Optimization in city logistics

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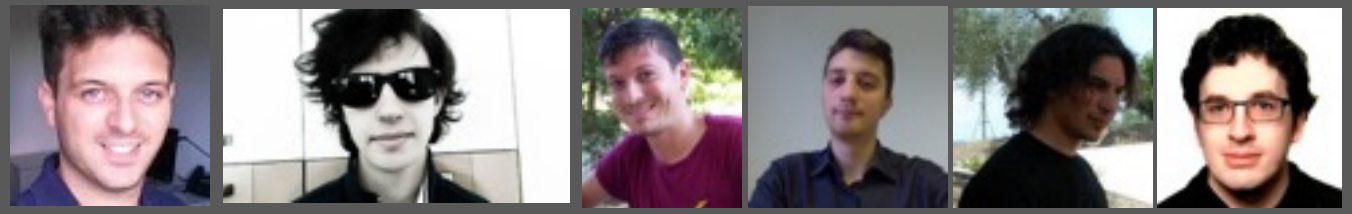
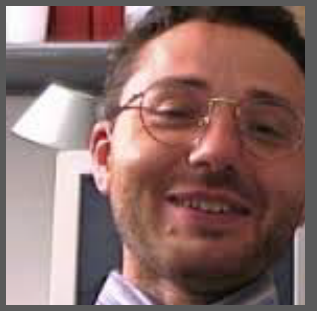


Instructors: Daniele Manerba, Renata Mansini, Romeo R



Introduction

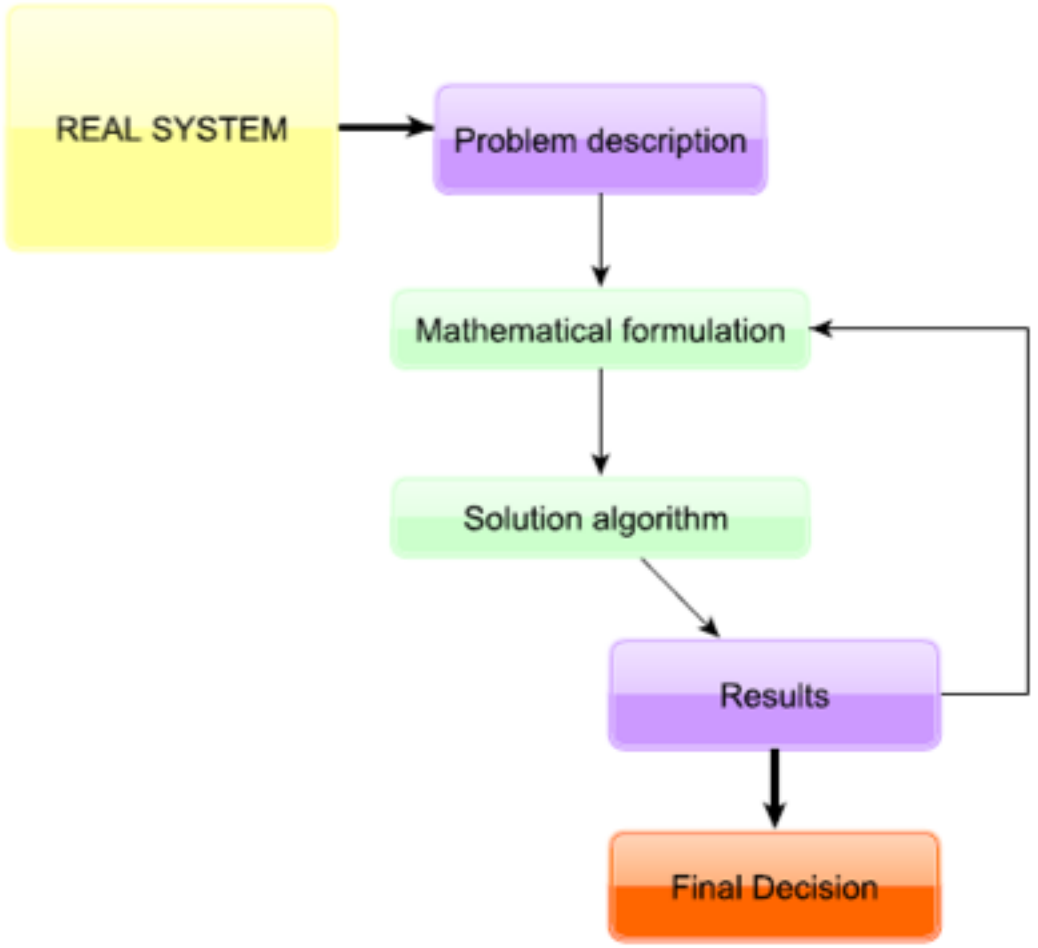
Operations research is a discipline that deals with the application of advanced analytical methods to help make better decisions.

For our purpose:

- Optimization of logistics and transport activities by private companies in urban areas;
- Target: improving environmental, economic, and social sustainability of urban areas.

