# Tactical planning of a multi-period capacitated two-echelon distribution network with delivery patterns

Lucas Baussay[1,2], Audrey Derrien[1], Mike Hewitt[3,1], Fabien Lehuédé[1], Juliette Medina[2]

[1] IMT Atlantique, LS2N, Nantes, France

{lucas.baussay,fabien.lehuede,audrey.derrien}@imt-atlantique.fr

[2] CRC Services, Rueil-Malmaison, France

{l.baussay,j.medina}@crc-services.com

[3] Quinlan School of Business, Loyola University Chicago mhewitt3@luc.edu

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A shipper is a company which outsource its transportation to carriers to deliver its customers. Typically, in the retail industry, suppliers can ship several times a week small quantities (a few pallets) to multiple retailer warehouses and superstores. In order to reduce its cost and secure its contracts with its carriers, a shipper typically resorts to integrating a mix of carriers and transportation rates (full-truck load and less-than-truck load), together with consolidation on regional hubs and collaboration with other shippers. This leads to the definition of two echelon distribution networks. The planning of such distribution networks includes defining efficient load plans for long haul routes, freight consolidations on regional hubs and distribution routes from hubs to customers [3]. The overall objective is mainly to take decisions related to the booking of resources such as trucks or cross-dock capacities and organize a good collaboration with other shippers. In this context, we focus on several constraints that are seldom integrated in the operations research literature : (i) customers require some regularity : a commodity has to be delivered several times a week [1] on predefined days, (ii) shippers, hubs and customers have capacity constraints that model workload balancing requirements over the days of the week. Accordingly, given a set of suppliers, hubs and customers, given an order history of several weeks, we investigate the problem of assigning a set of delivery weekdays (called *delivery patterns* [2]) to each customer and for each commodity, in a two echelon distribution network, such that the sum of transportation costs are minimized and the capacity of each network node is respected.

## Problem description

We consider a two-echelon distribution network as illustrated on Figure (1). It is composed of a set of suppliers, a set of hubs, and a set of customers. Each customer is delivered by a single predetermined hub. On the first echelon (from suppliers to hubs), each supplier delivers each hub with direct routes. The cost of a direct route depends on a fixed cost per truck and

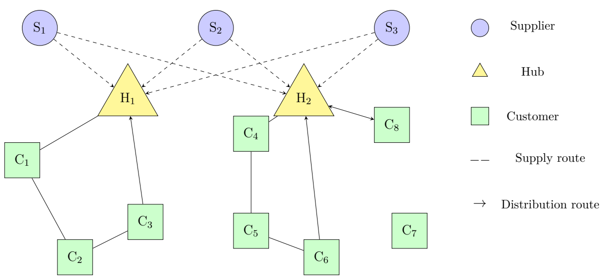


FIG. 1 – A two echelon distribution network

a variable cost per pallet. On the second echelon (from the hub to the customers), different vehicle routes starting at each hub deliver the hub customers. Vehicle routing costs at this echelon are calculated according to the travelled distance and the number of stops.

Each pair of customer and supplier is called an OD pair. Each OD pair has a quantity for each day of the time horizon. On each delivery, a supplier delivers the quantity needed to meet the daily demand of the customer for its product until the next delivery. The possible delivery weekdays which can be assigned to an OD-pair are called *delivery patterns*. If a delivery pattern is assigned to an OD-pair, the customer is delivered on the corresponding weekdays over the whole time horizon.

Each stakeholder (supplier, hub, customer) has a capacity constraint that prevents them from shipping or receiving more goods than they can process on each day. We introduce the P-2E-CDP (*Periodic - 2 Echelon - Capacitated Delivery Problem)* which consists of assigning a delivery pattern to each OD-pair and determining the first-echelon and second echelon routes for each day of the time horizon such that each demand is satisfied, the capacity constraints are satisfied for each stakeholder and the sum of transportation costs is minimized.

## Solution approach and first results

To solve this problem, the P-2E-CDP was first formulated as a mixed integer linear program (MIP). Second, we identified three types of valid inequalities (VI) to reinforce this formulation. To solve large instances, a decomposition based heuristic was devised with the following principle : A first phase selects a delivery pattern for each OD-pair assuming single customer routes at the second echelon. Based on these patterns, the second phase selects the best distribution routes for each day of the time horizon. Finally, this heuristic provides a feasible solution which is used to warm-start the solver.

TAB. 1 – Results and Gap to the best solution found

| Name | MIP | | VI | | Heuristic | | Warmstart | |
|---|---|---|---|---|---|---|---|---|
| | Cost | Gap to BKS | Cost | Gap to BKS | Cost | Gap to BKS | Cost | Gap to BKS |
| 1S_2H_5C | 11769 | 0.0% | 11769 | 0.0% | 25661 | 54.09% | 11769 | 0.0% |
| 1S_2H_10C | 26119 | 0.77% | 25917 | 0.4% | 39311 | 36.29% | 26018 | 0.53% |
| 4S_3H_10C | 95614 | 14.1% | 78634 | 0.45% | 110630 | 29.36% | 85432 | 8.22% |
| 4S_3H_15C | 454399 | 66.78% | 208597 | 27.62% | 175390 | 14.02% | 151529 | 0.0% |
| 6S_4H_15C | - | - | 341592 | 37.62% | 250630 | 16.43% | 209594 | 0.0% |
| 6S_4H_20C | - | - | 448180 | 43.71% | 287163 | 13.54% | 248655 | 0.0% |

These different approaches were validated on a set of instances that have been generated based on a use case of the CRC Services company. We defined six instances categories with varying number of suppliers (S), hubs (H) and customers (C), each containing three instances. Each model was solved with a time limit of two hours. Table 1 summarizes, for each method, the average cost per category and the average gap to the best found solution for each instance.

We find that the initial MIP model fails to find solution for the largest instance classes. One of the proposed valid inequalities provides a significant reinforcement which compensates this weakness. The performance of the proposed heuristic is still limited but it is useful to warm-start the solver. Other exact decomposition or heuristic approaches are still under investigation.

## Références


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