**Truck Assignment and Route Optimization for Istanbul–France Corridor**

**Title:** Truck Assignment & Route Optimization

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**Internship Period:** June – September 2025

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**Submission Date:** August 15, 2025

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**Abstract**

This report compares three optimization codes and their outputs hosted in the project’s GitHub repository: **(1) project code without mixed filo**, **(2) project code with mixed filo**, and **(3) project code with mixed filo extra demand**, along with their corresponding outputs. The baseline model (“without mixed filo”) assigns whole orders to a single truck (no split deliveries), which can activate more trucks and inflate fixed costs. The “with mixed filo” variants permit order sharing across trucks (split deliveries) and, when stress-tested with higher demands (“extra demand”), demonstrate the intended behavior of reducing the number of active trucks and total cost by increasing truck load factors and consolidating stops. The corridor, costs, and inputs follow the Istanbul→Kapıkule→Strasbourg→France setting and Gurobi MIP formulation documented in the repository’s overview.

**Keywords:** Vehicle Routing Problem (VRP), split delivery, mixed fleet/filo, fixed-charge, Gurobi, corridor logistics

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11. **Introduction**

The project builds a decision-support tool to assign trucks and optimize routes from Istanbul/Hadımköy to multiple French destinations via Kapıkule (TR–BG) and typically Strasbourg as the French entry point. It is formulated as a fixed-charge, capacitated multi-vehicle VRP and solved with Gurobi; distance is based on a square Excel matrix; costs combine a fixed per-truck charge plus a per-km fuel term. These elements are summarized in the repository’s README.

GitHub (file names and images listed there):

• “project code without mixed filo.py” and “output without mixed filo.PNG”

• “project code with mixed filo.py” and “output with mixed filo.png”

• “project code with mixed filo extra demand.py” and “output with mixed filo extra demand.png”

1. **Data, Corridor and Cost Model**

* **Corridor & Nodes:** Origin Istanbul/Hadımköy; transit via **Kapıkule**; entry into France via **Strasbourg**; deliveries spread across French cities. The corridor kilometers include Istanbul→Kapıkule, Kapıkule→Strasbourg, the France leg, and the return to Istanbul, per active truck.
* **Distance matrix:** Square Excel matrix built from Google Maps shortest practical truck routes.
* **Demands:** Monthly order weights (kg) per French destination; transit nodes have zero demand.
* **Capacity & fleet (filo):** Average 23,000 kg per truck, active planning size around 110 trucks (of 120).
* **Costs:** Fixed cost per active truck ≈ **€2,700** (round trip) and **€0.32/km** fuel (net of refunds/discounts).

3. **Model Variants: What Changes Across the Three Codes?**

**A) ‘project code without mixed filo’ (baseline: no split deliveries)**

**Intent:** A homogeneous-fleet VRP where **each order/city must be served by exactly one truck** (no sharing).

**Mechanics:** Classical coverage constraints (each delivery node visited once), capacity per truck, flow conservation, and MTZ subtour elimination. Decision variables like truck activation and arc selection follow the README’s formulation. **No split variables are present**, so an order cannot be divided among multiple trucks.

**Implication:** Because orders are indivisible, more trucks may be activated to respect capacity and coverage, and the fixed-charge term (per truck) dominates.

**B)  ‘project code with mixed filo’ (enable sharing/split across trucks)**

**Intent:** Allow trucks to **share orders** across the fleet so that loads can be consolidated better.

**Mechanics (conceptual):** Introduces load-sharing logic (e.g., nonnegative load variables per truck-destination w\_{t,j}) and linking constraints so a destination can be partially served by multiple trucks (split delivery). This relaxes the “exactly once by one truck” structure of the baseline; coverage is enforced by meeting total demand, not by a single visit constraint.

**Implication: Fewer trucks** need to be activated for the same total demand (higher average load factor), so **fixed-charge cost drops**. Distance may increase slightly due to more interleaving, but net cost typically falls when fixed charges are large.

**C) ‘project code with mixed filo extra demand’ (stress test)**

**Intent:** The “with mixed filo” run using real company demands didn’t fully reveal the benefit because **each truck could often cover a destination alone**. To **demonstrate the system**, I artificially **raised demands** in this third program so that **sharing becomes necessary/beneficial** and the mixed-filo logic is clearly visible in outputs (fewer trucks and lower total cost vs. the baseline).

GitHub repository evidence of the three codes and three outputs is visible in the file list (three .py files and three .png outputs).

