Metaheuristics for the integrated operational transportation planning problem: An Overview

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Abstract: In this paper we present the integrated operational transportation planning probem as the extention of the traditional pick-up-and delivery-problem-with-time-windows. The extention consists in the possibility of forwarding the requests to subcontractors on different terms: from the simple forwarding of single requests at the defined costs to the most complex integrated freight optimisation problem. Different types of approaches based on metaheuristics have been applied to the problem: from the savings algorithm up to the tabu search and complex memetic algorithm. They also diversify with respect to different types of integration: hierarchical or simultaneous planning is the matter of consideration. We present the comparison of existing approaches and the results that they generated.

Keywords: tabu search - vehicle planning - outsourcing - pick-up-and-delivery-problem-with-time-windows - logistics

1 Introduction

A great number of enterprises source the transportation tasks out by hiring independent freight carriers to execute the necessary transport activities. Independent shipment contracts of different types and specifications are then awarded for completion. We assume a customer request to be a delivery request describing a single transportation demand, which typically results in the direct transportation process of carrying less-than-truckload packet from the pickup location to the delivery location [10].
The location of pickup and the location of the delivery are specified as well as the quantity to be moved. Furthermore, time limits for the loading and unloading operation are usually declared. A carrier company should fulfill the customer demands using the available resources in an efficient manner. Two models of the order fulfillment are available for the freight carrier. Own vehicles can be used for the execution of corresponding tasks. Otherwise, another carrier (called a logistics service provider) receives a charge for the request fulfillment [12]. In order to realize the profit the freight carrier has to generate the positive difference between the transaction volume and the costs. Turnover results from the constant long-term tariffs for the customers and cannot be influenced on the operational level. Furthermore, the operational planning does not incorporate long-term decisions relative to overheads. Therefore, a decision whether a logistics service provider is incorporated or own resources used as well as the dispatching of the orders are based on the relevant variable costs.

2 Assumption of the integrated operational freight carrier planning model

The main objective of the integrated operational freight carrier planning model is to find a partition of the portfolio into tariff-fulfillment clusters that can be fulfilled with minimum costs [4].
The costs of the usage of own resources are calculated on the basis of a constant tariff per

distance unit. The distances result from routing and scheduling a fleet of homogenous vehicles with given capacity. The research for the direct delivery requests is focused on the pick-up-and-delivery-problem-with-time-windows (PDPTW).
There are different models for the calculation of the costs of incorporating a logistics service provider. The disposal of a single request at a competitive price results from the subcontractor's vehicle capacity utilization. In case of selling the request separately on the spot market, the fixed price for the fulfillment is needed. Thus, the characteristic of a request is augmented with the constant value describing the execution costs of this request on the spot market. The second possibility to make a profit in case of incorporating a logistics service provider results from freight flow consolidation [3] [4]. The less-than-truckload requests are bundled and a least cost flow through a given transportation network is searched. As in case of the usage of own resources, the marginal costs of a single request refer to the additional travel cost of the used vehicle. But, the costs can be calculated either in consideration of the sole constant tariff per distance unit or in accordance with the tariff which covers the distance and the loading weight. In the further case, the hole vehicle is leased from the subcontractor and the costs are calculated on the same way as in case of vehicles in the own vehicle fleet. The parametrised subcontraction combines the different possibilities.
Two additional assumptions of practical relevance can be introduced to the model. The first one should imply that the number of vehicles in the own vehicle fleet is limited. In the second case, a certain amount of requests is subject of fulfillment by the own vehicle fleet. The compulsory self-execution of orders results mostly from eliminating the risk factor particularly in accordance with the strategic clients.
Two different techniques can be used to plan the requests. The traditional hierarchical method assumes that the requests are assigned to one of the clusters at first: either to the self-fulfilment- or to the subcontraction cluster. Then the optimisation is accomplished inside the clusters. The second method of simultaneous planning is more complex. In this case the requests are the subject of switching between the particular routes of an own vehicle and one of the subcontractor. It means that the assignment to the cluster as well as optimisation process inside the clusters run pararely.

3 Existing approaches

The integrated operational freight carrier planning problem is NP-hard, therefore the solution should be based on metaheuristics. A few types of heuristics have been taken into consideration since early nintees as the problem was first presented. All the authors have modelled the standarised pick-up-and-delivery-problem-with-time-windows in the self-fulfillment cluster. The two aspects that vary in the models are: the type of subcontraction and the type of integration of both clusters.
In the simpliest models it is assumed that the requests are schifted to the subcontractor independently, on uniform conditions [10] [2]. Secondly, only complete tours are subject of forwarding to the subcontractor, which means that the vehicle is leased [9] [11].
Parametrised subcontruction was introduced by [12]. At first, the freight costs are calculated as for the isolated forwarded requests, on the basis of a linear function and then multiplied with the adjustment parameter, generated on the basis of the distance for the round trip of the vehicle that fullfills all the requests. The parameter is defined as follows:
$\gamma = \frac{driven\, distance\, of\, the\, round\, trip}{sum\, of\, demanded\, distances\, of\, single\, requests}$
The most complex model was presented by [8]. The costs for subcontraction of bundled requests are calculated in line with the freight optimisation tariff with two variables: distance and weight. Time window constraints are not considered.
The method of integration of both clusters is implied by the used heuristic. A hierarchical approach is presented by [1], where the heuristic, similar to the savings-algorithm is introduced. At first, it is assumed that the freight costs are always higher than the costs of fulfillment by the

own truck. Therefore, the customers are sorted in ascending order based on the freight charged. If the demand is greater than the capacity of the own fleet, then the requests with the lowest freight costs are forwarded to the subcontractor. Secondly, the refining procedure runs only for the routes of the own vehicles and combines intra-route and inter-route improvements.
In [8] a semi-hierarchical planning within the usage of a genetic algorithm is introduced. The individuums of the population only represent the set of assignments of the requests to one of both clusters, but the value assessment of the individuum is based on the approximation of costs for the complete schedule. In every next generation only the best assignment with the lowest costs are passed on. In the end, hill climbing algorithms are used to improve the best plan coupled with the individuum with the lowest costs.
A simultaneous approach within the usage of a memetic algorithm is presented by [12]. In this case the individuums represent the complete solutions: assignment of requests to the clusters as well as the schedules inside the clusters. As in [8] the best individuums are able to inherit, which contributes to the improvement of solutions in each next generation. At the end, the best solution is chosen and then hill climbing algorithms are used to improve and to repair the solution in case it is not feasible.
The more complex optimisation method, tabu search, that guarantees the simultaneous planning, was introduced by [2]. In the tabu search heuristic two types of neighbourhoods are defined: swapping pairs between the routes and single insertion within the route. Thus, in each iteration it is possible to change the position of a single request in a schedule of own fleet or to plan the request out of this schedule and assign it to the subcontractor. Due to such definition of the tabu search steps, the most unprofitable requets, which cause high costs for the own fulfillment are forwarded to the foreign carrier. On the other hand, the costs of subcontraction are treated as punishment costs, which guarantees the maximal capacity utilization of the own fleet.

4 Conclusions

Due to the rising competitiveness on the forwarding market, pressure of sinking costs of transportation request fulfillment and the rising importance of software for logistics and scheduling problems, the integrated operational transportation planning problem seems to be of high practical importance. Even though, it has been rarely mentioned in the literature. The existing models do not include all the aspects of this problem as they try to find compromise between the complexity of the heuristic and practical assumptions. Therefore, although all the models are benchmarked on the basis of the same theoretical test instances (see [7]), it is not possible to compare the results directly.

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