Extending Vehicle Routing by Collaboration and Sub-contraction:
Experiments for the estimation of the efficiency improvement

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Transportation planning requires both, decisions on the choice of transport resources and decisions on the deployment of the chosen resources. Therefore, transportation orders must be assigned to resources for fulfillment while the operations for the usage of each resource have to be planned. Most freight forwarding companies have to cope with a strongly fluctuating demand on the transportation market which varies considerably over time. Aside from these market-fluctuations they have to manage the daily variations of their volume of orders. Therefore, freight forwarding companies have to ensure that enough resources will be provided. On the other hand, the fixed costs of the own vehicle fleet force to reduce the number of own vehicles since it makes no sense for a forwarder to provide enough transportation capacity capable to cover the peaks of a volatile volume of orders. A rigorous reduction of the own fleet size is mostly profitable because it allows the so called cherry-picking which means to perform only the most suitable requests in a very efficient manner by self-fulfillment. But cherry-picking does not really make sense unless the remaining requests are fulfilled in a cost-efficient way as well. Usually, only a part of the upcoming requests is fulfilled by own transportation resources. The remaining part of requests is either fulfilled by entrusting external freight carriers (subcontracting) or by exchanging requests within a coalition of collaborating forwarders. These two different approaches for "external freight fulfillment" result in specific extensions of the common planning problems for vehicle routing. Besides the possibility to fulfill additional requests which would otherwise exceed the own transportation capacity, the approaches for external freight fulfillment can be used to improve the quality of transportation planning.

The efficiency of transportation planning can be increased drastically by extending the usual vehicle routing and scheduling problems by the possibilities of collaborative planning and of subcontracting. Both types of problem extension transform the usual vehicle routing and scheduling problems to more general operational transportation problems. In this contribution, we analyze the motivation, the chances, the realization, and the challenges of the general operational transportation planning problems obtained by the above extensions. We report on experiments for combining several isolated vehicle routing problems of single partners to a common problem (Krajewska et al. 2008) and we report on experiments for extending the plain vehicle routing problem to an enlarged problem with combined forwarding by means of different sub-contraction types (Kopfer and Wang 2009).

We present an approach for collaborative operational transportation planning and then we analyze this approach from the perspective of game theory (Krajewska et al. 2008). The synergy (i.e. the positive effect of collaboration) is reached by adjusting the planning processes between the partners belonging to a closed coalition. The adjustment refers to the exchange of transportation requests. The exchange-process is realized by performing a combinatorial auction which all the partners of the coalition participate in. Of course, the amount and the type of planning information exchanged between the partners are to be minimized although the coalition is not open to foreign forwarders or carriers. The improvement reachable by this approach is exemplarily demonstrated by computational experiments on well-known benchmark data and on some practical data from a German forwarder. The experiments show that the resulting transportation plans are much more efficient than the isolated planning without collaboration. But the introduced form of collaboration by means of combinatorial auctions requires that the partners can dispose of flexible resources with an extremely varying number of available vehicles (i.e. a flexible size of the fleet) because they do not know in advance the outcome of the auctions and they possibly might win much more bids for transportation requests than they expected at the beginning of the auction. So, they might be in need of much more vehicles than available and even in much more vehicles than they would ever have been able to provide by their own fleet. This necessary flexibility with respect to the transportation capacity can be reached by introducing the second type of extension, i.e. forwarding.

Using own vehicles for the execution of requests is called self-fulfillment, while the forwarding of transportation requests to external carriers is called subcontracting. Forwarding allows the outsourcing of requests as an alternative for using vehicles of the own fleet and is used for the fulfillment of additional transportation requests whose acceptance would exceed the capacity of the own fleet. Especially, the possibility of forwarding requests is a prerequisite for a collaborative approach realized by combinatorial auctions.

The problem extension realized by forwarding in (Kopfer and Wang 2009) is formalized as a mixed integer linear programming model and it is solved by a commercial mathematical programming solver. The computational results show tremendous costs savings even for small problem instances by allowing subcontracting. Additionally, the performed experiments for the operational transportation planning are used for an analysis of the decision on the optimal fleet size for own vehicles and regularly hired vehicles.

Extending the usual planning problems of vehicle routing and scheduling by the additional possibility of subcontracting a part of the requests raises two main questions for the research on operational transportation planning. The first question concerns the long-term planning horizon and refers to the optimal size of the own fleet. The second question affects the short-term planning horizon and applies to the selection of requests to be performed by self-fulfillment and those to be fulfilled by subcontracting.

The complex selection decision for self-fulfillment or sub-contraction has to take into account dependencies among all available requests since they are to be clustered to common bundles and the resulting transportation costs depend on the bundling performed by the dispatchers of the freight forwarding company. The process of constructing an entire fulfillment plan for self-fulfillment and sub-contraction with the highest reachable quality corresponds to solving the combined vehicle routing and forwarding problem which is also called the integrated operational transportation problem (IOTP). Although this problem is very important for forwarders in practice there exist only few approaches that investigate and solve that problem in literature. A survey of existing approaches can be found in Kopfer and Krajewska (2007).

Caused by the tendency to outsource a tremendous part of the daily transportation requests to external carriers, the need for solving the IOTP in practice is even soaring. The IOTP concerns almost all forwarders with an own fleet of vehicles. For each request to be executed during the next planning period they have to choose an appropriate mode of fulfillment, i.e. they must decide whether a request should be executed using own resources or whether it should be forwarded to an external carrier. In order to minimize the costs of the own fleet, the forwarders have to solve a usual vehicle routing and scheduling problem for all those requests that are dedicated for self-fulfillment. The fulfillment costs incurred by the engagement of carriers can also be influenced for the set of all forwarded requests by means of a skillful operational planning of the employment of subcontractors. This usually can be reached by building favorable bundles of requests which are tied together and are assigned to be forwarded to an elected carrier. The corresponding planning process is called freight consolidation. The goal of the forwarder during the freight consolidation process is to minimize the incurring external freight costs. The solution space of the freight consolidation problem is built by all feasible choices on different possibilities of concentrating requests to bundles and all choices on assigning the constructed bundles to elected carriers of diverse types.

In a collaborative planning scenario each partner of the coalition has to solve its own IOTP and then has to adapt this plan with the other partners in order to gain additional profits.

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