A Green Transportation Problem for E-commerce Deliveries

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ROADEF, 28th February 2025

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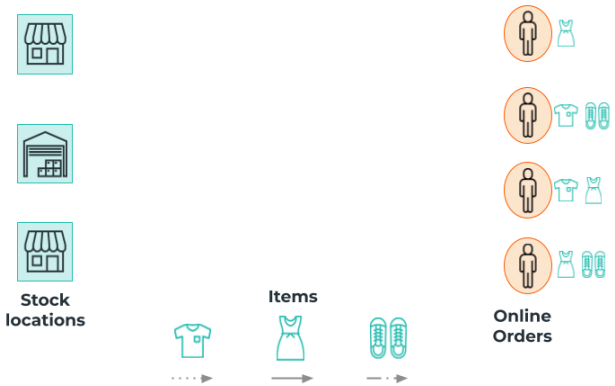
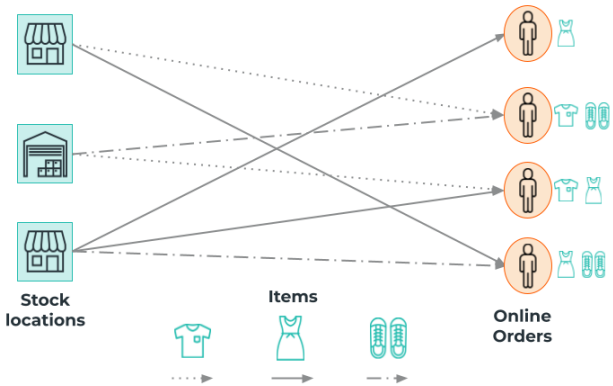


Figure: Illustration of OneStock orchestration

OneStock : Order Management System ⇒ software to orchestrate online orders

- **Orchestration** = orders assignment to stock locations



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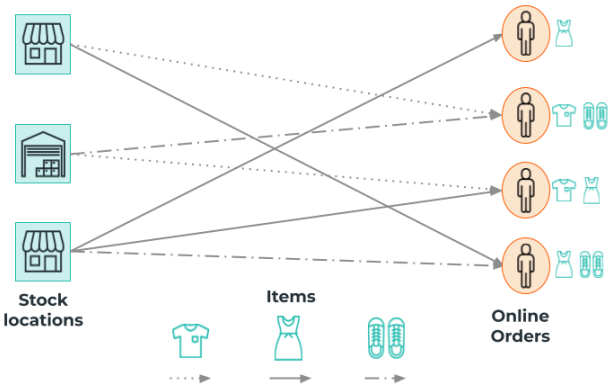

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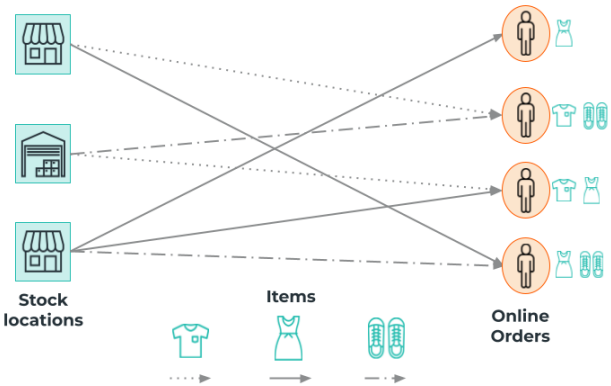
OneStock : Order Management System ⇒ software to orchestrate online orders

- **Orchestration** = orders assignment to stock locations
- No routing decision
- Currently :
  - Several times per hour
  - Online orchestration
  - Hand-made rules



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Decision Variables : $x_{kso} \in \mathbb{N}$

$$\text{Minimize Costs} \quad f(x_{kso})$$

$$\text{s.t. Respect stocks} \quad \sum_{o \in O} x_{kso} \leq \text{Stocks}_{ks} \qquad \forall k \in K, s \in S$$

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Literature : order orchestration

- Can be modeled as a Network Design or Transportation Problem
- First dedicated paper : [Xu et al., 2009] → economic objective

Data : K = Items, S = Stock locations, O = Orders
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Minimize Costs	$f(x_{kso})$ →From economic to ecological?	
s.t. Respect stocks	$\sum_{o \in O} x_{kso} \leq \text{Stocks}_{ks}$	$\forall k \in K, s \in S$
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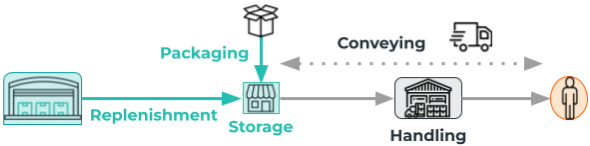

Figure: Ecological costs over the path of a parcel ([CPV Associés et al., 2023])

