Modelling and analysis of urban logistics networks and potential of their interconnection

Iris JIANG Hao

Supervised by: **Prof. Eric BALLOT, Prof. Shenle PAN**

CGS, MINES ParisTech

Plan

- Introduction
- Research problem
- Methodology
- Case study
- Conclusion
- Q&A

Introduction

Urban logistics

- **Logistics?**

  To transport **right goods** to **right places** in **right time** at the **lowest cost** taking into account of the **negative impacts**.

- **Urban?**

  20% of the transportation cost

  30%-50% of negative impacts

  (noise, congestion, air pollution…)

Introduction

Urban logistics

An old and new issue with challenges

- **Urban population growth**
  54% in 2011 → 66% in 2050
- **Growing importance of e-commerce**
  home delivery: curse or blessing?
- **Desire for speed in supply chain**
  same-day delivery → 30-mins delivery?
- **Rise of sharing economy**
  collaborative consumption and business
- **Increased attention to sustainability**
  traffic congestion, air and noise pollution, traffic accidents, greenhouse gas emissions…

1.042 billion orders of TMall on 2018.11.11

amazon Prime

Research problem

Urban logistics

- **Solutions to test**
  - Time window to deliver city centre
  - Light duty vehicle only
  - Electric vehicles
  - Omni-channel logistics (dark stores…)
  - Dynamic delivery systems (crowd shipping…)
  - Integrating public and freight transportation networks (bus, metro, taxi…)
  - **Multi-echelon networks** *(Taniguchi et al., 2001; Quak, 2009; Tavasszy, 2011; Cuda et al., 2015)*
    (cross dock, urban consolidation centre…)
  - ……
- **Explore the impact**
  - Cost
  - Congestion
  - Air pollution

Research problem

Multi-echelon networks

- **Gap**

Existing models mainly focus on the operational level (VRP, location…) with detailed solutions

- **New models for evaluating distribution schemes and design a good one?**

  Min transportation cost

  Min negative impacts

- **Objective**

To analytically explore and analyze the potential of different sets of logistics schemes (shared or not) for the city as well as the interests for different logistics actors.

- **To evaluate different distribution schemes and to optimize some variables like transportation means, number of hubs…**

Research questions

- **RP: How to reduce the negative impacts and logistics cost?**

- Research question 1

  What are the distribution schemes?