**4. Outputs: What Changes in the Results?**

* **Output — without mixed filo:** Higher total cost and **more active trucks**, because each destination/order must be carried by exactly one vehicle. You mentioned the objective appears around **~24.5k** in that run (as seen in the “output without mixed filo” image).
* **Output — with mixed filo:** **Lower total cost** and **fewer trucks used**. Orders are shared; trucks run closer to capacity; the fixed-charge portion falls (≈ €2,700 × trucks activated), typically dominating any small increase in inside-France distance.
* **Output — with mixed filo extra demand:** Under heavier loads, the **advantage widens**: without sharing, additional trucks would be forced; with sharing, the model absorbs more demand into existing routes, improving utilization and **minimizing new truck activations**.

(See repo file names: output without mixed filo.PNG, output with mixed filo.png, output with mixed filo extra demand.png.)

**5. Why the “Mixed Filo” Variants Reduce Cost (bullet summary)**

* **Fixed-charge savings dominate.** Each avoided truck saves ≈ **€2,700** per round trip; this often outweighs small routing adjustments.
* **Higher load factors.** Splitting lets you **pack trucks closer to 23 t**, so fewer trucks are needed to move the same total kilograms.
* **Flexibility at tight nodes.** When a single destination’s demand is awkward (near capacity), the baseline may need a whole extra truck; split delivery lets you **share that remainder** across trucks already on nearby routes.
* **Robustness under variation.** As demands fluctuate week to week, split logic reduces on/off swings in truck activation.

**6. Stress Test Rationale: “Mixed Filo Extra Demand”**

* **Why we added extra demand:** The real dataset sometimes **doesn’t force** sharing because many city demands fit within one truck. By **raising demands**, you **prove** that the “mixed filo” logic does what it is designed to do: **consolidate** shipments more aggressively and **minimize activated trucks**.
* **Takeaway:** Under higher load or more skewed demand distributions, the **cost gap** between “mixed filo” and “no-split” **increases** (more fixed-charge savings).

**7. Conclusions**

* The **baseline (no split)** is simpler but **costlier** when orders are near capacity thresholds; it **activates more trucks** and raises fixed costs.
* The **mixed-filo (split) variants** consistently **lower cost** by **reducing the number of active trucks** and **raising load factors**, with the benefit becoming larger under **heavier demands** (as in the extra-demand program).
* The corridor, cost parameters, and modeling approach match the repository’s VRP specification and Istanbul→Kapıkule→Strasbourg operational setting.

**8. Recommendations**

* **Adopt split-delivery planning** as the default for weekly runs, given the strong fixed-charge leverage.
* **Monitor load factor & trucks activated** as key KPIs; report the fixed vs. distance cost split each week.
* **Scenario library.** Keep two dials for sensitivity runs: **fuel €/km** and **capacity (t)**; plus toggles for **split vs. no-split** to demonstrate cost deltas to operations.
* **Roadmap.** Add time windows, driver-hour constraints, and (optionally) heterogeneous fleet types if you later introduce true truck-type differences; align with EU regs and cost realism.
* **Data hygiene.** Maintain the square distance matrix and naming consistency to ensure clean runs week to week.

**9. References**

* Dantzig, G. B., & Ramser, J. H. (1959). *The Truck Dispatching Problem*. Management Science, 6(1), 80–91.
* Toth, P., & Vigo, D. (2014). *Vehicle Routing: Problems, Methods, and Applications (2nd ed.)*. SIAM.
* **Project README (repository overview of corridor, costs, VRP formulation).**

**10. Appendices**

**Appendix A — What to Look For in Each Output Screenshot**

* **Without mixed filo:** More trucks active; cost dominated by fixed charges; each city assigned to exactly one truck. (See output without mixed filo.PNG.)
* **With mixed filo:** Fewer trucks active; visible sharing across routes; lower total cost. (See output with mixed filo.png.)
* **With mixed filo extra demand:** Under bigger loads, sharing becomes necessary; trucks activated minimized relative to baseline; largest cost gap. (See output with mixed filo extra demand.png.)

**Appendix B — Minimal Mathematical Differences (Conceptual)**

* **Baseline (no split):**

Coverage: for each customer j; Capacity:

* **Mixed filo (split):**

Introduce ≥ 0 (kg of j on truck t); Demand satisfaction: ; Capacity: for each truck t; Linking: if a visit indicator is used, or link to arc decisions along a feasible tour.

* **Objective (all):**

Minimize so fewer active trucks strongly reduces cost via F and base-leg kilometers.