# A LNS and branch-and-check approach for a VRP with cross-docking and resource synchronization

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Resource synchronization constraints are appearing in many city logistics and transportation problems. Such type of constraints typically arise from limited parking spaces for unloading an loading at logistics warehouses or city logistics hubs. These constraints also arise when electric vehicles need to occupy charging stations for a significant amount of time. The limited number of such resources implies that operations should be planned over time to limit congestion and avoid waiting times at such locations.

When such resources are involved in distribution networks, optimizing pickup and delivery routes that comply with suppliers and/or customers time windows is a challenging topic: resource synchronization constraints create interdependencies between vehicle routes and represent complex scheduling problems integrated in routing problems. This topic has received limited attention in the literature yet.

As a first approach we study the integration of vehicle routing and resource scheduling in a vehicle routing problem with cross-docking (VRP-CD), in which the number of dock doors is limited. The problem is solved with an hybridization of the large neighborhood search metaheuristic (LNS), scheduling heuristics, and the solution of a set partitioning model which combines integer linear programming (IP) and constraint programming (CP) in a branch-and-check fashion.

## 1. Problem formulation

The considered VRP-CD is built upon the definition of [2]: we consider a set of transportation requests, each having different origins and destinations. Each vehicle starts from the depot, perform a pickup leg which ends at the cross-dock, then it performs a a delivery leg and return to the depot. At the cross-dock, some transportation requests are

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exchanged between vehicles, creating precedences between pickup and deliveries legs of different vehicles.

We introduce the VRP-CD with dock Ressource Constraints (VRPCD-RC) in which the notion of cross-dock capacity is added, ie the number of doors that can be processed simultaneously a the cross-dock is limited. This new constraint may introduce some additional waiting times for vehicles at the cross-dock (compared to the VRP-CD). We consider two cross-dock configurations:

- In the *shared* configuration, the total number of vehicles that can be processed simultaneously is limited to a number S.
- In the *separated* configuration, the unloading capacity is separated from the loading capacity into inbound and outbound doors.

## 2. Sketch of the solution method

To solve this problem, we adapt the method proposed in [1] for the VRP-CD. It is based first on a large neighborhood search metaheuristic in which each non-dominated vehicle route is saved to a memory. Second, periodic calls to a set partitioning based problem allow to reassemble good routes that have been produced in separate solutions.

To deal with the dock resource constraints, classical scheduling heuristics and a CP model have been studied. They can both be used as feasibility tests for insertions in the LNS.

In the set partitioning formulation, resource synchronization constraints are handled in a branch-and-check fashion: every time a feasible solution is found, a CP model is solved to accept or reject this solution.

## 3. Experiments

The experiments provide several insights. First in the method: we show that it is more efficient to use heuristics than CP in the LNS feasibility tests. A second key observation is that the addition of the branch-and-check component really improves the algorithm.

Second, we evaluate the impact of the cross-dock capacity on instances from the literature, showing the increase in routing costs compared to the decrease in cross-dock capacity.

[1] Philippe Grangier, Michel Gendreau, Fabien Lehuédé, and Louis-Martin Rousseau. A matheuristic based on large neighborhood search for the vehicle routing problem with cross-docking. *Computers & Operations Research*, 84:116–126, 2017.

[2] Min. Wen, J. Larsen, J. Clausen, Jean-François Cordeau, and Gilbert Laporte. Vehicle routing with cross-docking. *Journal of the Operational Research Society*, 60(12):1708–1718, 2008.