# A MIXED INTEGER LINEAR PROGRAMMING MODEL FOR SOLVING LARGE-SCALE INTEGRATED LOCATION-ROUTING PROBLEMS FOR URBAN LOGISTICS APPLICATIONS AT GROUPE LA POSTE

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WHU – Otto Beisheim School of Management

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# Outline

I Motivation
II Specific Problem Setting
III Optimization Model
IV Preliminary Analyses
V Managerial Implications

Section I

# MOTIVATION

# Need for Urban Logistics Infrastructure and Fleet Optimization

**Urban Logistics as a requirement for sustainable development**

Trends and developments leading to a **continuing increase in the demand for urban goods transportation**
- Ongoing urbanization
- Ongoing boom of e-commerce
- Transportation intensive trends in supply chain and production management

Increasingly severe **conflicts of interest** between stakeholders
- Accessibility and congestion
- Emissions, noise, smell and vibration
- Energy consumption

Need for **tighter coordination and consolidation** of individual consignments of different shippers and carriers within the same vehicles and facilities.
- No longer consider each shipment, transportation provider, and vehicle individually. Instead they should be seen as components of an integrated logistics system.

**Urban Logistics as a strategic option for postal operators**

POs are facing serious challenges due to the **deterioration of their revenue base from established business models**

At the same time the increasing demand for urban transportation and the related problems offer a strategic opportunity for **POs to broaden their product portfolio**
- Potential **synergies** of ULS with existing postal operations
- **Existing infrastructure and know-how** could be used for ULS

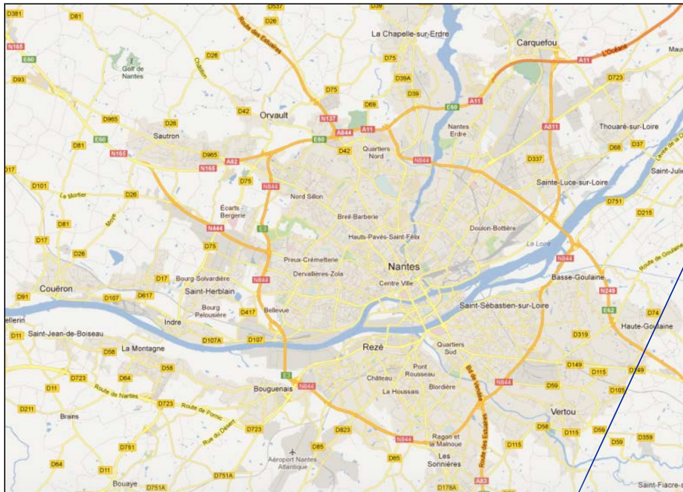
**Need for more sophisticated consolidation and coordination of urban goods transportation.**

**Need to develop optimization and simulation models to quantitatively evaluate possible strategic moves for postal operators in the domain of Urban Logistics Services, especially with respect to optimal infrastructure and fleet design.**