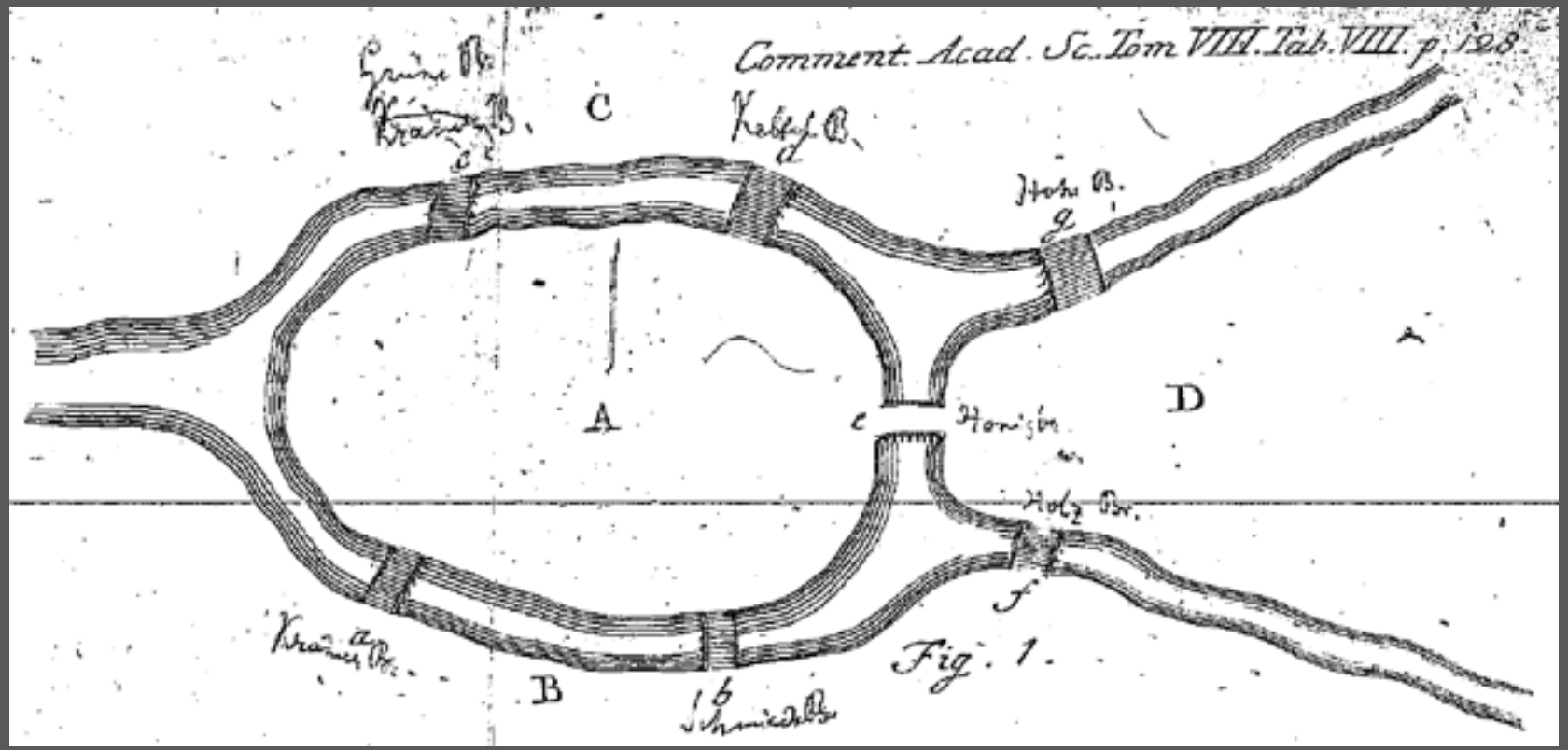
Introduction

1. Problem definition (identification of parameters);
2. Model construction (objective function, constraints);
3. Resolution (algorithms, computer science technologies);
4. Results application and possible model revision (feedback action).



Arc routing

Arc Routing is the process of selecting the **best path** in a network based on the route.



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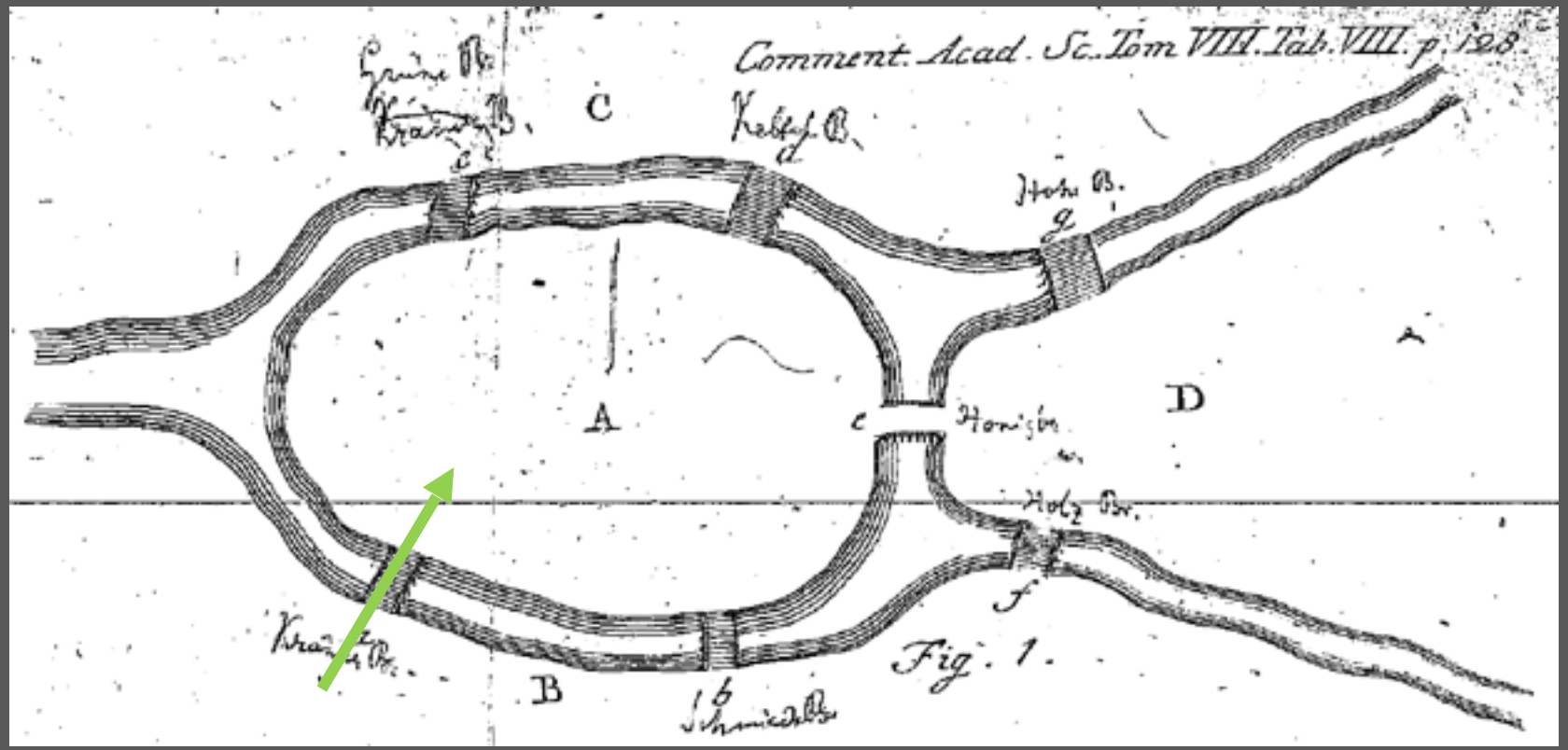