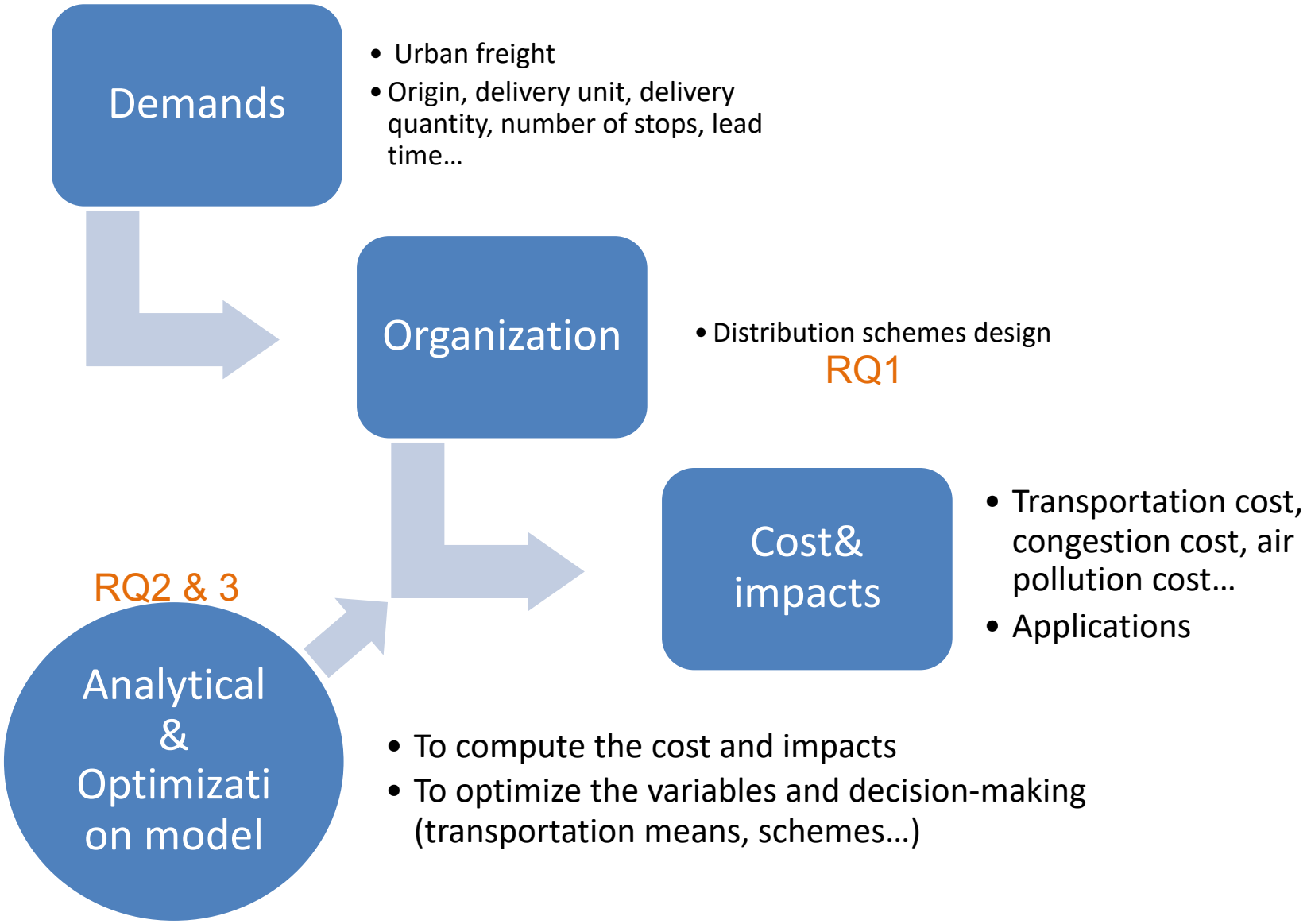
- Research question 2

  How to model the cost and impacts of different distribution schemes?

- Research question 3

  How to improve the current distribution schemes?

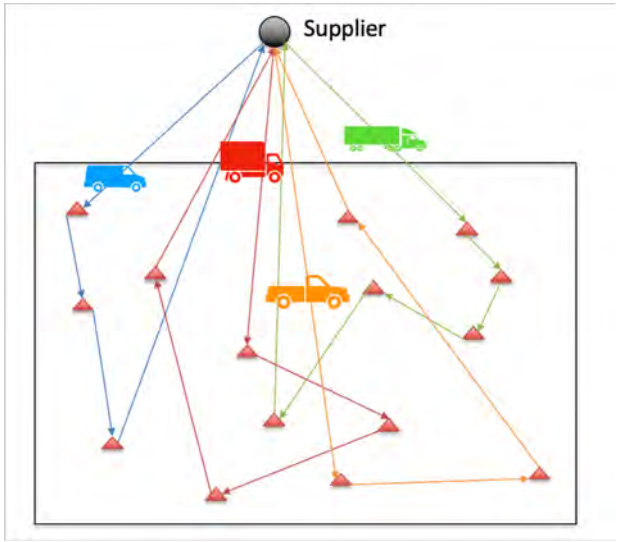
Methodology



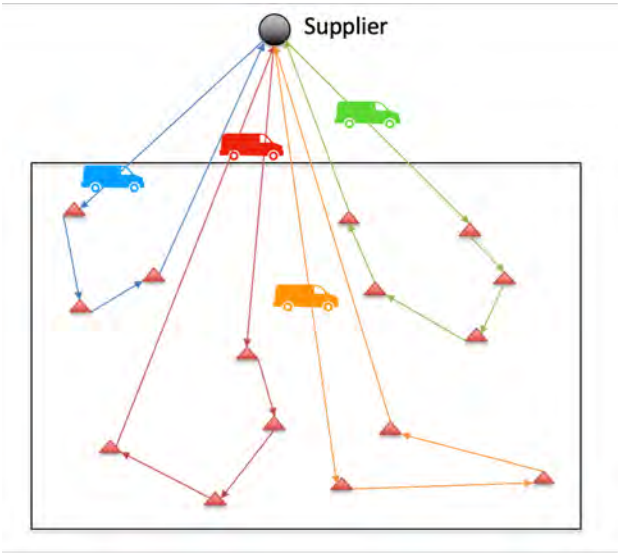
Methodology

RQ1: What are the distribution schemes?