Section II

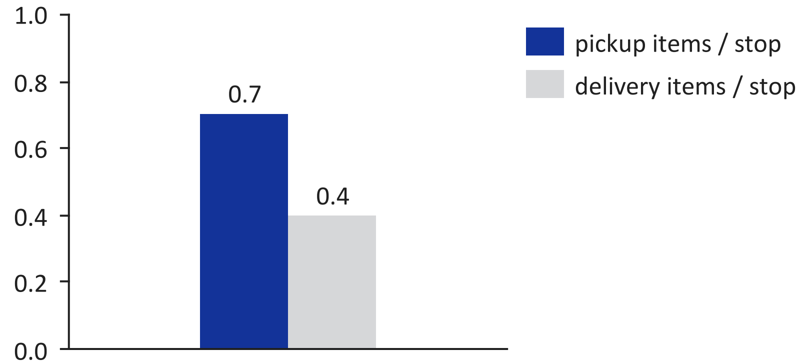
# SPECIFIC PROBLEM SETTING

# Accomodation of complex geographies and demand distributions

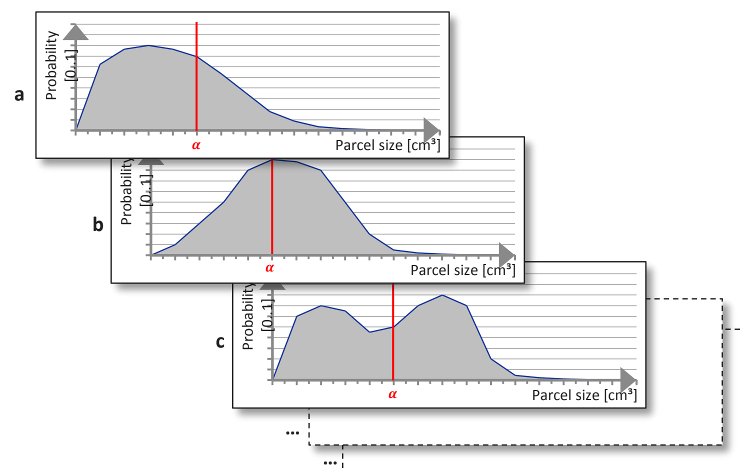



city segmentation

*Heterogeneous pickup and delivery demand*



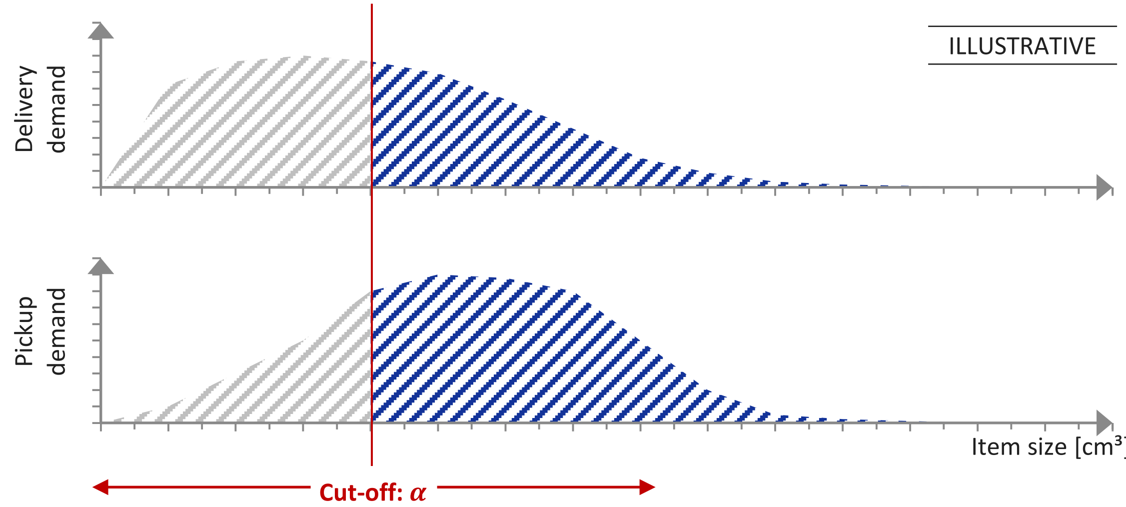

*Heterogeneous size distributions of pickup and delivery demand*



# Parallel network architectures & mixed fleets

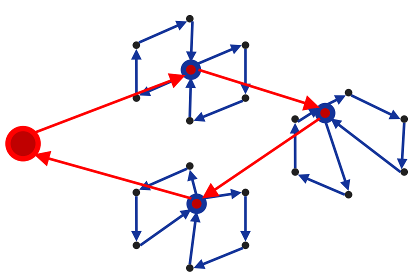
**Joint optimization of upstream and downstream item flow**

Item pickup and delivery are considered simultaneously




**Small items** | **Large items**

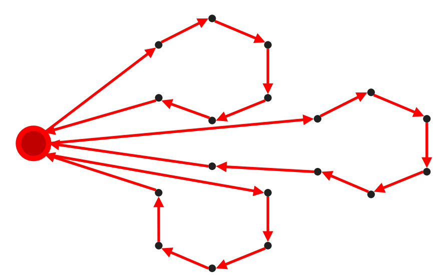
### Indirect delivery via intermediate depots