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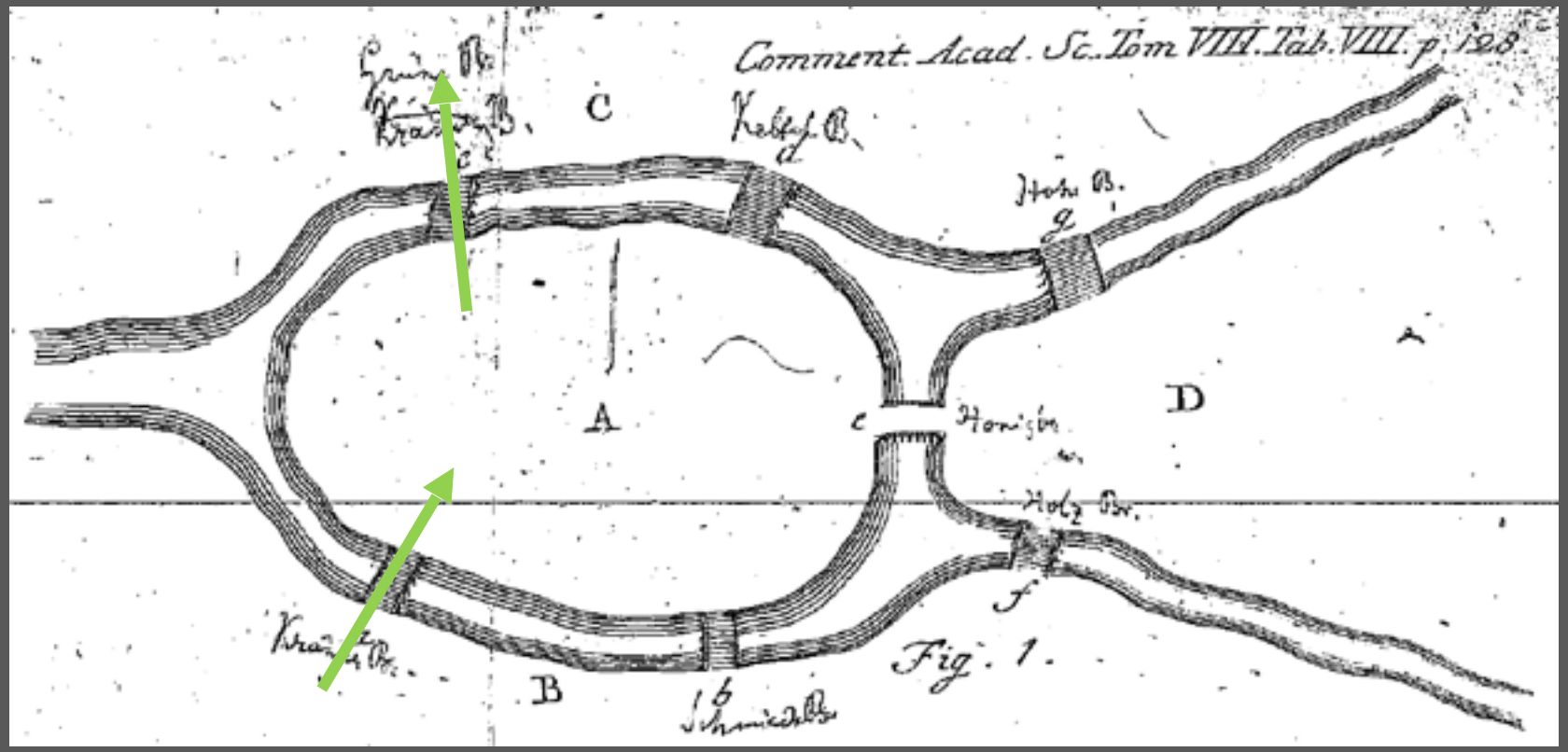

