To cite this work:
Problem statement

State of the art

Proposed approach
  – Data collection and demand generation
  – Optimization of the location of delivery areas
    • Mathematical model
    • Objective function and encoding of solutions
    • Genetic algorithm

Application to Paris (5th arr.)
  – Ex.1: Where to place 10 new LU spaces if none exist?
  – Ex.2: Where to place 2 new spaces taking into account the existing ones?
  – Ex.3: Assessing the pertinence of existing LU spaces?

Conclusion and perspectives
• Loading and unloading spaces (L/U) are designed to facilitate logistics operations in urban areas.

• Approach standpoint = local authorities
  – Aim: at finding a trade-off between sustaining the commercial dynamism related to local businesses and the scarcity of parking surfaces for inhabitants.

QUESTION: WHERE TO PLACE L/U SPACES IN ORDER TO MEET THE NEEDS OF THE AREA?
STATE OF THE ART

2005
Aiura et Taniguchi
Model to identify the optimal location of L/U spaces considering traffic.

2010
Dezi et al.
Technical solutions to improve the dimensions and quantities of L/U spaces (application to Bologna).

2013
Jaller et al.
Policy recommendations to increase the availability of L/U spaces (application to New York).

2015
Gadrat et Serouge
Hybrid method (FRETURB + CERTU) to quantify the demand of L/U spaces.

2009
CERTU
Best practices and recommendations for locating L/U spaces (A guide for communities).

2010
Delaître et Routhier
Combination of two tools (FRETURB and DALSIM) for the management of L/U spaces (application to La Rochelle).

2014
Alho et al
Framework for modelling demand of L/U spaces for cases with low data availability.

2016
Cuevas et al.
Methodology for locating L/U spaces using queuing models.
PROPOSED APPROACH (1/2)

DATA COLLECTION
- Businesses
- Existing L/U spaces
- Distances

DEMAND GENERATION
- CERTU method
- Statistic approximation
- Local survey

OPTIMIZATION MODEL
- Location of L/U spaces in an empty infrastructure
- Evaluation of the existing L/U spaces
- Location of new L/U spaces in an existing infrastructure
The proposed approach allows:

- **Quantifying the needs of L/U spaces** by considering the frequencies of logistics movements of the business in the area;
- **Optimally locating new L/U spaces** in order to satisfy the needs of the urban area;
- **Assess the relevance of the location of existing L/U spaces** in the urban area.

This approach allows integrating -in a simple manner- real and up-to-date information regarding cartography, L/U parking demand and existing L/U spaces.

Implementation:

- OpenStreetMap
- ParisOpenData
- GoogleMapsAPI
- Python
Objective: characterize the area of interest and define the logistic movements (loadings and unloadings) generated by each establishment.

Data collection: identify key features of the area of interest.

• Commercial establishments (location and activity for each);
• Existing delivery areas (location);
• Potential locations (coordinates and constraints).

Demand generation: quantify the needs in the area using statistical estimates.

• Output: list of all establishments with their contact information and demand of logistic movements (i.e. frequency of loading or unloading operations).
Movements of goods per week for each type of establishment

### DATA COLLECTION AND DEMAND GENERATION (EXAMPLE)

<table>
<thead>
<tr>
<th>Establishment</th>
<th>Coordinates</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>McDonalds</td>
<td>48.8461174, 2.3396435</td>
<td>Fast food restaurant</td>
</tr>
<tr>
<td>Le jardin</td>
<td>48.846396, 2.341408</td>
<td>Hotel</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Objective function: minimization of the weighted distance

Distance:

- $D_{S1E1} = 80m$; $D_{S1E2} = 70m$; $D_{S1E3} = 55m$
- $D_{S2E1} = 90m$; $D_{S2E2} = 75m$; $D_{S2E3} = 10m$

Frequency:

- $E1$ = 2 mouvements/period
- $E2$ = 5 mouvements/period
- $E3$ = 10 mouvements/period