*Employed vehicle types*

Truck | Van | Bike | Pedestrian

### Direct delivery from city hub



*Employed vehicle types*

Truck | Van | Bike | Pedestrian

Section III

# OPTIMIZATION MODEL

# Model Structure & Theoretical Contribution

### Decision variables

- City hub location
- Active depot locations
- Allocations of segments to depots and vehicle types for small item transport
- Allocations of segments to vehicle types for large item transport

### Data & Parameters

- Location data
- Cost data
- Vehicle data
- Demand data
- Model parameters

### Constraints

- Vehicle capacities
- Vehicle access restrictions
  - To facilities
  - To segments
- Facility capacities
- Existing / blocked infrastructure
- Maximum service times

### Objective function

**Total Cost**

- Routing
  - ✓ Stop & service
  - ✓ Inter stop transit
  - ✓ Tour setup
- Equipment
- Infrastructure
- Handling

1 **Augmented Routing Cost Approximation Formula**

### Optimization

**Mixed Integer Linear Programming Model (MILP)**

2 **Two-step optimization heuristic**

**GUROBI simplex solver**

### Output

- Optimal **facility count**
- Optimal **facility locations**
- Optimal facility **influence area** definition
- Optimal **modal choice** for each segment
- Optimal **vehicle routing** within segments

# ❶ Augmented routing cost approximation

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**Vehicle routing cost as a function of**

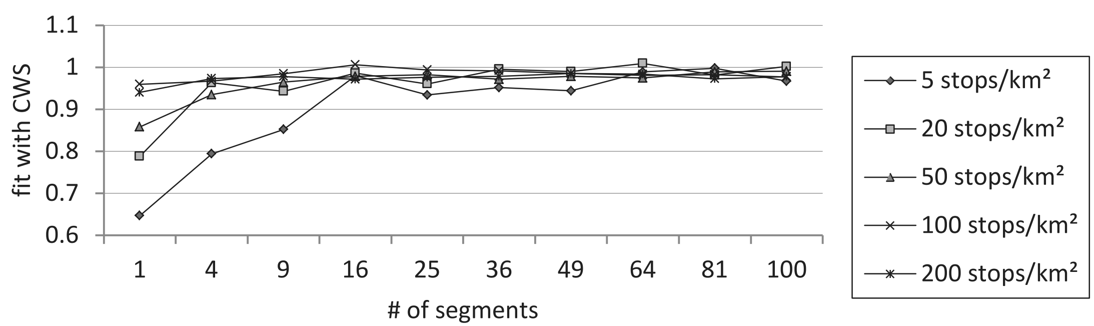
- ***vehicle characteristics***
  (capacity, speed, time requirements, cost, …)
- ***city segment characteristics***
  (distance from facility, size, …)
- ***demand characteristics***
  (stop density, item size distribution, pickup/delivery, …)

$$f_{d,i}\left(r_{d,i}, \xi^n, A_i, \gamma_i\right)$$

$$\approx q_{d,i}\left(m_{d,i}\left(t^s w + 2\frac{\kappa^o r_{d,i}}{s^o}\left(w + c^v\right) + n_{d,i}\left(t^a + \frac{\kappa}{s\sqrt{\gamma_i}}\right)\left(w + c^v\right) + n_{d,i} c^h\right) + f^v\right)$$

| | **Explicit routing simulation** [e.g. Clarke Wright Savings] | **Closed-form routing cost approximation** |
|---|---|---|
| + | ▪ Very flexible regarding the problem setting<br>▪ ***Transparent and comprehensible result generation*** | ▪ No algorithm required<br>▪ ***Suitable for an optimization routine***<br>▪ ***Results for a wide range of arguments*** |
| – | ▪ Long computation time<br>▪ ***Not suitable for direct use with optimization solver***<br>Regressions required to construct function | ▪ Certain constraints are difficult to implement while keeping the problem linear<br>▪ ***Approximation error needs to be assessed*** |

