



Repair Cost Minimization Problem for Containers: A Case Study

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Abstract. With the increase of global trade activities and the decrease in transportation costs, the volume of international trade has grown considerably, yielding to an increase in the logistics activities as well as the number of containers used in transport. Hence, containers gradually deteriorate over time and logistics companies start to diminish the repair costs of the containers, as well. This study addresses the repair cost minimization problem for containers where the objective is to minimize the total transportation, repairing and delay time costs. The problem is formulated as a variant of the well-known transportation problem, where we assume that the broken containers transport to repair depots, and the fixed containers are delivered from the repair depots to the customers until the requested due date. In order to monitor the performance of the proposed model, realistic test instances are constructed. Optimal solutions are achieved within 40 min for relatively small and moderate test instances.

Keywords: Logistics · Transshipment problem · Broken container repair
Cost minimization · Delay cost

1 Introduction

Along with the change of the world, the methods of competition of the enterprises also change rapidly. A growing importance of speed, agility and fierce competition in the global supply chain force companies to reconsider using traditional logistics services. As a result of the increase in both market competition and service level expectation of the customers, logistics service providers are forced to re-evaluate and concurrently improve their business services. The main goal in logistics is to reach a high level in customer service, to optimize the use of resources and investments, and to gain competitive advantage in this way. In order to establish the freight transportation in global manner, logistics providers should serve for complex networks with a large number of routing alternatives, which are mainly carried out by different transportation channels, including a collection of truck, rail, barge, air, and ship. Through containerization, all competitors have potentially the same level of access to an efficient and global freight distribution system through ports [1]. Therefore, containerization has become the main driver for global intermodal freight transport, which involves the

transportation of freight in containers of standard dimensions with the consideration of high level safety and environmental issues. Many containers are made from materials such as steel, aluminum, and these large boxes gradually deteriorate over time. Considering the damage level and repair alternatives as well as the coordination with the repair centers, the management of the repair operations for containers is a complex issue. Motivated from a real-life problem of a leading logistics company located in Izmir, Turkey, this study is focused on the assignment of broken containers to related repair centers and sending them to the related customers at a minimum cost.

The rest of the paper is organized as follows. In Sect. 2, literature review is proposed. The problem and its characteristics are defined in Sect. 3. The mathematical model is presented in Sect. 4. Section 5 includes the computational study where the solutions of sample problems are listed, tabulated and discussed. Finally, Sect. 6 includes our concluding remarks and future work.

2 Literature Review

Reinhardt et al. studied the drayage problem with the objective of reducing the efficiency of pre- and end-haulage bottlenecks. In this study, the pre- and end-haulages of containers are scheduled using techniques of vehicle routing problems since the problem is based on the movements between the customers and the depots. It has been shown that the model can be easily solved using column enumerating since the number of possible paths in the problem is limited. The effect of side constraints on overall cost has also been analyzed [2].

Häll et al. design vehicle routes and schedules for a dial-a-ride service where some part of each request may be performed by a fixed route service. Passengers can go from one place to another without changing the vehicle, however they can also exchange vehicle. Each request contains one or several passengers and requires a certain capacity in a vehicle, for the persons and any wheelchairs, walkers, luggage etc. They assume that all vehicles have the same capacity and the aim is to minimize the total routing cost [3].

Kiremitci et al. study one of the most important types of vehicle locating problems. The multi-vehicle distribution and collection problem with time windows, where the objective is minimization of total transport costs as well as the number of vehicles required, balancing routes for travel time and vehicle load. The number of variables is reduced by using real values as much as possible. New algorithms approaches are compared with old ones on some problems in the literature and it is observed that the proposed algorithm gives relatively better results [4].

Hlayel and Alia studied the transportation problem with the objective of reducing the transportation cost and time. The most important way of achieving the solution by the best candidate method (BCM) is to start with selecting the most suitable candidates and reduce the solution combinations accordingly. Combinations can be obtained without any means of intersection. By comparing the results obtained, the implementation of BCM in the proposed method achieves the best first applicable solution for a transport problem and achieves faster than current methods with minimal computation time and less complexity [5].

Eliyi et al. model the transfer problem of a company with a transfer warehouse with many subcontractors and customers in the transfer sector. Taking into account the supply times and the customer's deadlines distinguishes the work from others [6].

3 Problem Definition

As the need for containers increases during transport, the container damages increase accordingly. Logistics companies are trying to repair the broken containers in the shortest time and with the minimum cost and deliver them to the customers. Motivated from the real-life problem of the logistics company, who is serving as a pioneer of the maritime transportation business in Turkey, the decision of where and when to repair the broken containers is a complex issue. The problem is formulated as a transshipment problem, which is a variant of a transportation problem, where the source nodes are the points where the container is broken, and the sink nodes refer to the customer locations. The intermediate nodes between the source and sink nodes, i.e., transshipment points, denote the repair centers. Our problem differs from the classical transshipment problem, since time windows should also be considered. Time window restrictions imply that the customer containers need to arrive within a certain period of time. Moreover, each customer has a due date and additional penalty costs are incurred for each delay. In this direction, a solution method should be developed to minimize the problem of container repair, which is a problem that arise in real life.