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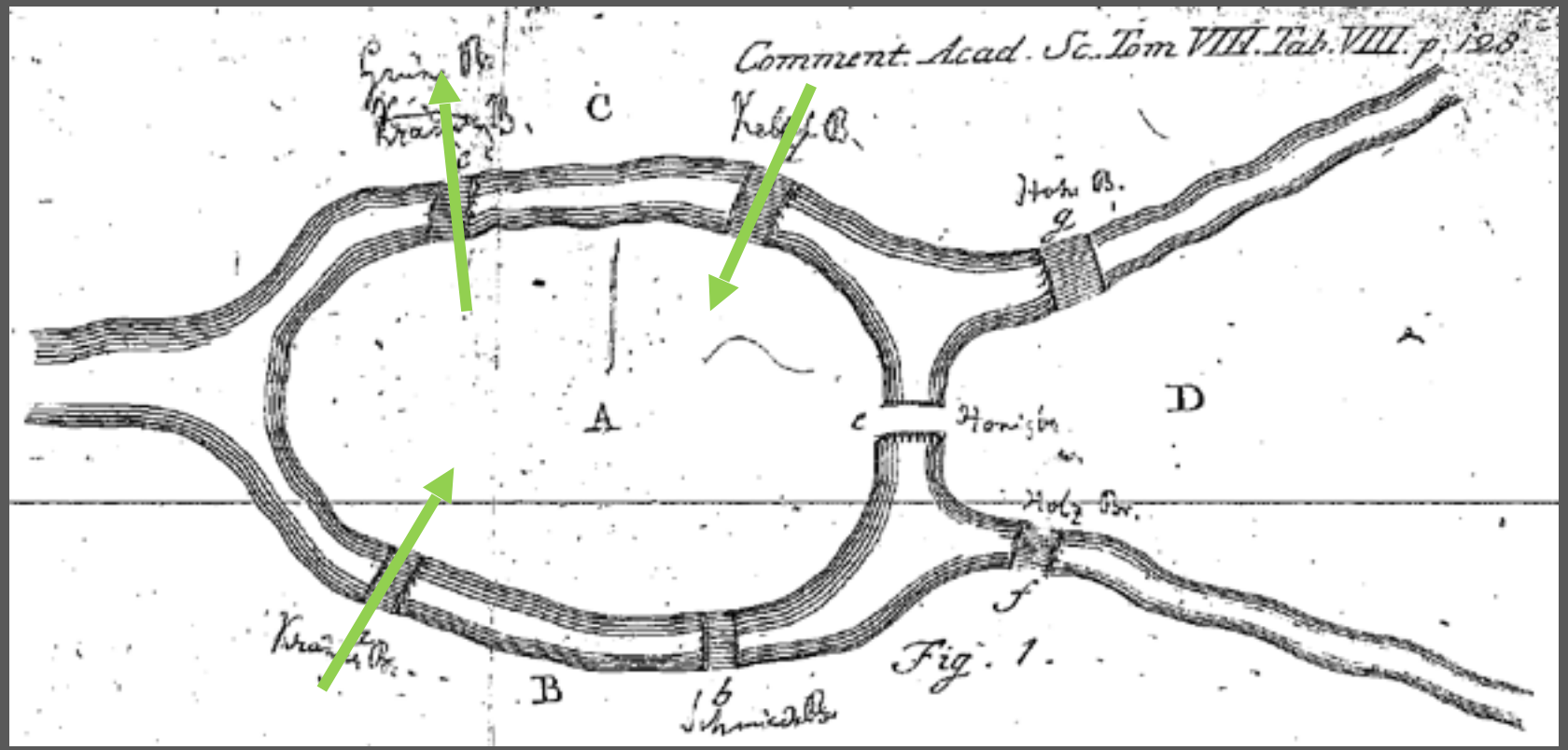

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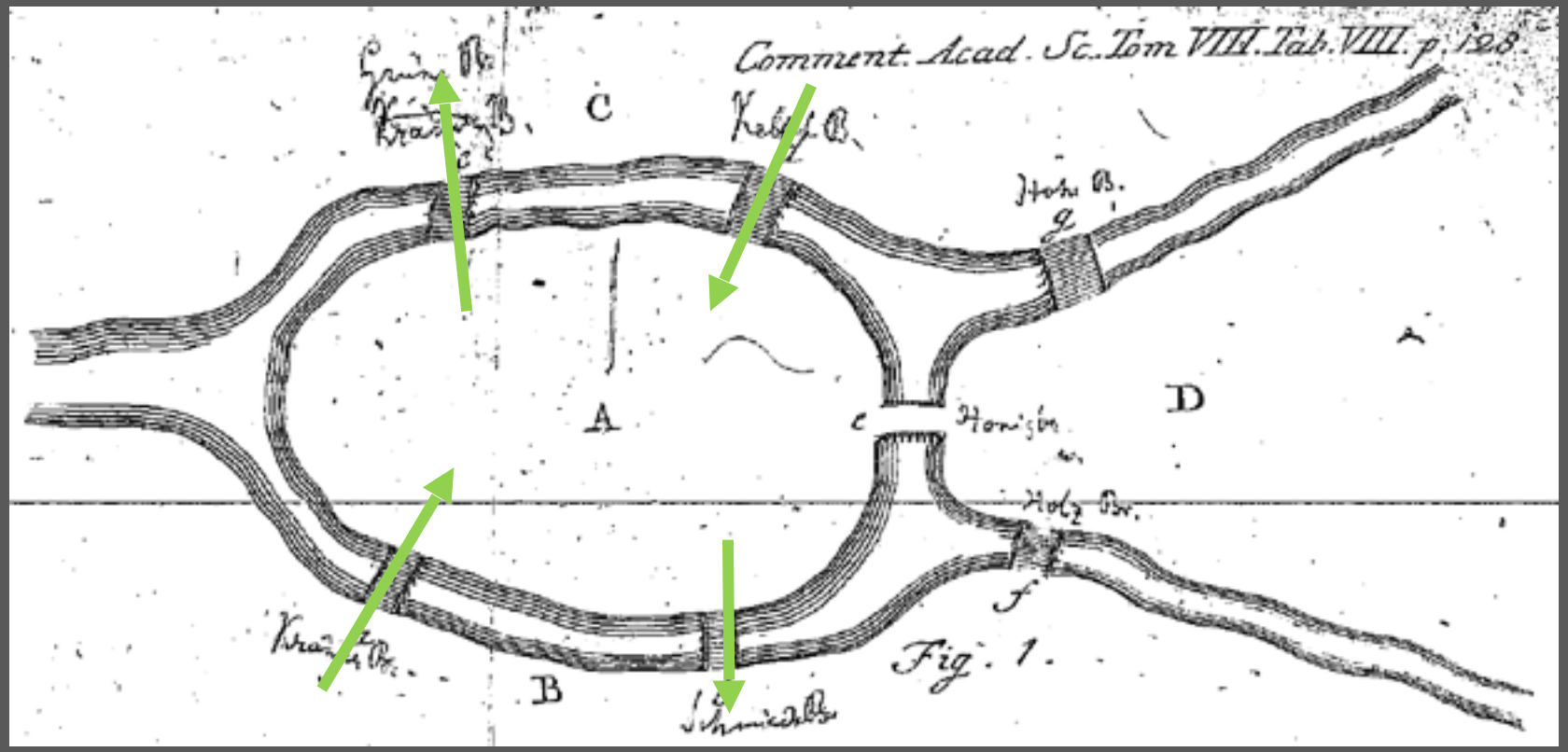