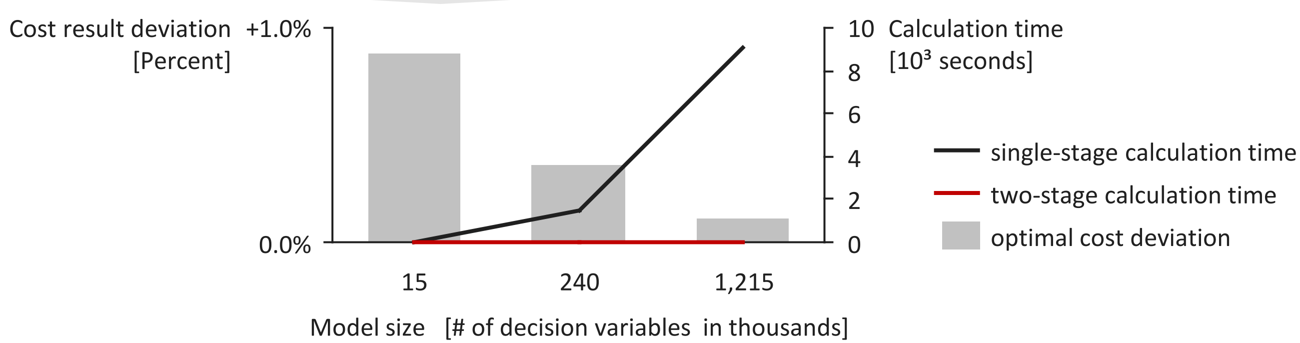
**Performance comparison**



# ❷ Two-step optimization heuristic

| | Single-stage optimization | Two-stage optimization Stage I | Two-stage optimization Stage II |
|---|---|---|---|
| **Decision dimensions** | | | |
| Number of facilities | Number of facilities fixed for each model run; changed iteratively to find optimum | | |
| Facility locations | ✓ | ✓ → | fixed |
| Allocation of city segments to facilities | ✓ | ✓ | ✓ |
| Modal choice | ✓ | lowest cost choice assumed → | ✓ |
| Vehicle routing | Augmented Routing Cost Approximation formula assumes optimal routing | | |
| **Constraints** | | | |
| Vehicle capacities | ✓ | ✓ | ✓ |
| Facility capacities | ✓ | relaxed → | ✓ |
| Vehicle Access Restrictions | ✓ | ✓ | ✓ |
| Max. service times | ✓ | ✓ | ✓ |

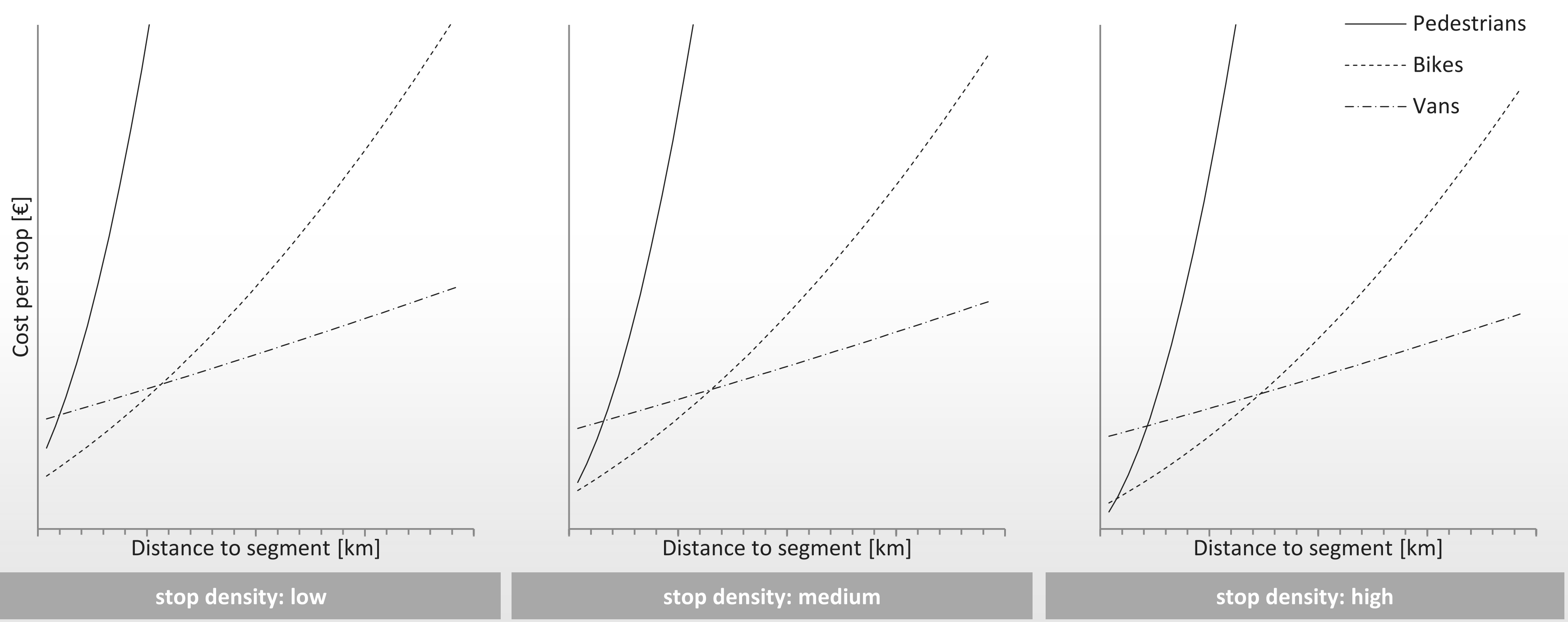
**Increasing performance gains**
vs.
**decreasing precision losses**