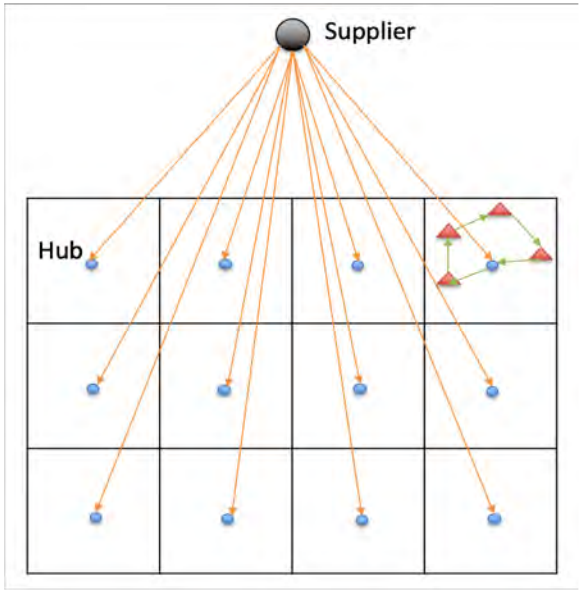
Distribution scheme 1:
Dedicated vehicle type
different vehicle for
different delivery unit



Distribution scheme 2:
All by one vehicle type



Distribution scheme 3:
With hubs
supplier to hubs then
hubs to stops



Methodology

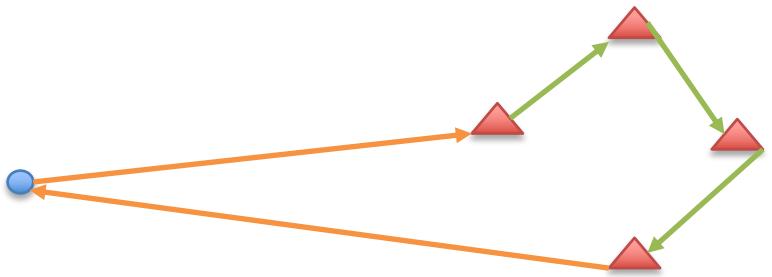
- **RQ2: How to model the cost and impacts of different distribution schemes?**

Analytical model

- $$m_i = max\left(\left\lceil\frac{\sum_j qp_j \cdot ap_{ij} \cdot Np_j}{cp_i}\right\rceil, \left\lceil\frac{\left(\frac{2 \cdot m_i \cdot r + k \cdot \sqrt{A \cdot \sum_j ap_{ij}}}{s_i}\right) + Ts \cdot \sum_j Np_j}{Lt}\right\rceil, \left\lceil\frac{\left(\frac{2 \cdot m_i \cdot r + k \cdot \sqrt{A \cdot \sum_j ap_{ij}}}{s_i}\right) + Ts \cdot \sum_j Np_j}{Sd}\right\rceil\right)$$

Number of tours m_i is constrained by
vehicle capacity (1.15t for van), **lead time** (3h), and **shift duration** (7h)

- $D_i = 2 \cdot m_i \cdot r + k \cdot \sqrt{A \cdot \sum_j ap_{ij}}$



Estimated total distance =
2*distance from supplier to first stop + **distance between stops**

- Transportation cost = transport **distance** cost + transport **time** cost

Methodology

○ **RQ3: How to improve the current distribution schemes?**

Optimization model

- **Modal shift decision**: percentage of delivery unit type to vehicle type

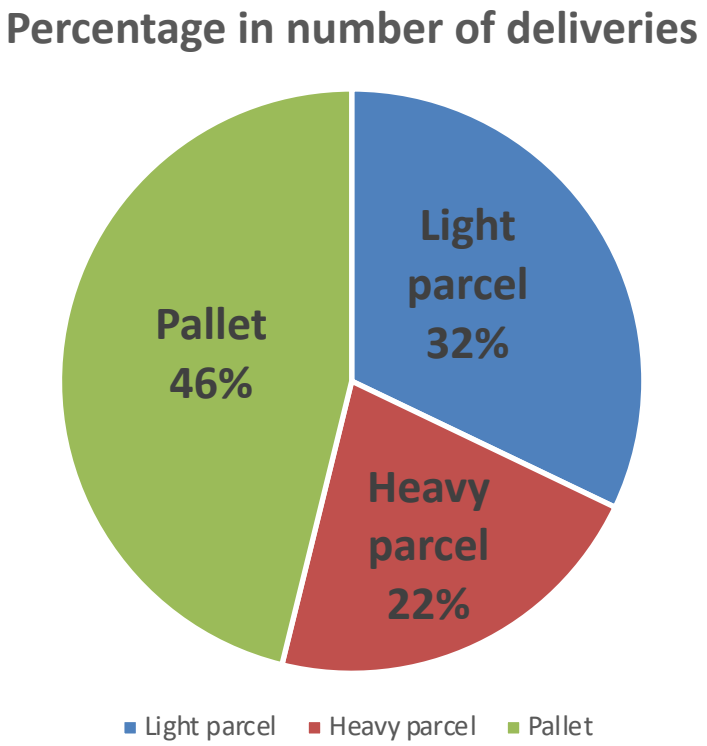
	Light parcel	Heavy parcel	pallet
Van (%)	*X1*	*y1*	*z1*
Light truck (%)	*x2*	*y2*	*z2*
Heavy truck (%)	*x3*	*y3*	*z3*
Total	*100%*	*100%*	*100%*

