

Collaborative Planning in Intermodal Freight Transportation

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Abstract: Very few research efforts have been spent on the coordination of plans and operations of independent carriers in an intermodal transportation chain. The impact of this lack of collaboration and coordination is shown in an accordant scenario and first ideas are presented to overcome this situation following the principles of decentralized planning.

1 Introduction

Intermodal freight transport can be defined as transportation of goods in one and the same loading unit or vehicle using successively at least two modes of transportation. The different tasks along the transportation chain are mostly executed by several operators that can be distinguished in drayage, terminal, network, and intermodal operators [MB04]. Drayage operators are responsible for carrying the freight between shippers and receivers, respectively and a terminal. At the terminal the modal shift takes place managed by terminal operators. Network operators take care of the infrastructure planning and long haul transport between terminals whereas intermodal transport operators conduct route selection for shipments through the whole intermodal network.

In the following we will not consider the terminal operators but focus on drayage and intermodal operators. Moreover the examination is limited to container transport.

Until now very few research efforts have been spent on the intermodal chain and the management of interdependencies among activities e.g. the coordination of plans and operations of independent carriers [CK05]. Macharis and Bontekonig [MB04] give a review of opportunities in intermodal freight transportation research and state that nearly always distinct operators are treated separately in scientific attempts. But the many decision makers in the transport chain need to work in collaboration to secure the system to run smoothly and with minimum costs. Therefore more cooperative decision-making support tools are required.

Within this paper it is shown that this lack of collaboration and coordination leads to sub-optimal results for the whole transportation chain and first ideas are presented to overcome this situation.

2 Description of the Planning Problem

A network consisting of various customer locations and a terminal in each of two remote regions A and B is given. The regions are connected via long haul transportation among the two terminals. Any of the three transport stages is operated by organisationally independent transportation service providers: Drayage and network operators. Besides, an intermodal operator is committed to plan the transportation of a number of shipments among the regions. In the following we presume an Intermodal Marketing Company (IMC) i.e. an intermediary that provides door-to-door intermodal services by purchasing transportation from a variety of carriers.

An order is typically specified by a container having a pickup location in A and a delivery location in B and vice versa. Moreover, a time window states an earliest pickup and a latest delivery period. Within the regions containers are hauled by motor carriers via trucks that can transport at most one container at a time i.e. full truckload transports are considered.

In the following only drayage operators will be examined for coordination because for long haul a regular liner service (e.g. an ocean liner or train service) is presumed.

In each planning period a capacity contingent of the carrier A's and carrier B's transportation capacity (in region A and B, respectively) is granted to the IMC. Up to this amount the carrier has to fulfil the tasks of the IMC at a predefined price per distance unit, for excess capacity a higher price can be charged. Within one region the IMC collaborates exclusively with the carriers i.e. there is no competition, but the carriers serve other customers besides the IMC, too. Moreover the carriers have the possibility of outsourcing transportation requests. Of course this is more expensive than using own capacity.

The aim of the planning problem of this paper is to provide a container shipment plan minimizing the total cost of the transportation chain over a planning horizon while meeting on-time delivery requirements and transportation capacity restrictions.

2.1 Initial Situation

Due to private information resulting from the organisational independency the IMC has no knowledge about the carriers' capacities given by the number of available trucks and drivers and already accepted orders from customers besides those from the IMC. Consequently transportation plans are generated decentrally and successively: The IMC plans the amount of their transfer orders (A_{IMC}) based on a mixed-integer programming (MIP) model and the objective of cost minimization meeting given time windows and capacity restrictions. Costs are thereby incurred for the long haul lines, additional capacity, storage at the terminals, and for empty travelling. The first three cost factors are evident, but maybe not the last one where the IMC anticipates the routing of the carriers. The motivation for this is taken from Ergun et al. [EKS07] where shippers identify and submit tours of (nearly) continuously loaded movements to the carriers' i.e. tours with a low fraction of empty travelling. Thus, the carriers' need for repositioning is lowered and consequently the carriers' costs are reduced. The resulting savings for the carriers may be returned to the shippers partly in the form of lower prices. In the setting examined here the IMC could also try to negotiate lower prices for nearly continuously loaded tours.

