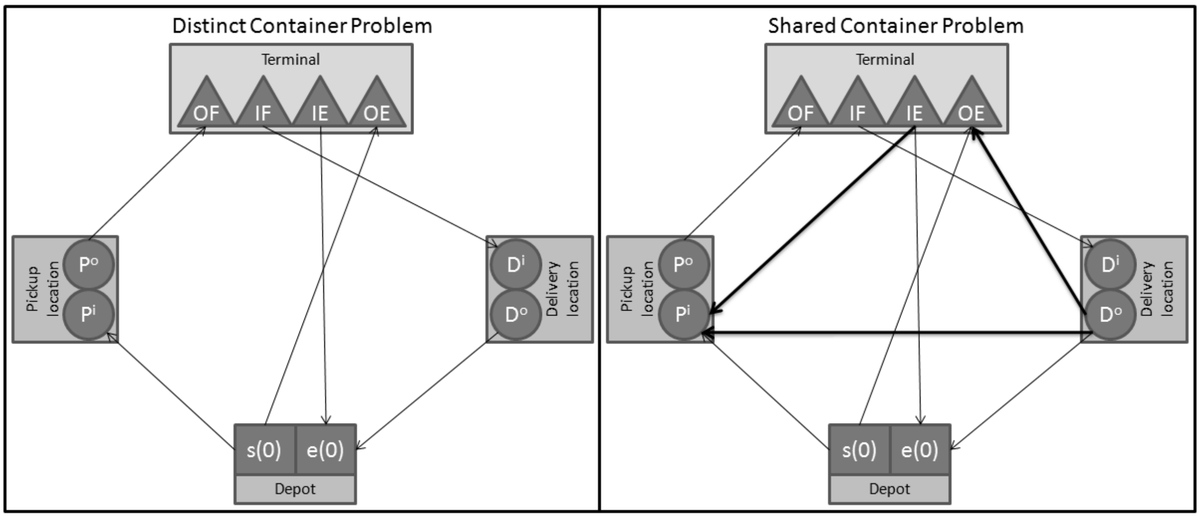

Figure 4: Possible arcs between the node sets

The optimization model for the distinct container problem with the objective of minimizing the total operating times of all trucks consists in the equation (1) and the restrictions (2) to (14).

Objective function: $$minimze \;\; z = \sum_{k\in K}(T_{e(0)k} - T_{s(0)k}) \qquad (1)$$

Restrictions:

$$\sum_{j\in V}\sum_{k\in K} x_{ijk} = 1 \qquad i \in P \cup D \cup H; i \neq j \qquad (2)$$
$$\sum_{j\in V\backslash\{s(0)\}} x_{s(0)jk} = 1 \qquad k \in K \qquad (3)$$
$$\sum_{i\in V} x_{ie(0)k} = 1 \qquad k \in K \qquad (4)$$
$$\sum_{j\in V} x_{jik} - \sum_{j\in V} x_{ijk} = 0 \qquad i \in P \cup D \cup H; k \in K; i \neq j \qquad (5)$$
$$\sum_{k\in K} x_{i(d+i)k} = 1 \qquad i \in P^o \qquad (6)$$
$$\sum_{k\in K} x_{i(i-2d)k} = 1 \qquad i \in H^{IF} \qquad (7)$$
$$\sum_{k\in K} x_{s(0)jk} = 1 \qquad j \in P^i \cup H^{OE} \qquad (8)$$
$$\sum_{k\in K} x_{ie(0)k} = 1 \qquad i \in D^o \cup H^{IE} \qquad (9)$$
$$T_{jk} \geq T_{ik} + t_{ij} - M(1 - x_{ijk}) \qquad i,j \in V; k \in K \qquad (10)$$
$$T_{ik} + t_{i(d+i)} + W \leq T_{(d+i)k} \qquad i \in P^i \cup D^i; k \in K \qquad (11)$$
$$T_{ik} + t_{i(d+i)} + W \leq T_{(d+i)m} \qquad i \in P^i \cup D^i; k,m \in K \qquad (12)$$
$$s_i \leq T_{ik} \leq e_i \qquad i \in V; k \in K \qquad (13)$$
$$x_{ijk} \in \{0,1\} \qquad i,j \in V; k \in K \qquad (14)$$