- **Minimizing Transportation cost only**
- **Respecting constraints:**
  - vehicle capacity (1.15t, 5t, 17t)
  - lead time (8h)
  - shift duration (7h)

Case study

Data input

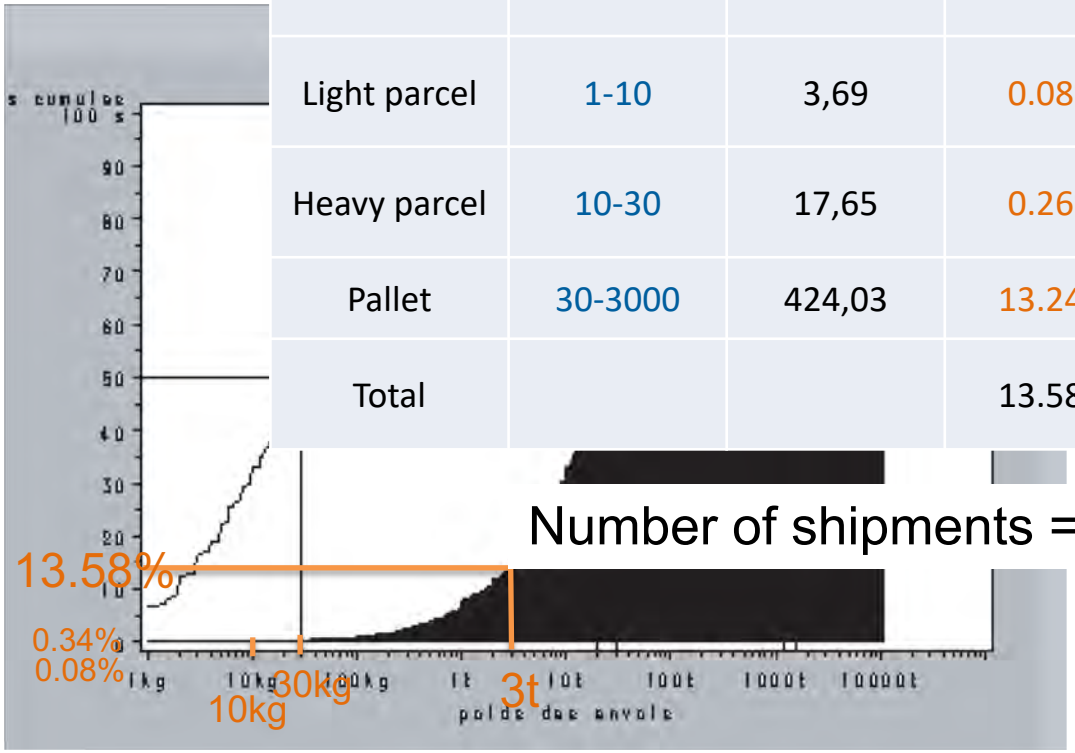
- One day delivery in Paris city (105.4 km2)
- 1000t, 4980 stops in total
- One delivery for each stop
- 10 carriers (100t for each)
- 3 vehicle types:
  - Van (1.15t)
  - Light truck (5t)
  - Heavy truck (17t)
- 3 delivery unit types:
  - Light parcel (1-10kg)
  - Heavy parcel (10-30kg)
  - Pallet (30-3000kg)
- 1599, 1082, 2299 shipments for each delivery unit type