The resulting long haul lines for each container and following reduced time windows for the feeder transports are transmitted to the regional motor carriers. The carriers now plan decentrally with their total amount of orders ($A_{carrier} \supseteq A_{IMC}$). Again planning is supported by a MIP model with the objective to minimize costs. Holding and empty travelling costs are taken into account, time windows are met and outsourcing is allowed. Due to the fact that only transports from/to the terminal exist, pickup and delivery combinations are built for tours. Without loss of generality it is assumed that the duration of a tour does not exceed more than one period.

2.2 Need for Coordination - Numerical Tests

Because of the interdependencies of the carriers' and the IMC's planning models successive planning commonly leads to suboptimal results. For example it could be that due to the line presetting by the IMC the optimal (and also feasible) transportation plan of a carrier is no more realizable, and of course it is also possible that the optimal plans of both carriers are not compatible. Additionally, the IMC may choose too expensive lines because of the contingent restriction. The impact of these interdependencies on the overall costs was investigated in numerical tests. In the following main attributes of the test data are described: In each instance transportation plans for 100 carrier orders (half the orders in each direction) over 10 planning periods have been generated, whereof 50 of the orders are equivalent to the IMC orders. Time windows were set varying from 2 to 6 periods for the IMC orders and from 1 to 4 periods for the pure carrier orders. For long haul 3 lines varying in duration (from 1 to 2 periods), price, and frequency are given for all instances. Moreover, the IMC's contingent at a carrier in each period is set to 60% of the maximum travel distance that would be needed to fulfill all IMC orders (i.e. without any pickup and delivery combination) divided by the number of periods. Additional capacity for the IMC is available at an extra charge of 30% and the carriers' costs for outsourcing an order come up to the costs of a combination with the dummy node.

The resulting variable transportation chain costs were calculated for 50 instances by successive planning as described in section 2.1. For reference the decentrally generated results are compared with the overall costs of the corresponding central planning model providing the best achievable solution.

Comparing the results of successive planning with the central solution it was shown that the regarded costs of the former are on average by about 16% higher.

3 Collaborative Planning

Due to information asymmetry and the necessity to plan decentrally the plans resulting from successive planning are suboptimal. This shows the need for Collaborative Planning. Collaborative Planning is defined as "a joint decision making process for aligning plans of individual supply chain members with the aim of achieving coordination in light of information asymmetry" [Sta07]. In the scenario examined the alignment of plans takes place via target time windows allowed to the carriers.

For the case of aligning production plans Dudek and Stadler [DS05] have shown that it is possible to approximate the central optimum through decentralized planning by means of negotiations. The central idea of the negotiation scheme is that the supply chain partners try to find out modified supply and order proposals which lead to substantive cost savings for themselves and to low cost increases for the partner. In the course of negotiations only purchase and supply plan proposals as well as cost effects are exchanged i.e. no critical information.

Because of the differing planning problems considered in this paper the coordination scheme is not easily transferable to the intermodal scenario. In contrary to the production scenario, a kind of a central decision maker (i.e. the IMC) exists besides the carriers in the transportation chain having a wide influence on the decision space of the carriers. Thus, the IMC has to be included in the mechanism, too.

In the developed mechanism incentives are incorporated in the IMC's planning model. These incentives are provided by the carriers and try to influence the IMC to consider the carriers' preferences also.

4 Further Research

Further numerical tests have to be conducted to validate the coordination scheme. In addition, the scenario could be further extended i.e. for orders within the region not starting or arriving at the terminal or less-than-truckload transports within the regions.

Another important question arising in this context is how to share the resulting savings and to secure that the mechanism can handle opportunistic behaviour of the actors. Moreover, the solution procedures of the underlying mathematical models will be investigated.

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