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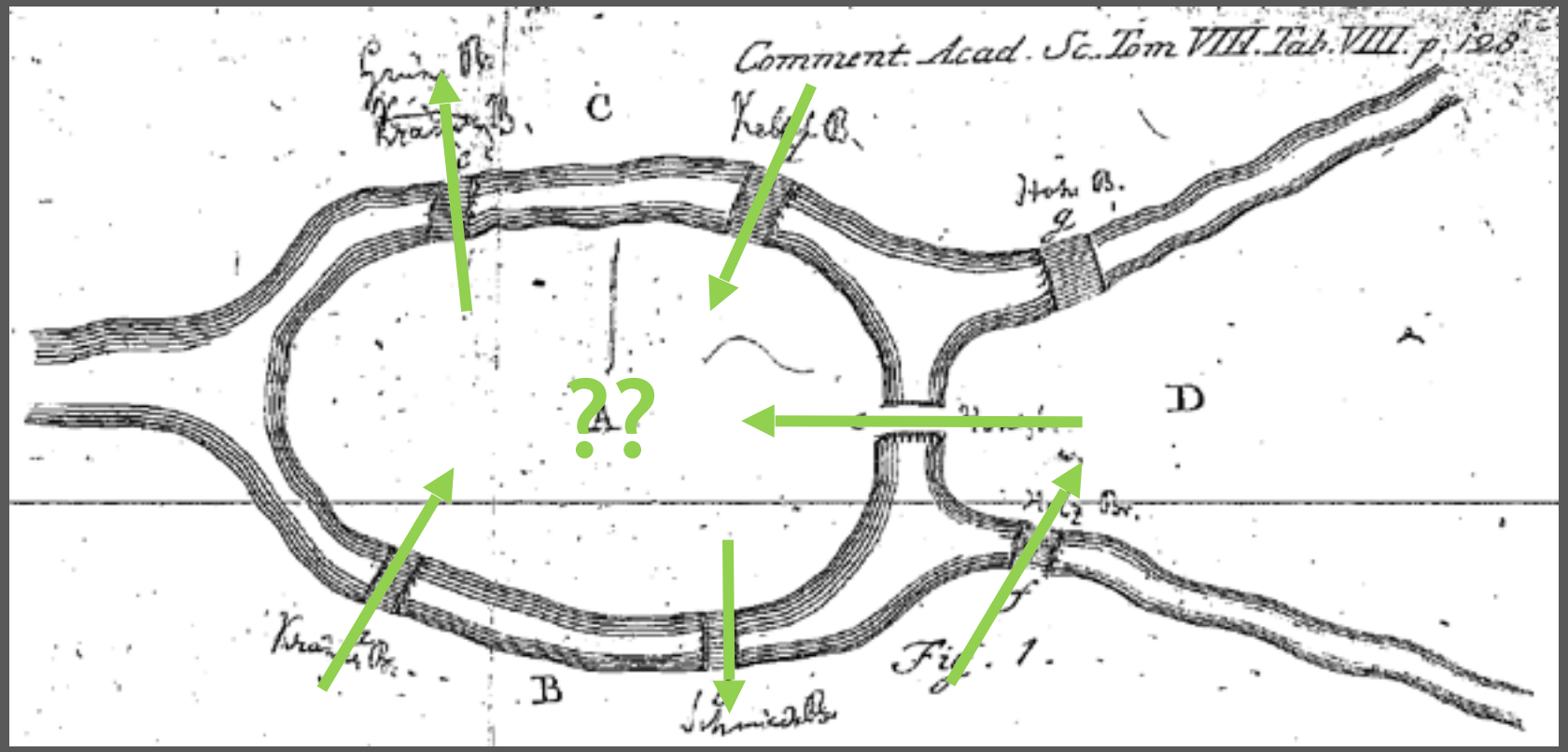

