A path-based formulation for the inbound logistics optimization in the automotive industry

Issa Bou Zeid[1,3], Gülgün Alpan[1], Bernard Penz[1], Alain Nguyen[2], Christian Serrano[3]
[1] Univ. Grenoble Alpes, CNRS, Grenoble INP [†], G-SCOP, 38000 Grenoble, France
[2] Direction Transformation Digitale, Pôle optimisation, Renault, 92359 Le Plessis Robinson, France
[3] Direction Supply Chain, Renault, 78280 Guyancourt, France
{issa.bou-zeid,alain.nguyen,christian.serrano}@renault.com
{gulgun.alpan,bernard.penz}@grenoble-inp.fr

1 Introduction

Automobiles are manufactured goods created through the assembly of thousands of parts. Effective collection and delivery of these parts to assembly or manufacturing plants are ensured by a mixed inbound logistics network typically used within the automotive industry. The three widely used strategies are direct shipment, milk runs, and indirect shipment [1]. In addition to the complexity given by the involvement of hundreds if not thousands of suppliers within this network, multiple practical constraints have to be considered. In this work, we present a path-based formulation that improves the arc based formulation proposed in [2].

2 Problem description

Within the automotive industry context, an assembly plant consists of multiple receiving docks ($\mathcal{D}$), each dedicated to receiving specific types of parts by one or multiple suppliers ($\mathcal{S}$). Given the mixed inbound logistics network, the parts are delivered to the plant by either direct shipment (directly between a supplier and the plant), milk-run shipment (tour between multiple suppliers), or indirect shipment (via a cross-docking platform) through a fleet of unlimited homogeneous vehicles with two loading capacities in loading meter and kilogram.

Multiple stakeholders, each with different operational requirements involve in designing a transportation plan. Therefore, a practical plan should adhere to their requirements and constraints. For instance, to decrease variability in the transportation plan, and increase the familiarity of drivers with their routes, restrictions are imposed on the maximum number of suppliers ($MaxS$), receiving docks ($MaxD$), and the maximum distance that a vehicle can travel between two consecutive suppliers ($MaxL$). In addition, suppliers must be partitioned into clusters with a known maximum size k. Fig. 1 illustrates an example of the mixed inbound logistics network including the clustering constraint.

Our aim is to design a transportation plan that satisfies the constraints, while minimizing the total cost of assigning suppliers to the transportation strategies. A feasible solution to our problem determines the transportation strategies, and for both direct and milk-run suppliers, their optimal pick-up tour visiting sequence, collected volumes, and frequencies.

3 Solution Approach

In [2], a three-phase approach is proposed to solve the above-mentioned problem. Phase-1, called clustering, generates all feasible clusters concerning k, and $MaxL$. Phase-2 solves an arc-based formulation that finds the optimal transportation plan for each cluster. Finally, phase-3

[†]Institute of Engineering Univ. Grenoble Alpes

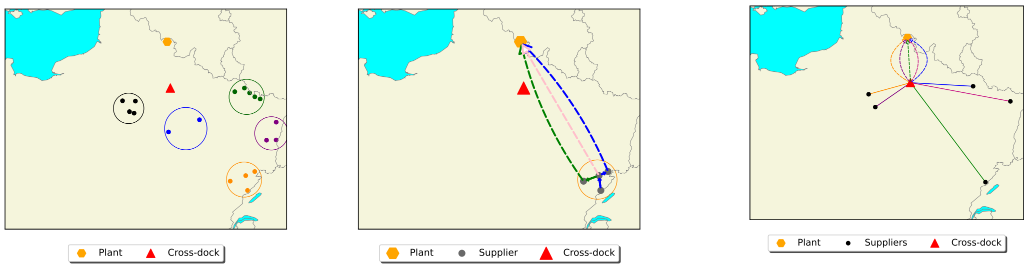

FIG. 1 – Clustering and the three transportation strategies.

solves a Set Partitioning Problem to find the optimal subset of clusters, such that the total cost is minimum, and each supplier is in one cluster.

In contrast to the arc-based formulation in phase-2, we propose in this work a novel path-based formulation based on enumerating the set of routes Ω and subsequently locating the optimal strategies and routes.

Formally, a route $r \in \Omega$ is described as an elementary path (without cycles) between a subset of suppliers ($\mathcal{S}'$) and receiving docks ($\mathcal{D}'$) such that $|\mathcal{S}_r^{'}| \leq MaxS$, $|\mathcal{D}_r^{'}| \leq MaxD$, and $l_{s_i s_j} \leq MaxL, \forall\ s_i, s_j \in \mathcal{S}^{'}, i \prec j, i, j \in \{0, 1, \ldots, |\mathcal{S}^{'}|\}$.

To significantly reduce the size of Ω, we introduce two dominance properties obtaining the set of non-dominated and feasible routes $\mathcal{R} \subseteq \Omega$. In the first property, route r dominates $r^{'}$ if they both contain the same set of suppliers and receiving docks but $l_r \leq l_{r'}$. In the second one, r dominates $r^{'}$ if they both contain the same set of suppliers but the set of receiving docks in $r^{'}$ are $\mathcal{D}_{r'} \subseteq \mathcal{D}_r$. These two properties reduce the complexity of the path-based models and subsequently improve the performance of the optimization process.

4 Results

Preliminary computational experiments on real-world instances show significant improvement in computational time for small and medium-size instances, while obtaining solutions for some larger instances within the defined time limit.

5 Conclusions and perspectives

Although the new path-based formulation is more efficient than the arc-based formulation in tackling phase 2 of the approach, it is still challenging to solve instances with a huge number of clusters and with high volumes. Therefore, for future works, we will consider advanced decomposing approaches to tackle larger instances.

Références

[1] Issa Bou Zeid, Christian Serrano, Gülgün Alpan, Bernard Penz, and Alain Nguyen. Vehicle routing optimization for inbound transportation plan of factories in the automotive sector. A Renault case study. In *23ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision*, Villeurbanne - Lyon, France, February 2022. INSA Lyon.

[2] Issa Bou Zeid, Gülgün Alpan, Bernard Penz, Serrano Christian, and Alain Nguyen. Selecting transportation strategies in transportation planning for automotive supply chain. In *24ème congrès annuel de la Société Française de Recherche Opérationnelle et d'Aide à la Décision*, RENNES, France, February 2023. Rennes School of Business.