Solving a continent-scale, multi-attribute inventory routing problem at Renault

One-day workshop on the IRP

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Existing approaches

Large Neighborhood Search

Results

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Introduction

Figure 1: Illustration of the Inventory Routing Problem (only one day represented).
Europe instance

Figure 2: Visual of the Europe instance.
Depots, customers and routes

**Sites:** Multi-depot instances, multicommodity release and demand.

**Vehicles:** Infinite fleet of homogeneous vehicles.

**Routes:**
- Transport may last several days as considered by Lagos, Boland, and Savelsbergh [11].
- Vehicles have size $L$: a 1D bin packing problem is solved.
- Split deliveries are allowed.
- Limit on the number of stops $S_{max}$ per route.
Our optimization problem

\[
\min_{\text{routes, inventory}} \text{routes' cost} \\
\quad + \text{depots' inventory cost} \\
\quad + \text{customers' inventory cost} \\
\quad + \text{customers' shortage cost}
\]

\[\text{(IRP)}\]

s.t.

- Routes are feasible.
- Inventory dynamics are respected.
- Inventory dynamics and routes are coherent.
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We can distinguish several trends:

- Branch and bound Coelho and Laporte [6] and Desaulniers, Rakke, and Coelho [9].
- Metaheuristics Benoist et al. [3].
- Matheuristics Archetti, Boland, and Speranza [1], Bertazzi et al. [4], Su et al. [13], Coelho, De Maio, and Laganà [7], and Archetti et al. [2].
- Two-step heuristics Campbell and Savelsbergh [5] and Cordeau et al. [8].
Challenges

The main difficulties we face are:

- The multi-depot and multi-commodity aspects.
- The multiple-day routes.
- The size of the instances: $|D| = 15$, $|C| = 600$, $|M| = 30$, $T = 20$ compared with the benchmark OR-Brescia - Benchmark Instances [12].

→ No algorithm is known to scale to our context.
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Overview

Initialization + local search: get quickly a non-trivial solution.

Matheuristic: solve large neighborhood MILPs up to a small gap to select and reload promising routes.

LNS: iteratively apply local search and solve large neighborhoods and perturbations MILPs with higher gap and time criteria.

Figure 3: Algorithms principles.
Contributions

- Review the literature.
- Implement and adapt 13 route neighborhoods.
- Adapt a matheuristic as large neighborhood.
- Design two new perturbations.

→ Scale to our instances.
Reload fixed-path vehicles principle

Figure 4: Initial solution (only one day represented).
Reload fixed-path vehicles principle

Figure 5: Routes related to one depot.
Reload fixed-path vehicles principle

Figure 6: New solution.
Reload fixed-path vehicles

Ideas:

- Neighborhood version of Bertazzi et al. [4] and Archetti, Boland, and Speranza [1]
- Simultaneously choose the routes to keep and the quantities to be delivered.

Remark: this neighborhood can be applied on any set of routes.

Implementation: We use Gurobi solver Gurobi Optimization, LLC [10] with a warm start → a few seconds of computation per depot.
Customer reinsertion principle

Figure 7: Initial solution (only one day represented).
Customer reinsertion principle

Figure 8: Removal of a customer (only one day represented).
Customer reinsertion principle

Figure 9: Reinsertion of a customer (only one day represented).
Customer reinsertion

Ideas:

• Use coupled flows.
• Pre-compute as much cost as we can.
• Sparsify the graphs.

Proposition

Our MILP is a relaxation of the customer reinsertion problem.

• Remark: We systematically reconstruct a feasible solution.
• Implementation: We use Gurobi solver Gurobi Optimization, LLC [10] with a warm start \(\rightarrow\) a few seconds of computation per customer.
Commodity reinsertion principle

Figure 10: Initial solution (only one day represented).
Commodity reinsertion principle

Figure 11: Removal of a commodity (only one day represented).
Commodity reinsertion principle

Figure 12: Reinsertion of a commodity (only one day represented).
Commodity reinsertion

Ideas:

- Use 2 coupled flows.
- Restrict to new direct routes.
- Combine with a fast local search.

Remark: We systematically reconstruct a feasible solution.

Implementation: We use Gurobi solver Gurobi Optimization, LLC [10] and warm start → a few seconds of computation per commodity.
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Global results of the LNS

<table>
<thead>
<tr>
<th></th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of instances</td>
<td></td>
</tr>
<tr>
<td>Average number of depots</td>
<td>15</td>
</tr>
<tr>
<td>Average number of customers</td>
<td>602</td>
</tr>
<tr>
<td>Average number of commodities</td>
<td>30</td>
</tr>
<tr>
<td>Average horizon (days)</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 1: Instances overview.

\[
S_{\text{max}} = 3 \quad S_{\text{max}} = 10
\]

Gap initialization + local search | 121% | 77%
Gap matheuristic                  | 87%  | 64%
Gap LNS                           | 66%  | 40%
Time limit                        | 90 minutes | 180 minutes

Table 2: Average gap results.
Time per operator

Figure 13: Duration allocated per operator.
Cost gain per CPU time and operator

Figure 14: Cost gain per CPU time and operator.
Gaps cumulative distributions

Figure 15: Cumulative distribution of the gaps for $S_{\text{max}} = 10$. 
Gaps cumulative distributions after ablation

Figure 16: Cumulative distribution of the gap over instances.
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**Literature review** on IRP.

**LNS** (to be submitted):  
- 13 routing neighborhoods adapted.  
- One route-based large neighborhood.  
- Two new perturbations.  
- Implementation and numerical experiments.

**Perspectives:**  
- Industrialization.  
- Address the "forecast dispatch" problem.  
- Use machine learning for operations research techniques.
Bibliography I


Bibliography II