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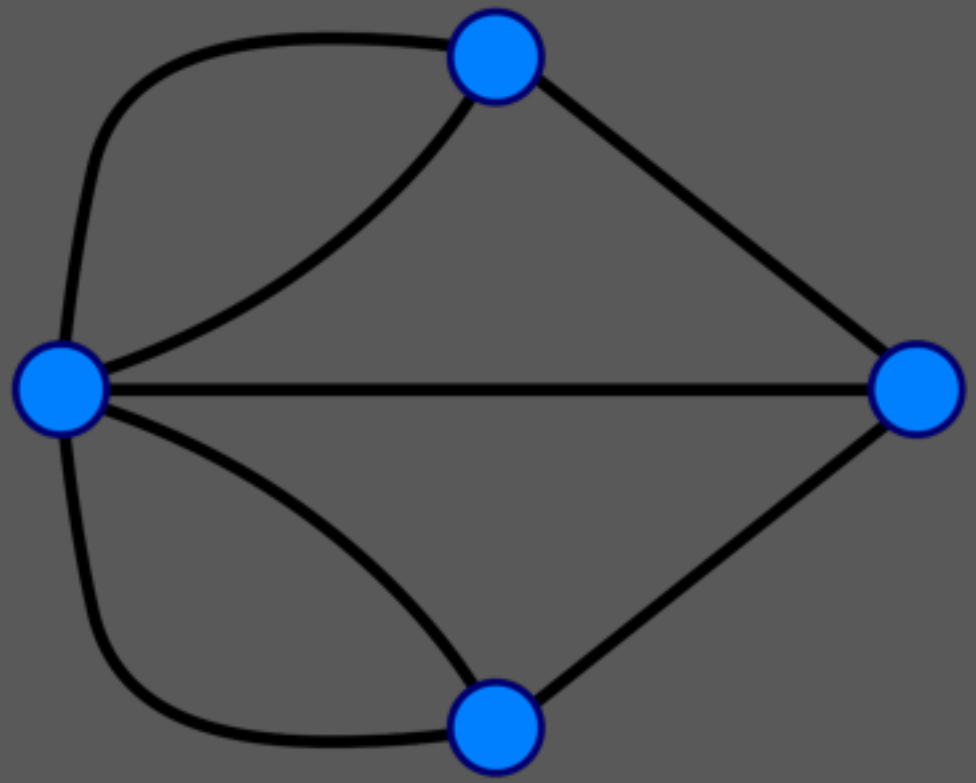
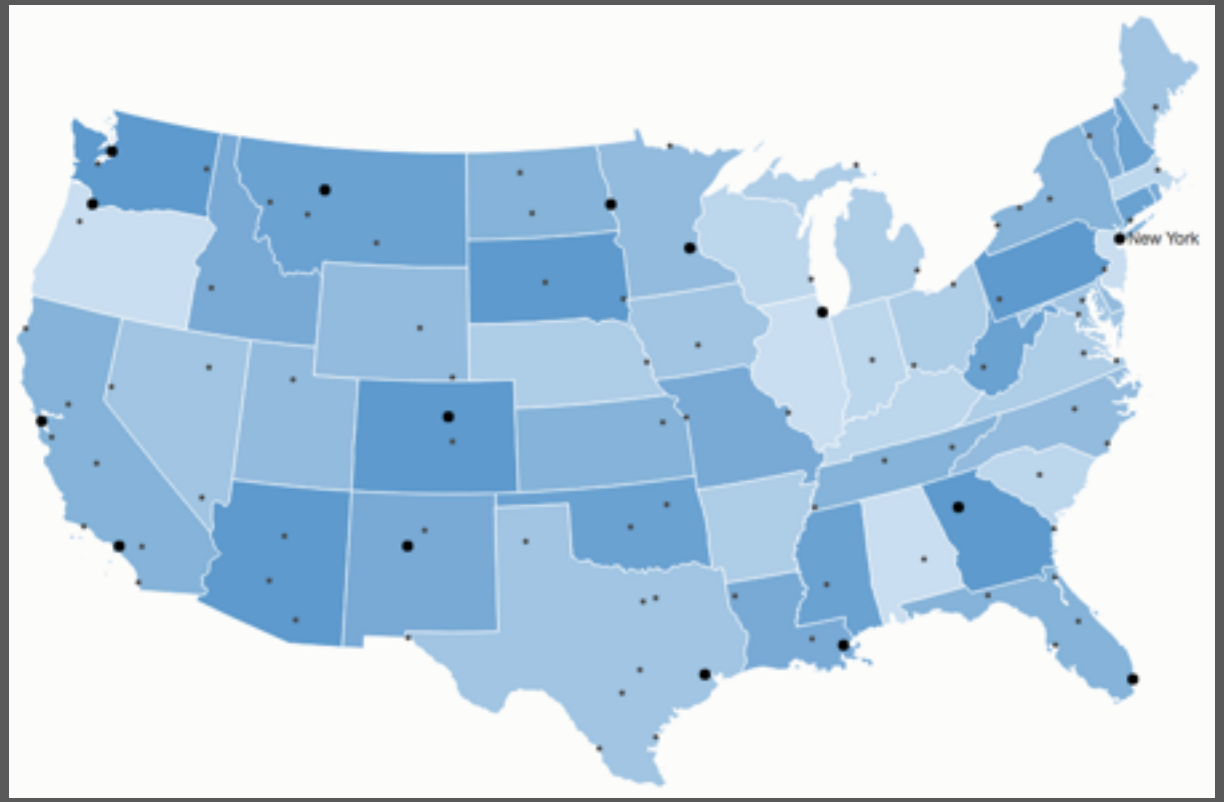


Node routing

Node Routing is the process of selecting the **best path** to visit all nodes in a network.



Credit Gurobi

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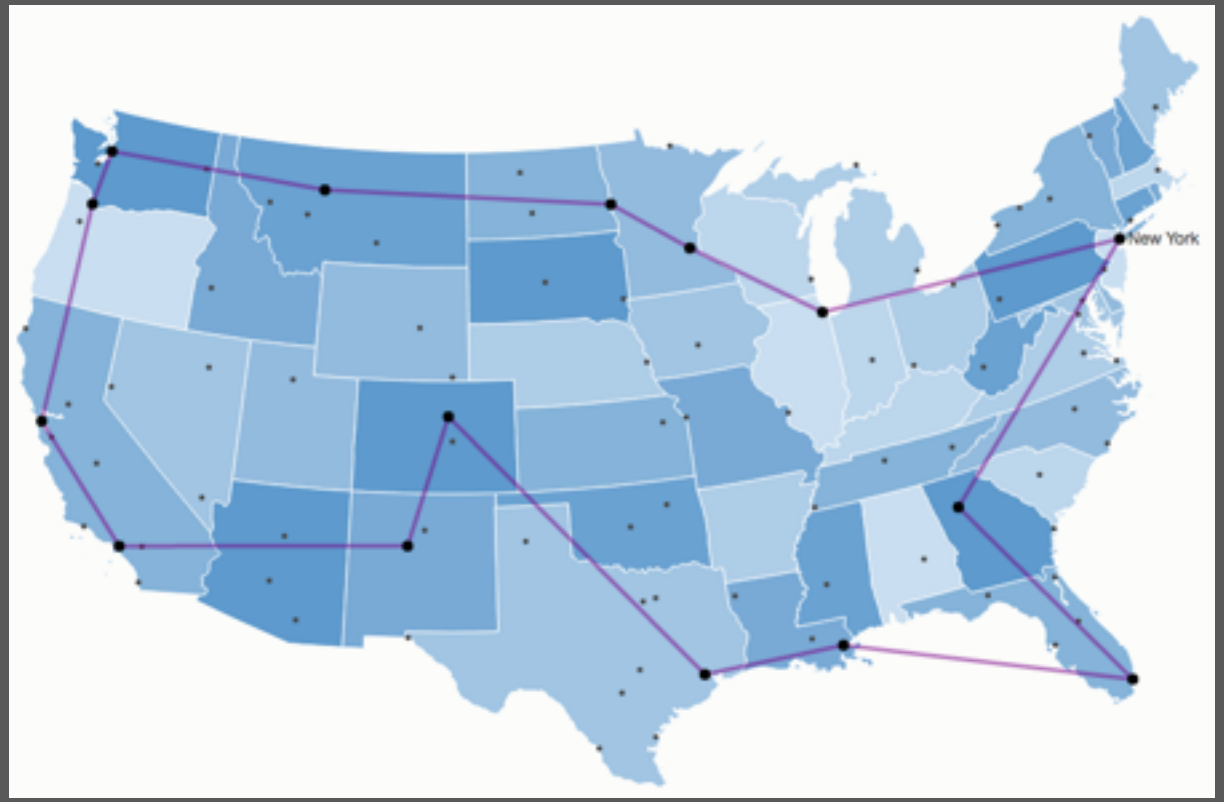

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QGIS

QGIS is a cross-platform free and open-source desktop geographic information system (GIS) application that provides data viewing, editing, and analysis.