4 Mathematical Model

The following section describes our mathematical model. The problem is formulated as a transshipment problem where the objective is to minimize the total transportation, repairing and delay time costs. The mathematical model decides on how to transfer the broken containers from the breakdown points to one of the suitable depots and then to one of the candidate customers. We assume that there are three different vehicle types used for carrying containers from/to depots, breakdown points and customers. The indices and parameters used in the model of transshipment problem are defined as below:

- i : breakdown point index
- j : depot point index
- k : customer point index
- S_i : The number of total containers in breakdown point i
- D_k : The number of demand of customer k
- RT_j : Repairing time of depot j
- TT_{ij} : Transportation time from breakdown point i to depot j for truck
- TT_{jk} : Transportation time from depot j to customer k for truck
- ST_{ij} : Transportation time from breakdown point i to depot j for ship
- ST_{jk} : Transportation time from depot j to customer k for ship
- RT_{ij} : Transportation time from breakdown point i to depot j for train

- RT_{jk} : Transportation time from depot j to customer k for train
- WT : Waiting time of container, including the waiting time of the vehicle and in the queue
- DD_k : Due date which is given by customer k
- t : Delay time of container
- tc : Cost of delay
- C_{ij} : The transportation and repairing cost for truck from i to j
- X_{ij} : The transportation and repairing cost for ship from i to j
- Y_{ij} : The transportation and repairing cost for train from i to j
- C_{jk} : The transportation cost for truck from j to k
- X_{jk} : The transportation cost for ship from j to k
- Y_{jk} : The transportation cost for train from j to k
- QT_{ij} : The number of broken container which is transported by truck from i to j
- QT_{jk} : The number of fixed container which is transported by truck from j to k
- QS_{ij} : The number of broken container which is transported by ship from i to j
- QS_{jk} : The number of fixed container which is transported by ship from j to k
- QR_{ij} : The number of broken container which is transported by train from i to j
- QR_{jk} : The number of fixed container which is transported by train from j to k

Decision variables are defined as follows.

$$T_{ij} = \begin{cases} 1, & \text{if the container which is transported by truck from breakdown point } i \text{ to depot } j \\ 0, & \text{otherwise} \end{cases}$$

$$S_{ij} = \begin{cases} 1, & \text{if the container which is transported by ship from breakdown point } i \text{ to depot } j \\ 0, & \text{otherwise} \end{cases}$$

$$R_{ij} = \begin{cases} 1, & \text{if the container which is transported by train from breakdown point } i \text{ to depot } j \\ 0, & \text{otherwise} \end{cases}$$

$$T_{jk} = \begin{cases} 1, & \text{if the container which is transported by truck from depot } j \text{ to customer } k \\ 0, & \text{otherwise} \end{cases}$$

$$S_{jk} = \begin{cases} 1, & \text{if the container which is transported by ship from depot } j \text{ to customer } k \\ 0, & \text{otherwise} \end{cases}$$

$$R_{jk} = \begin{cases} 1, & \text{if the container which is transported by train from depot } j \text{ to customer } k \\ 0, & \text{otherwise} \end{cases}$$

Based on the definitions above, the MILP formulation of the problem is as follows.

$$\begin{aligned} \text{Min } & \sum_i \sum_j C_{ij} * QT_{ij} + \sum_j \sum_k C_{jk} * QT_{jk} + \sum_i \sum_j X_{ij} * QS_{ij} + \sum_j \sum_k X_{jk} * QS_{jk} \\ & + \sum_i \sum_j Y_{ij} * QR_{ij} + \sum_j \sum_k Y_{jk} * QR_{jk} + t_c * t \end{aligned} \tag{1}$$

s.t.

$$T_{ij} + S_{ij} + R_{ij} \leq 1, \quad \forall i, j \tag{2}$$

$$T_{jk} + S_{jk} + R_{jk} \leq 1, \quad \forall j, k \tag{3}$$

$$\sum_j (QT_{ij} + QS_{ij} + QR_{ij}) \leq S_i, \quad \forall i \tag{4}$$

$$\sum_j (QT_{jk} + QS_{jk} + QR_{jk}) \geq D_k, \quad \forall k \tag{5}$$

$$\sum_i S_i = \sum_k D_k \tag{6}$$

$$\sum_i (QT_{ij} + QS_{ij} + QR_{ij}) = \sum_k (QT_{jk} + QS_{jk} + QR_{jk}), \quad \forall j \tag{7}$$