Frequency $E3 = 0$ because $E_3$ is within the radius of influence of $S_2$

Weighted distance function:

\[ Z = (80 \times 2) + (70 \times 5) + (55 \times 0) + (90 \times 2) + (75 \times 5) + (10 \times 0) \]

\[ Z = 1065 \text{ meters} \times \text{ mouvements / period} \]
OPTIMIZATION: MATHEMATICAL MODEL

Minimize:

\[ Z = \sum_{j=1}^{m} \sum_{i=1}^{n} x_j w_i d_{ij} \]

with:

\[ x_j \in \{0; 1\} \]

\[ \sum_{j=1}^{m} x_j = Q \]

\[ d_{ij}(b_i, x_j) = f(lat_{bi}, lon_{bi}, lat_{xj}, lon_{xj}) \]

where,

- \( x_j \): binary variable indicating if an L/U space is located in the available location \( j \)
- \( b_i \): business \( i \)
- \( Q \): quantity of L/U spaces to locate
- \( w_i \): weight of the business \( i \), given by its frequency of movements of goods
- \( d_{ij} \): distance between the L/U space \( j \) and the business \( i \)
- \( r \): radius of influence
- \( n \): number of businesses
- \( m \): number of possible locations for L/U spaces

\[ w_i d_i \mid \forall_{j} = \begin{cases} 0, & \text{if } d_{ij}(b_i, x_j) \leq r_{ij} \\ w_i d_i, & \text{if } d_{ij}(b_i, x_j) > r_{ij} \end{cases} \]
Problem encoding

Each solution of L/U spaces allocation is represented by a **binary vector** in which each position of the vector is linked to an available spot (the size of the vector is equal to the number of available spots).

In this example there are 11 possible spots for locating 3 new L/U spaces. The proposed solution locates the new spaces in spots 2, 6 and 7.
OPTIMIZATION: GENETIC ALGORITHM (1/2)

1. Population generation
2. Evaluation and selection
3. Reproduction
4. Mutation

Decision:
- Yes: Results
- No: Repeat process

End?
OPTIMIZATION: GENETIC ALGORITHM (2/2)

Population generation

Evaluation and selection
Calculating the objective function of each individual and affecting the number of reproductions (the best individuals will have more children)

Reproduction operator

Mutation operator
EX.1: WHERE TO PLACE 10 NEW L/U SPACES IF NONE EXIST?

Data collection and demand generation

Convergence of the genetic algorithm

WEIGHTED DISTANCE vs ITERATIONS OF OPTIMIZATION (I.E. GENERATIONS)

Best distance
Average distance
EX.2: WHERE TO PLACE 2 NEW SPACES TAKING INTO ACCOUNT THE EXISTING ONES?

16
EX.3: ASSESSING THE PERTINENCE OF EXISTING L/U SPACES?

Existing L/U spaces (29 in total)

Pseudo-optimal location of 29 new spaces

**Pairing function:**
Counting the number of “equivalent” spaces, that is, the real spaces within the zone of influence of the optimal spaces.

A pertinence score is calculated by relating the equivalent spaces to the total number of spaces.
EX.3: ASSESSING THE PERTINENCE OF EXISTING L/U SPACES?

Pertinence result:

\[ P = \frac{\text{number of equivalent spaces}}{\text{number of spaces in the area}} \]

\[ P = \frac{22}{29} \approx 76\% \]

\[ \text{Cost}_{\text{OPTIMIZED}} \approx \frac{\text{Cost}_{\text{EXISTING}}}{5} \]
Advantages of the model

- Simplicity of implementation: use of collaborative data and free cartography.
- Scalability: the genetic algorithm is very easily modifiable to take into account other constraints (e.g. size of places).

Perspectives

- Create of a demand generation model to quantify the demand for parking during the different hours of the day.
- Integrate size constraints.
- Develop a tool for dynamic management of areas, which could have private and logistic usages according to the hour of the day.
THANK YOU FOR YOUR ATTENTION

QUESTIONS?

Simon TAMAYO, Arthur GAUDRON, Arnaud de LA FORTELLE
MINES ParisTech, PSL Research University, Centre de Robotique
60 boulevard Saint-Michel, Paris, France