Section IV

# PRELIMINARY ANALYSES

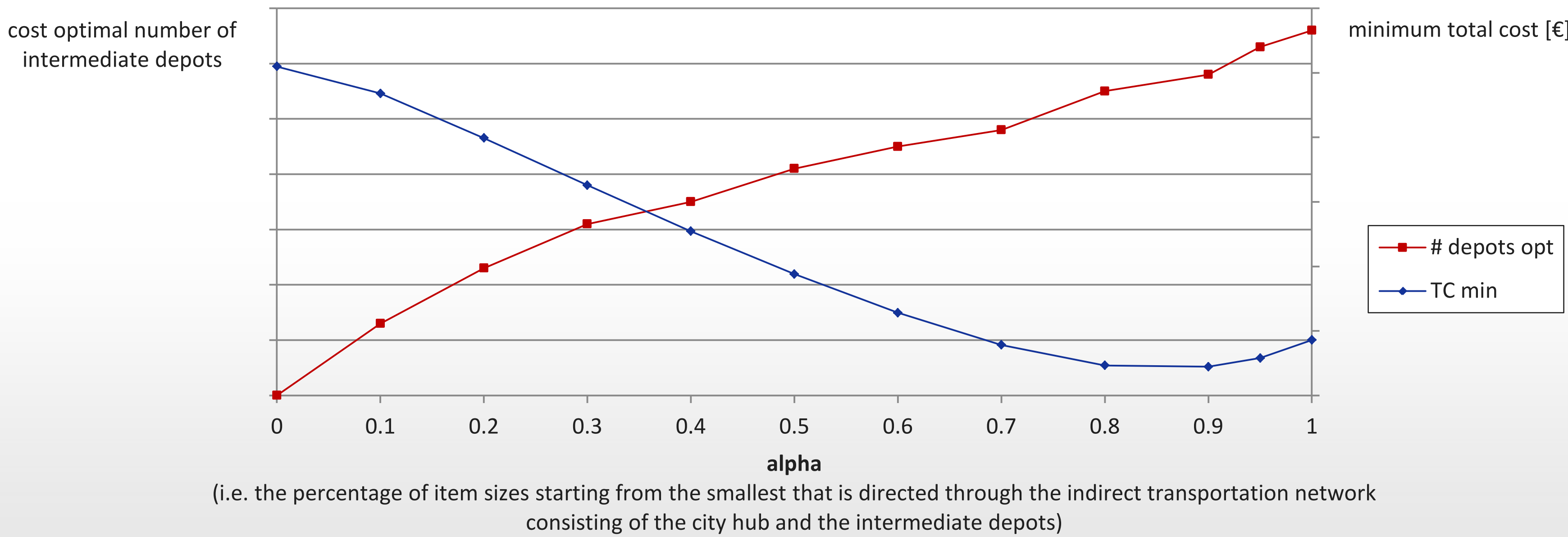
# Relative vehicle competitiveness




- **Bikes are strongly dominant** vehicle choice.
- **Pedestrians** only to be preferred for **very short line-haul distances** and **very high stop densities**.
- **Vans** only become optimal for **very long line-haul distances** and **low stop densities**.