Case study

- **1599, 1082, 2299 shipments for each delivery unit type?**

Delivery unit type	Weight range (kg)	Average weight (kg)	Percentage in weight	Relative Percentage in weight	Total weight (kg)	Number of shipments
Light parcel	1-10	3,69	0.08%	0,59%	5900	1599
Heavy parcel	10-30	17,65	0.26%	1,91%	19100	1082
Pallet	30-3000	424,03	13.24%	97,50%	975000	2299
Total			13.58%	100,00%	1000000	4980



Number of shipments = Total weight / Average weight

(Guilbault, 2008)

Figure 1: Cumulative distribution of shipments in France

Case study

Scenarios

Scenario 1:

- van(1,15t) → light parcel (0-10kg)
- light truck (5t) → heavy parcel (10-30kg)
- heavy truck (17t) → pallet (30-3000kg)

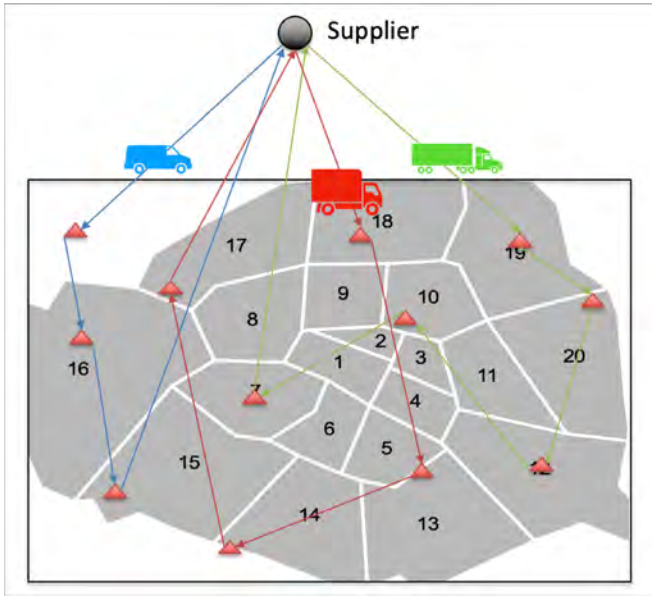
Scenario 2:

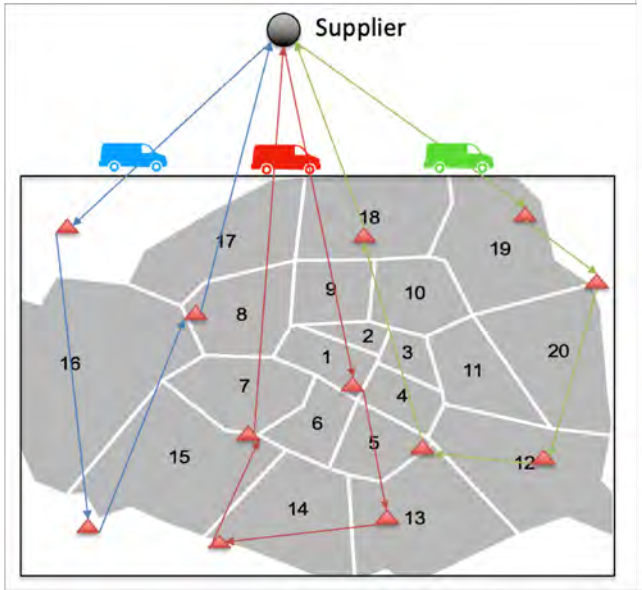
Deliver all by van (1,15t)

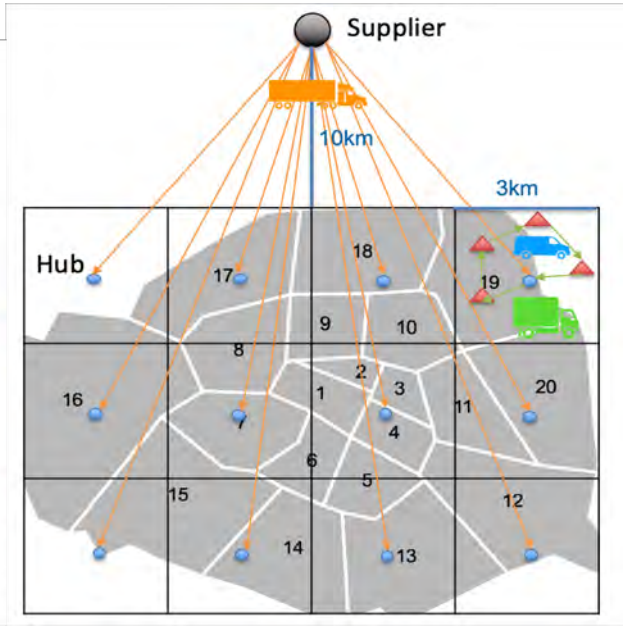
Scenario 3:

