The cooperative facility location problem

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Severe competition in global markets and the heightened expectations of customers have caused profit margins of transport companies to shrink. In order to survive under the ever increasing pressure to operate more efficiently, they are obliged to adopt a collaborative focus. Companies operating at the same level of the supply chain may cooperate horizontally to increase their productivity, improve their service level and enhance their market position. This paper studies collaborative logistics from a carrier perspective. Existing scientific literature on the operational planning of carrier collaboration may be divided into multiple research streams distinguishing between various horizontal cooperation techniques.

One approach to horizontal carrier collaboration is the sharing of warehouses or distribution centres with partnering transportation organisations. This problem may be classified as the cooperative facility location problem [1]. By jointly and optimally deciding on which distribution centres to open and on the allocation of product flows, collaborating carriers aim to minimise the total logistics cost level. In this way, this problem is an extension of the general facility location problem, now with multiple independent companies owning already established distribution centres which may or may not be used in the cooperation. It is assumed that the supply network of this cooperative facility location problem consists of carriers transporting similar products to multiple customer zones. This transportation activity comprises of two stages, namely primary transport from each carrier's central depot to a number of distribution centres and secondary transport from these distribution centres to the different customer zones. The goal of the cooperative facility location model is to share distribution centres between participating carriers with the aim of reducing costs and improving distribution efficiency. The decisions to be taken relate to which cooperative partnership is formed (carrier selection), which distribution centres to open and the allocation of primary and secondary product flows. The problem may be mathematically formulated as a mixed integer linear programming problem (MILP).

To demonstrate the benefits of collaborative optimisation, we examine the cooperation potential of a U.K. case study consisting of carriers distributing similar products in two phases and employing multiple sourcing. We apply the cost minimising MILP to a supply network with three carriers A, B and C having their central depots located in Scotland, London and Wales respectively. The carriers that take part in the cooperation agree to share their distribution centres, which are spread around the U.K., with partner organisations for product distribution. Fixed costs, maximum capacities and location of the ten distribution centres are known in advance, as well as primary and secondary transportation costs. Transportation demand stems from ten different customer zones representing large geographical areas in the U.K. and is also known beforehand.

From an analysis of the main results of applying the cooperative facility location model to this case study, it appears that nine out of ten distribution centres need to be operational to minimise costs. Moreover, examining the product flows in detail shows that every carrier is willing to cooperate with each of the other carriers. This may imply that the grand coalition is formed. Next, a sensitivity analysis is performed to investigate the impact of increasing the fixed costs of setting up distribution centres, leaving all other data unchanged. As a consequence, changes arise in the design of the product distribution network connecting carrier depots, distribution centres and customer zones, in comparison to the original scenario. Carriers are still prepared to form the grand coalition though. It also remains optimal to open nine out of ten distribution centres, however the choice of distribution centre to be closed has changed. In addition, comparing the utilisation rates of the distribution centres with the original scenario results, reveals that the number of fully utilised distribution centres increases from five to seven. Distribution centres are thus better utilised in the sensitivity case to make up for their increased fixed cost level.

In order to ensure long-term stability of the cooperation project, the incurred logistics costs need to be allocated fairly to the collaboration partners. For this reason, Shapley value is applied to the minimal cost solution both for the original and sensitivity scenario, assuming that all companies cooperate. Based on the original case study Shapley allocations, it may be stated that the core is empty. Since subgroup rationality is not satisfied, carriers will have the incentive to leave the grand coalition and form subgroups as they are associated with lower cost levels. On the contrary, the Shapley allocations for the sensitivity case study ensure grand coalition stability. No individual nor any subgroup coalition will be better of acting alone. Comparing this result with the conclusion for the original case study clearly shows the importance of fixed costs to the decisions made by each participating carrier.

Références

[1] Goemans, M.X. and Skutella M. (2004). Cooperative facility location games. *Journal of Algorithms*, 50, 194-214.