- Conveying costs : French carrier formula relying on **parcel volume**
- Packaging costs : proportional to **package weight**

$\Longrightarrow$ we need to know the package used

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$V_{boxes} > V_{items}$ $\sum_{b \in B} \text{Volume}_b y_{bso} - \alpha \sum_{k \in K} \text{Volume}_k x_{kso} \geq 0$ $\forall s \in S, o \in O$

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Minimize Ecolo-Costs $\sum_{s \in S} \sum_{o \in O} \left(\sum_{k \in K} \text{CostItem}_{kso} x_{kso} + \sum_{b \in B} \text{CostBox}_{bso} y_{bso} \right)$

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Replenishment, Storage, Conveying

Packaging, Handling, Conveying

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GTP-ED

- Fixed Charge Transportation Problem is a particular case of the GTP-ED $\Rightarrow$ NP-hard
- Transportation problem with packing constraints [Flamand et al., 2023]

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Ecological Transportation Problems

- Multi objective Transportation Problem with ecological cost [Midya et al., 2021], [Shojaie and Raoofpanah, 2018], [Das et al., 2018]

$\Rightarrow$ focused on the conveying costs

3 questions to investigate

- Are CO2 savings significant compared to current orchestration?
- Is it justified to use such a complex objective function?
- What about the compatibility with economic requirements of retailers?

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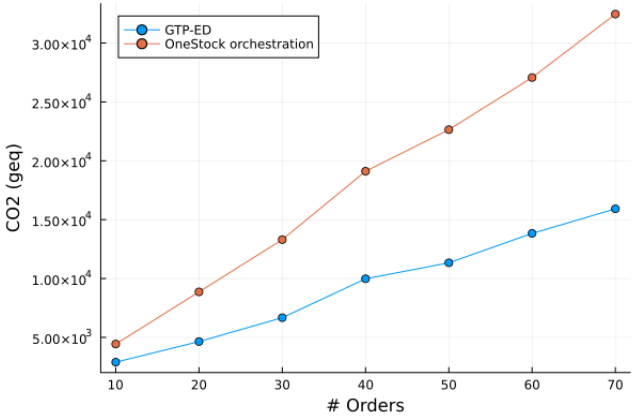
Instances

- Data origin
  - Industrial data (OneStock and a French carrier): orders, stocks and boxes
  - Randomly generated based on [CPV Associés et al., 2023] : ecological costs
  - Randomly generated to match fashion retailers : items parameters
- Size of the instances :
  - Larger instance : 70 orders, 135 stock locations, 244 items
  - Smaller instances obtained from the larger one

Set-up

- Time Limit 1h, Intel Core i5, 2.4 GHz, RAM 16GB, Julia 1.8, CPLEX 22.1



- $\sim$ 50% of CO_2 savings
- $\Rightarrow$ **Yes, GTP-ED improves significantly** the ecological performance

Figure: Ecological costs of GTP-ED vs OneStock orchestration

An easier ecological objective?

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Distance TP-ED :

$$\min \sum_{b,s,o} \text{Distance}_{so} y_{bso}$$

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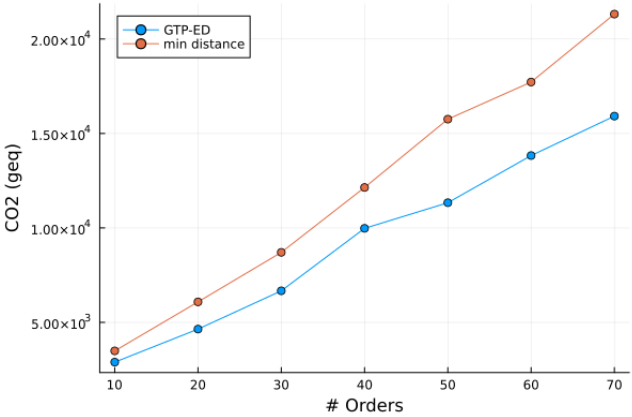


Figure: Ecological Costs of GTP-ED vs min distance

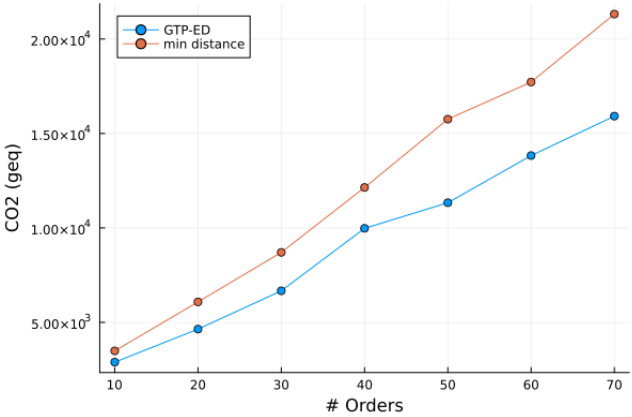
An easier ecological objective?