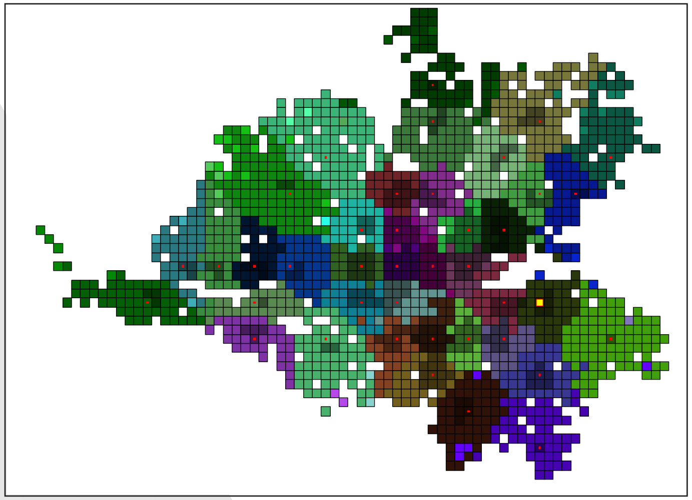
- By allowing for **mixed fleets**, each city segment can be served by its cost optimal vehicle choice, lowering total cost of transportation.

# Optimal threshold between parallel network infrastructures

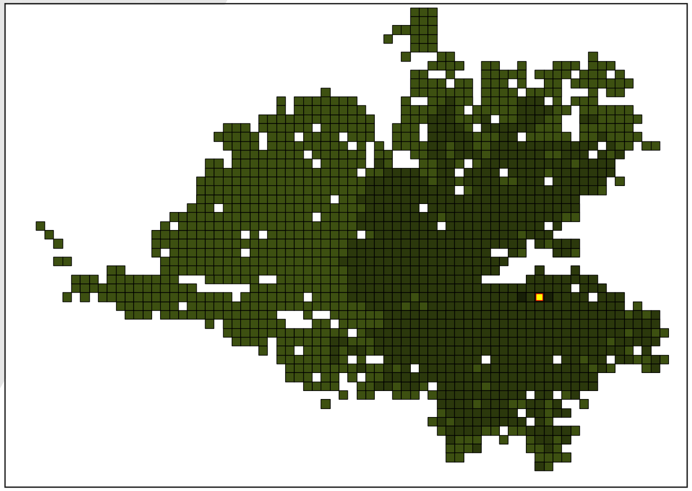



Distinct **optimal load balance** between parallel network infrastructures and corresponding **degree of consolidation** can be identified

# Snapshot:
# Influence area definition & modal choice



**Small item transportation**



**Large item transportation**

Section V

# MANAGERIAL IMPLICATIONS

# Some results for La Poste

- A **first complete model representation** of parcel delivery at the city level (extensible to other similar products): number and location of facilities, choice of vehicle type, facility influence area definition.

- A **model splitting the global cost of a parcel delivery** within a city into about 10 elementary cost (handling, line haul, setup, etc..) and showing the evolution of these elementary cost when the input parameters change.

- A confirmation by the model of our actual operational choices of **the best vehicles to deliver according to the line haul distances**.

- The **antagonistic link** between the **number of depots** and the **number of vehicles** to serve a city with an optimal choice.

# Optimum costs and relevant variables

The optimum cost is a balance between

- line haul: cost of the vehicles and of the postmen
- number of depots: real estate cost

With the model parameters (cost per $m^2$ of facilities, vehicle operating cost, postmen salary, etc.) being set close to the actual observable figures of La Poste the **optimum is flat**:

→ The model **shows a large range of number of depots with similar parcel delivery costs**

The flat shape of the optimum may however change if the input parameters evolve with divergence.

→ The model gives La Poste the capability to **react e.g. to increases in the cost of transportation** by a **reduction of the cost of depots**.

Thank you.

# QUESTIONS?