$$QT_{ij} \leq M * T_{ij}, \quad \forall i, j \tag{8}$$

$$QS_{ij} \leq M * S_{ij}, \quad \forall i, j \tag{9}$$

$$QR_{ij} \leq M * R_{ij}, \quad \forall i, j \tag{10}$$

$$QT_{jk} \leq M * T_{jk}, \quad \forall j, k \tag{11}$$

$$QS_{jk} \leq M * S_{jk}, \quad \forall j, k \tag{12}$$

$$QR_{jk} \leq M * R_{jk}, \quad \forall j, k \tag{13}$$

$$\begin{aligned} RT_j + (TT_{ij} * T_{ij}) + (TS_{ij} * S_{ij}) + (TR_{ij} * R_{ij}) + (TT_{jk} * T_{jk}) + (TS_{jk} * S_{jk}) + (TR_{jk} * R_{jk}) + \\ WT - (DD_k + M * (1 - (T_{ij} + S_{ij} + R_{ij}))) \leq t, \quad \forall i, j, k \end{aligned} \tag{14}$$

$$T_{ij}, T_{jk}, S_{ij}, S_{jk}, R_{ij}, R_{jk} \text{ binary}, QT_{ij}, QT_{jk}, QS_{ij}, QS_{jk}, QR_{ij}, QR_{jk}, t \geq 0 \text{ integer}, \quad \forall i, j, k \tag{15}$$

The objective function in (1) minimizes the total transportation, repairing and delay time costs. Constraint set (2) enforces that every container must be transported with at most one transportation way (either with land route, shipping way or railway) from breakdown point i to depot point j . Constraint set (3) satisfies that every container must be transported with only one transportation way (land route, shipping way or railway) from depot point j to customer k . Constraint sets (4) and (5) ensure that the broken containers on the breakdown point i are transferred to the relevant customer point k . Constraint set (6) satisfies the supply and demand equality at breakdown and customer points. If a container transports to depot j , it should be send to the customer at

depot j . Constraint set (8–13) calculates the total number of containers transferred via each vehicle type. Constraint set (14) ensures that the total repair time for all depots, transshipment times between breakdown points and depots and customers should be smaller or equal to the due date of customers k . Finally, constraint set (15) defines the decision variables.

5 Computational Results

The performance of the proposed mathematical model is tested on several test instances generated by realistic assumptions. The proposed mathematical model is solved using IBM ILOG CPLEX Optimization Studio 12.7.1 on a computer with an i7 processor and 16 GB of RAM. The smallest test instance includes 2 different container breakdown points, 3 different repair depots and 2 different customer points. Then, the instance is extended with 3 and 4 broken containers at each point. Figure 1 visualizes all possible combinations of the smallest instance tested.

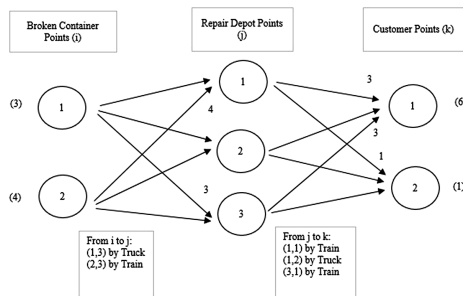


Fig. 1. Network diagram of the toy data solution

The performance of the proposed model is observed in larger test instances. The properties of the large test instances are reported in Table 1. The case of where 10 breakdown, repair and customer points are considered can be denoted as *small*, and the remaining two cases, i.e., with 20 and 30 points in each, are labeled as *moderate* and *large*, respectively. We also expand our computational experiment by employing the number of broken container at each breakdown point as 1, 2 and 3, respectively. All test instances are solved optimally by CPLEX and Tables 2, 3 and 4 report the computational time performance of each problem tested. Note that, the computational time gradually increases as the problem size increases, as expected. The computational time performances of *small* and *moderate* cases are comparable (see Tables 2 and 3). Especially with 30 breakdown points, 30 depots and 30 customer points the solution time increased exponentially as the number of broken containers increased.

Table 1. Characteristics of the large test instances

Number of breakdown points	Number of repair depots	Number of customer points	Number of broken container
10	10	10	1
10	10	10	2
10	10	10	3
20	20	20	1
20	20	20	2
20	20	20	3
30	30	30	1
30	30	30	2
30	30	30	3

Table 2. Computational results for the test instances with 10 points

Number of broken container	Time (in sec)
1	85
2	753
3	1298

Table 3. Computational results for the test instances with 20 points

Number of broken container	Time
1	322
2	545
3	2379

Table 4. Computational results for the test instances with 30 points

Number of broken container	Time
1	2376
2	7510
3	21072

6 Conclusions

In this study, minimization of the transportation and repair costs of containers, which is one of the real-life problems, has been discussed. The problem is formulated as a variant of the transshipment model and solved optimally by IBM ILOG CPLEX Optimization Studio 12.7.1. The test problems with various sizes are constructed so as to reflect the real-life complexity. We can deduce that the model yields similar performances on relatively small and moderate test instances, whereas the computational time performance is low for larger test problems.

Since assignment of the broken containers is an operational level decision making as the future extension, sophisticated heuristic methods can be applied to obtain good quality solutions within reasonable time. Moreover, the formulation can be extended by using the real-time availability on each repair depot.

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