With 12 hubs in Paris

- from supplier to hubs: heavy truck
- from hubs to stops:
  - van → light parcel
  - van → heavy parcel
  - light truck → pallet

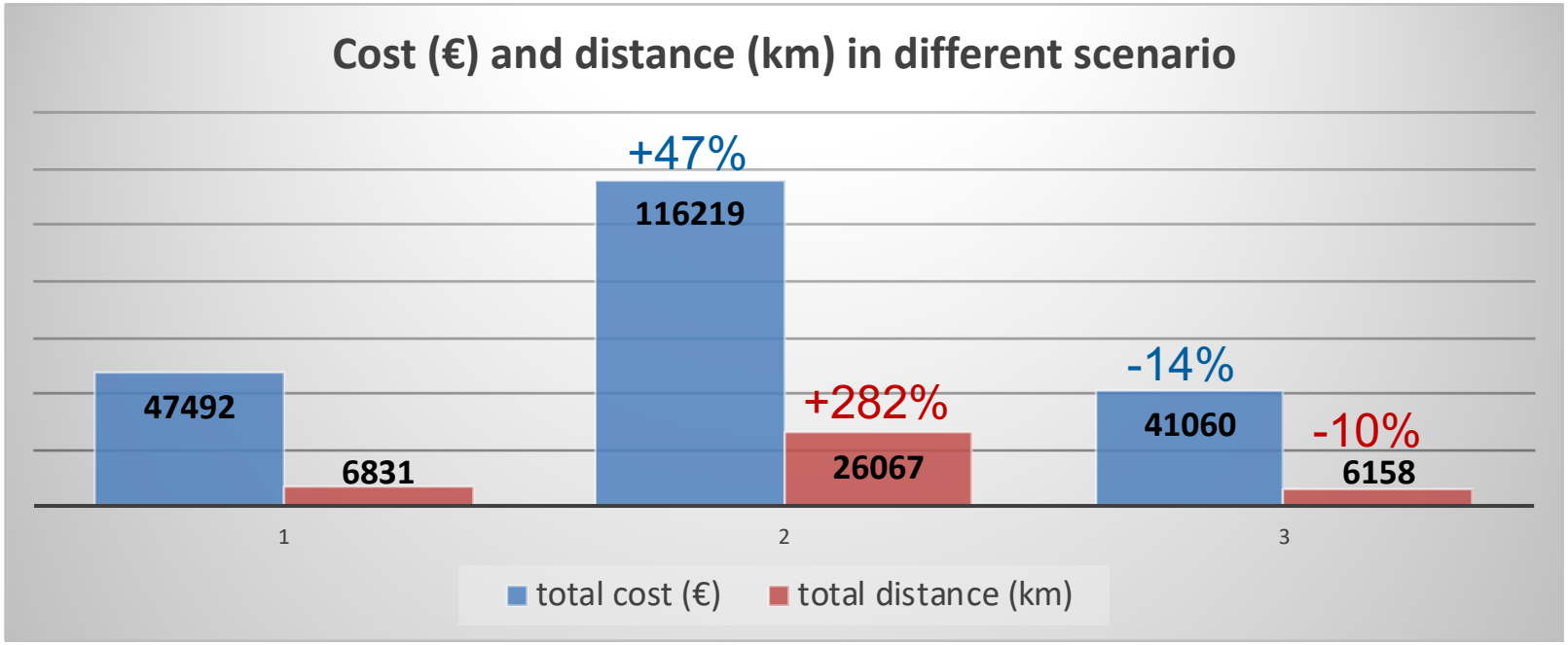






Preliminary results

Scenarios comparison



- Scenario 2 (all by van):
  (+) 47% of the total cost,
  (+) 282% of the total distance.