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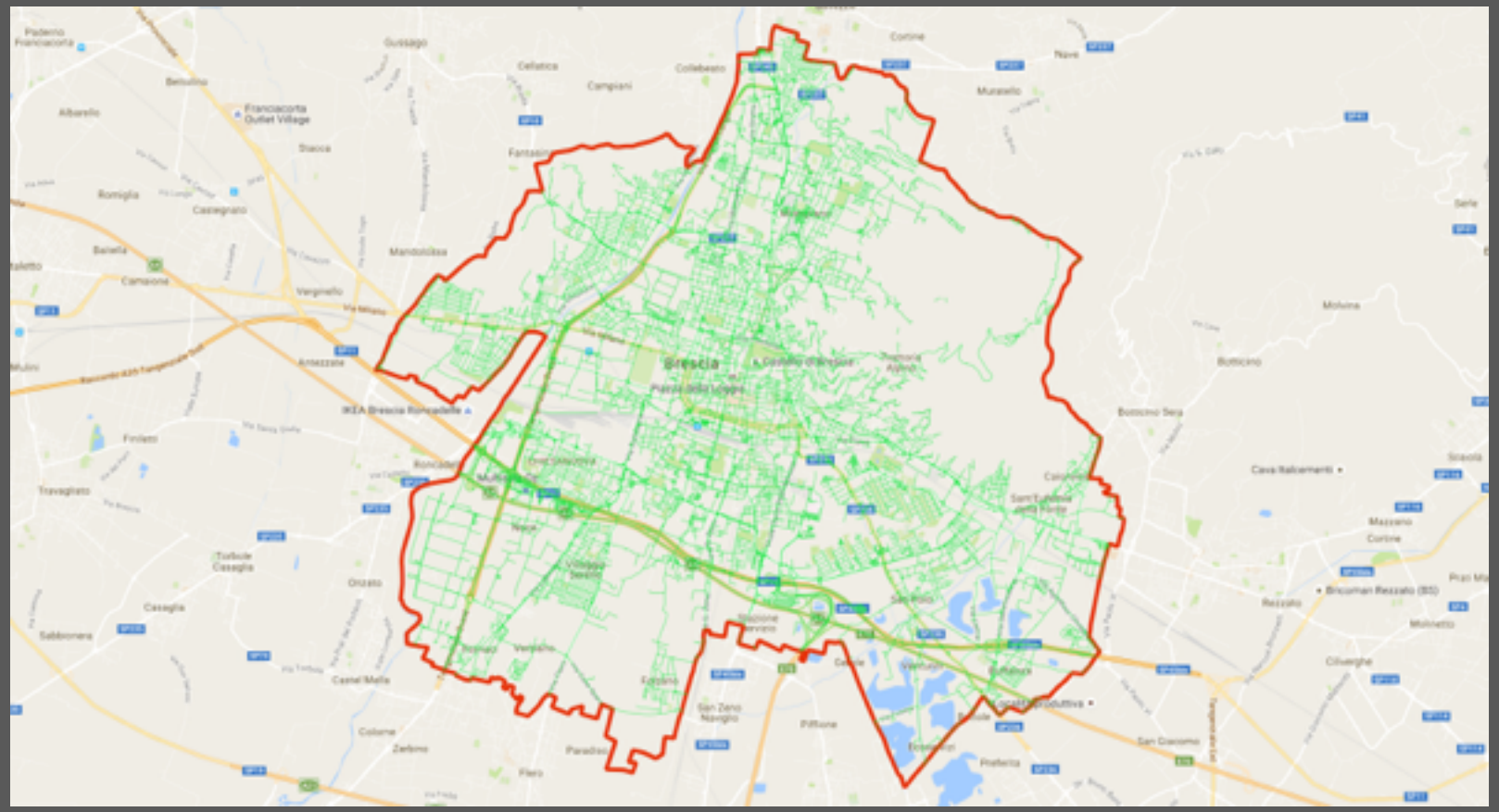