The objective function (1) deals with the minimization of the total operating time of the trucks. Restriction (2) assures that every vertex is visited exactly once. While (5) guarantees the route continuity, restrictions (3) and (4) mean that a truck starts a tour from the depot and beyond ends the tour at this location. The following two restrictions ensure that a truck which picks up an outbound full container from a pickup vertex (i.e. during the second time window) drives to the terminal. Furthermore, a truck driving to an inbound full terminal node has to move an inbound full container to the related delivery customer. Constraints (8) and (9) guarantee that every pickup location and every outbound empty terminal node is supplied by empty containers from the depot. Furthermore empty containers from the terminal or a delivery customer node must be moved to the depot. While the time continuity during a tour is assured by (10), the waiting time for the loading and unloading operation at the pickup and delivery vertices is guaranteed through (11). According to this restriction, constraint (12) states that the container is transported as well from the pickup or delivery node after waiting time, if two different trucks pass the first and the second time window of the same customer location. Finally, (13) assures that a truck reaches a location in its defined time window.

The optimization problem for the shared container problem is represented by the objective function (15) and the restrictions (16) to (44).

Objective function: $minimze\quad z = \sum_{k\in K}(T_{e(0)k} - T_{s(0)k})$ (15)

Restrictions :

$\sum_{j\in V}\sum_{c\in C} y_{ijc} = 1$	$i \in P \cup D; i \neq j$	(16)
$\sum_{i\in V}\sum_{c\in C} y_{ijc} = 1$	$j \in H^{OF} \cup H^{OE}; i \neq j$	(17)
$\sum_{j\in V}\sum_{c\in C} y_{ijc} = 1$	$i \in H^{IF} \cup H^{IE}; i \neq j$	(18)
$\sum_{i\in H^{IF}}\sum_{j\in V} y_{i(i-2d)c} = 1$	$c \in C^{IF}$	(19)
$\sum_{j\in e(0)\cup P^i}\sum_{c\in C^{IE}} y_{ijc} = 1$	$i \in H^{IE}$	(20)
$\sum_{j\in V} y_{s(0)jc} = 1$	$c \in C^a$	(21)
$\sum_{j\in V} y_{s(0)jc} = 0$	$c \in C^{IF} \cup C^{IE}$	(22)
$\sum_{i\in V} y_{is(0)c} = 0$	$c \in C$	(23)
$\sum_{j\in V}\sum_{c\in C} y_{ijc} = 0$	$i \in H^{OF} \cup H^{OE} \cup e(0); i \neq j$	(24)
$\sum_{i\in V}\sum_{j\in H^{OF}\cup H^{OE}\cup e(0)} y_{ijc} = 1$	$c \in C; i \neq j$	(25)
$\sum_{i\in s(0)\cup D^o}\sum_{c\in C} y_{ijc} = 1$	$j \in H^{OE}; i \neq j$	(26)
$\sum_{c\in C} y_{i(d+i)c} = 1$	$i \in P^i \cup P^o \cup D^i$	(27)
$\sum_{j\in V} y_{jic} - \sum_{j\in V} y_{ijc} = 0$	$i \in P \cup D; c \in C; i \neq j$	(28)
$L_{jc} \geq L_{ic} + t_{ij} - M(1 - y_{ijc})$	$i,j \in V; c \in C; i \neq j$	(29)
$L_{ic} + t_{i(d+i)} \leq L_{(d+i)c}$	$i \in P^o; c \in C$	(30)
$L_{(2d+i)c} + t_{(2d+i)i} \leq L_{ic}$	$i \in D^i; c \in C$	(31)
$L_{ic} + t_{i(d+i)} + W \leq L_{(d+i)c}$	$i \in P^i \cup D^i; c \in C$	(32)
$s_i \leq L_{ic} \leq e_i$	$i \in V; c \in C$	(33)
$\sum_{j\in V}\sum_{k\in K} x_{ijk} = 1$	$i \in P \cup D \cup H; i \neq j$	(34)
$\sum_{j\in V} x_{s(0)jk} = 1$	$k \in K$	(35)
$\sum_{i\in V} x_{ie(0)k} = 1$	$k \in K$	(36)
$\sum_{j\in V} x_{jik} - \sum_{j\in V} x_{ijk} = 0$	$i \in P \cup D \cup H; k \in K; i \neq j$	(37)
$\sum_{k\in K} x_{ijk} \geq y_{ijc}$	$i \in s(0) \cup P^o \cup D^o \cup H^{IE} \cup H^{IF}; j \in V; c \in C; i \neq j$	(38)
$\sum_{k\in K} x_{ijk} \geq y_{ijc}$	$i \in V; j \in P^i \cup D^i \cup H^{OF} \cup H^{OE}; c \in C; i \neq j$	(39)
$T_{jk} \geq T_{ik} + t_{ij} - M(1 - x_{ijk})$	$i,j \in V; k \in K; i \neq j$	(40)
$T_{ik} = L_{ic}$	$i \in P \cup D \cup H; k \in K; c \in C$	(41)
$s_i \leq T_{ik} \leq e_i$	$i \in s(0) \cup e(0); k \in K$	(42)
$x_{ijk} \in \{0,1\}$	$i,j \in V; k \in K$	(43)
$y_{ijc} \in \{0,1\}$	$i,j \in V; c \in C$	(44)