Distance TP-ED :

$$\min \sum_{b,s,o} \text{Distance}_{so} y_{bso}$$

$s.t.$ previous constraints

- $\sim$ 30% of CO_2 increase
- $\Rightarrow$ **Minimizing distance is not such a good approx.** to $\searrow$ CO_2



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- $\sim$ 60% of CO2 increase

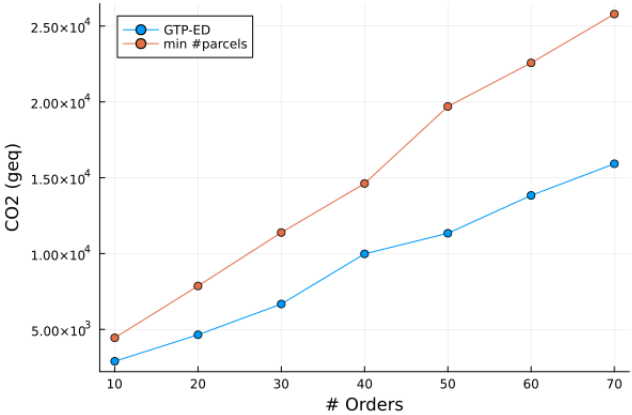


Figure: Ecological Costs of GTP-ED vs min #parcels

Operational relevance (2)

- $\sim$ 120% of #parcels increase

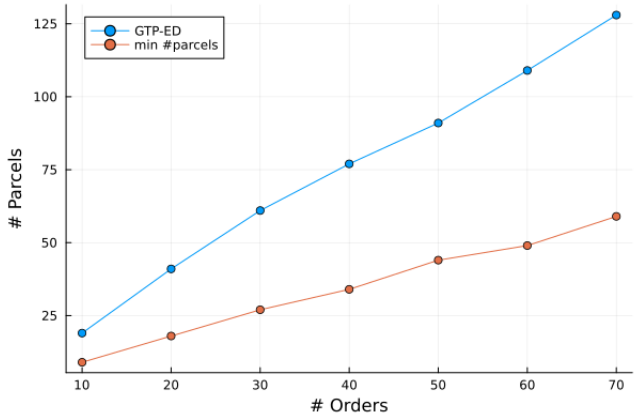
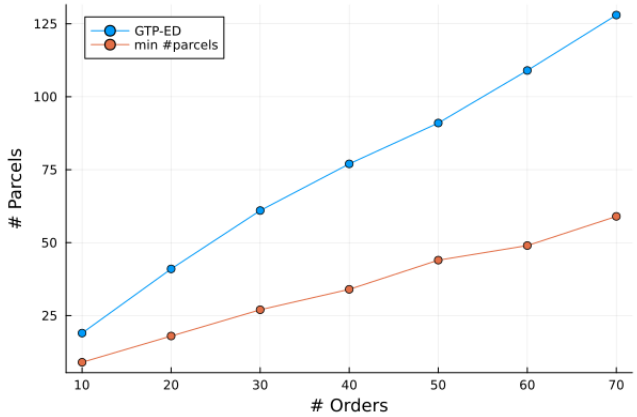


Figure: #Parcels of GTP-ED vs min #parcels (no parcel for CkC orders)

Operational relevance (2)

- $\sim$ 120% of #parcels increase
- $\Rightarrow$ Our **ecological and economic objectives are in great tension**, unlikely to get the GTP-ED operated in real life in such a context



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Contributions

- GTP-ED, a MILP to reduce the ecological footprint of order orchestration
  - A comprehensive ecological function
- Improvement of the industrial orchestration from an ecological point of view
- Highlight of tensions between our CO2 ecological objective and parcel-based economical objective

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Limits and future works

- Generalize conclusions to other types of retailers
- Improve the scalability of the MILP
- We need to develop alternative objective functions to simplify the access of ecological data and to reduce the tensions between ecological and economical objectives

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Colissimo formula

$$D_2 \times \left(\frac{E_v \times V}{V_{t2}} + (E_p - E_v) \times \frac{m}{C}\right)$$

Objective function

$$\min \sum_{o \in O} \sum_{s \in S} \left[\sum_{k \in K} x_{kos} (CS_{ks} + CR_{ks} + \frac{(E_{pos} - E_{vos})}{C_{os}} m_k) + \right.$$
$$\sum_{r \in R} y_{osr} \left(CP_r + CH_{os} + \frac{(E_p - E_v)}{C} M_r + \right.$$
$$\left. \left. V_r \left(\frac{E_{t1os}}{V_{mt1os}} + D_{2os} \frac{E_{vos}}{V_{t2os}} + \frac{D_{3os}}{D_{m3os}} \frac{E_{t3os}}{V_{mt3os}} + \frac{E_{t4os}}{V_{mt4os}} \right) \right) \right]$$