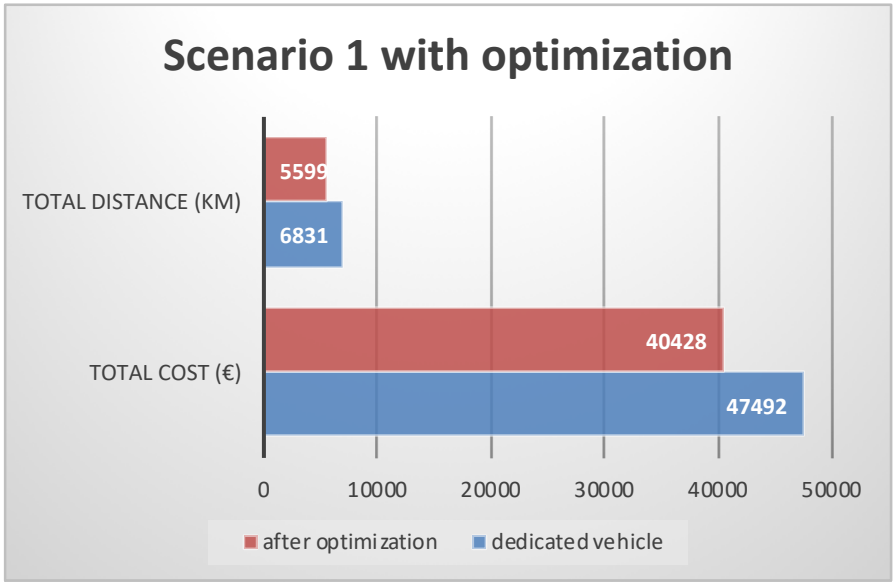
  Regulations to limit the vehicle weight is inefficient.

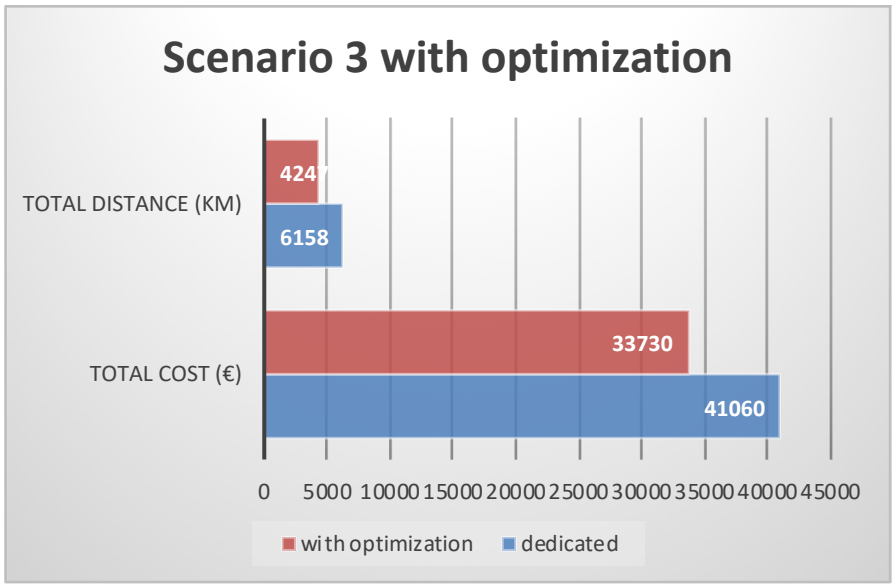
- Scenario 3 (with hubs):
  (-) 14% of the total cost,
  (-) 10% of the total distance.

  Hubs consolidate the goods, raise the fill rate.

Preliminary results

Optimization comparison





- (-) 14.9% cost, (-) 18% distance
- optimal solution: all by heavy truck

- (-) 17.9% cost, (-) 31% distance
- optimal solution: all by light truck

Optimization reduces the cost and distance.

Optimal solution is always to use vehicles with large capacity.

Conclusion

- Small capacity vehicles cost more because it require more tours.
  Regulations only limiting the vehicle weight is inefficient.

- The cost and distance of scenario 3 with hubs decrease
  because hubs consolidate the goods and raise the fill rate of vehicles.
  The distribution scheme with hubs is a good solution.

- The performance of optimization varies (depends on the input data).

- Because the optimization model only considers the transportation cost,
  the optimal solution is always to use vehicles with large capacity.

Limitation and next steps

Limitations:

- The data of number of shipments is assumed according to Enquête ECHO report in 2008, not real data from enterprises.
- Only consider transportation cost, not take environmental impacts into consideration yet.

Next steps…

- Investigate with real data from enterprises in Bordeaux
- Include environmental impacts in the model with parameters from enterprise (noise, emission, …).

Thank you!

Questions & Discussion