The objective function deals with the minimization of the total operating and waiting time of the trucks. While constraints (16) to (33) assure the containers' routes, (34) to (44) guarantee the routes of the trucks. Thus, (16) states that every pickup and delivery node is visited once by a container. Restrictions (17) and (18) assure that the terminal is either visited or left once according to the export or import vertices. The starting and end nodes of the different kinds of containers are guaranteed by restrictions (19) to (26). Thereby IF containers need to be moved from the terminal to the delivery customers. While IE containers can be transported to ingoing pickups nodes or the depot, (21) states that additional empty containers originate from the depot. The three types of containers are not allowed to start their tour from a different starting node stated by (22)-(24). Constraints (25) and (26) assure that the containers will end their tour either at the depot or the export terminal. While route continuity is stated by (28) restriction, (27) ensures that a container visits the related node of a pickup, terminal or delivery node and furthermore passes the filling and emptying process of the container. According to these restrictions the time continuity ((29-31)) and the service time for the loading and unloading operation at the pickup and delivery nodes ((32)) have to be held. Finally, restriction (33) assures that a container reaches a location in its defined time window. The truck constraints (34)-(44) are comparable to the restrictions for the distinct container problem. Attention should be paid to restrictions (38), (39) and (41) which assure that the trucks are interlinked with the containers and pass every location at the same time. Hence, the trucks cover the containers' routes but can skip the waiting time at the pickup and delivery vertices.

5. CONCLUDING REMARKS ON FUTURE RESEARCH

The models presented in Section 4 deliver a precise formulation of the ICT problem with and without container sharing. The problem is interesting from a theoretical point of view since there are two levels of transportation planning which are intervolved with each other and have to be matched together. On the lower level there is the resource planning for the containers which are to be used for transportation, and on the upper level there is the resource planning for the trucks that are needed for the movement of the containers which are planned for transportation. CPLEX has been used for the solution of small instances of models presented in Section 4. By comparing the results of the solutions of instances of the distinct container problem with the results obtained by the solutions of instances of the shared container problem the benefit of container sharing can be estimated and analyzed in dependence of the characteristics of the given problem instances. This benefit is measured with respect to the reduction of the transportation costs for inland container transportation in a local area. Unfortunately, CPLEX is only able to solve small problem instances of the ICT problem. We assume that the benefit reached by container sharing is relatively small for undersized problem instances and will grow tremendously when the problem instances become bigger and bigger. In order to check this assumption in our future work we will develop heuristic approaches for the solution of the ICT problem for both scenarios, with and without container sharing.

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6. REFERENCES

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