Problem 1:
Optimizing garbage collection using mathematical tools

Door to door VS selective bins collection

VS

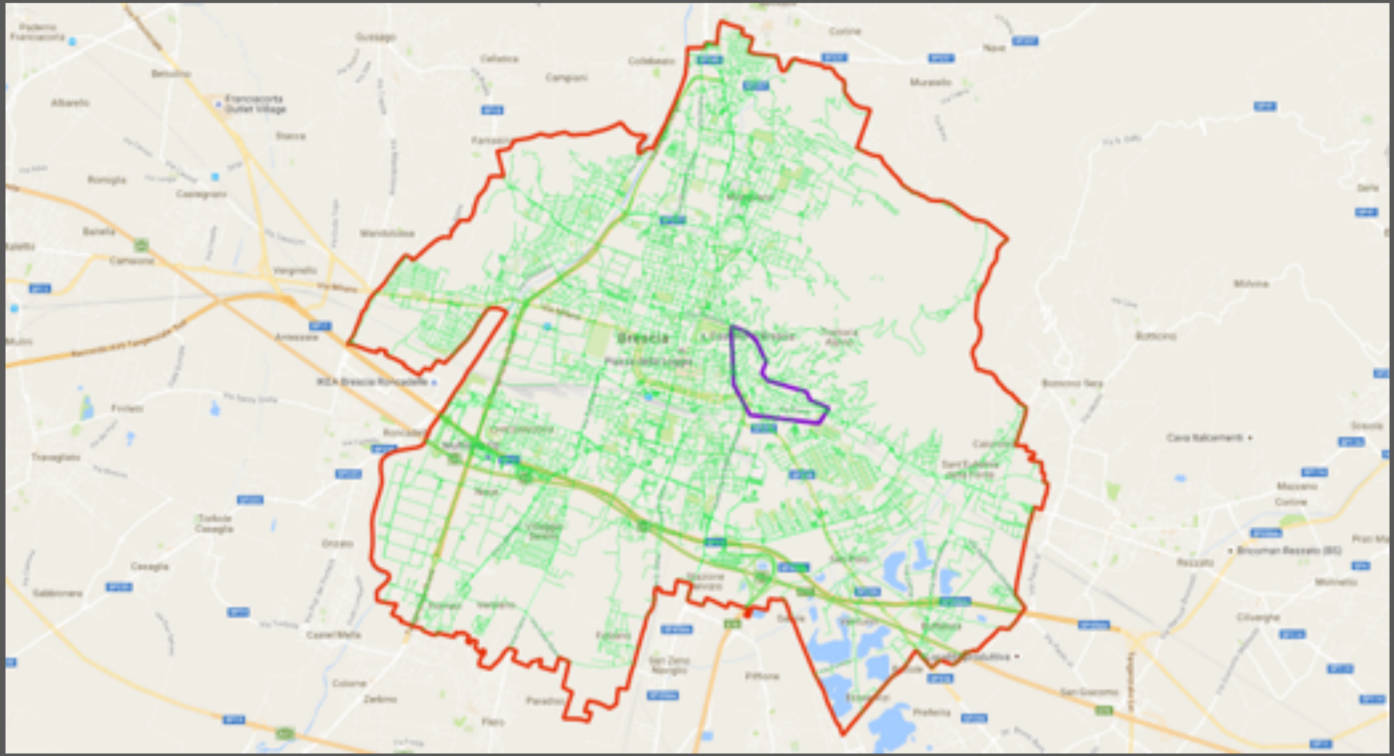
Study area

Brescia is moving from a bins-based system to a door-to-door service.

The city needs to
- Re-organize the activity of a huge number of trucks and workers
- Define the routes for the new service and the corresponding schedule

We can use a mathematical model to find an **optimal** route (**minimize costs**, guarantee a fixed schedule for each type of waste…)

Study area



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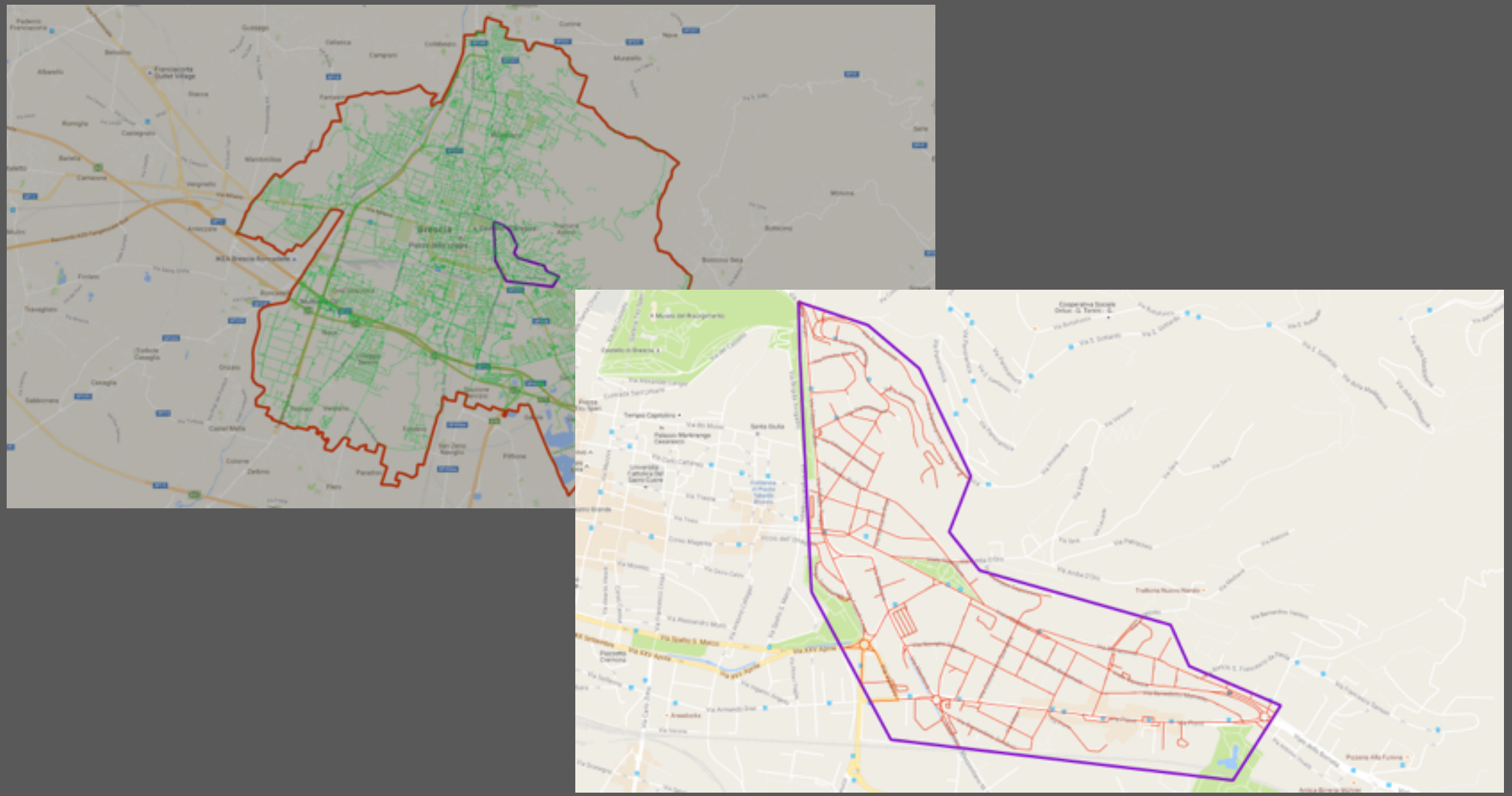
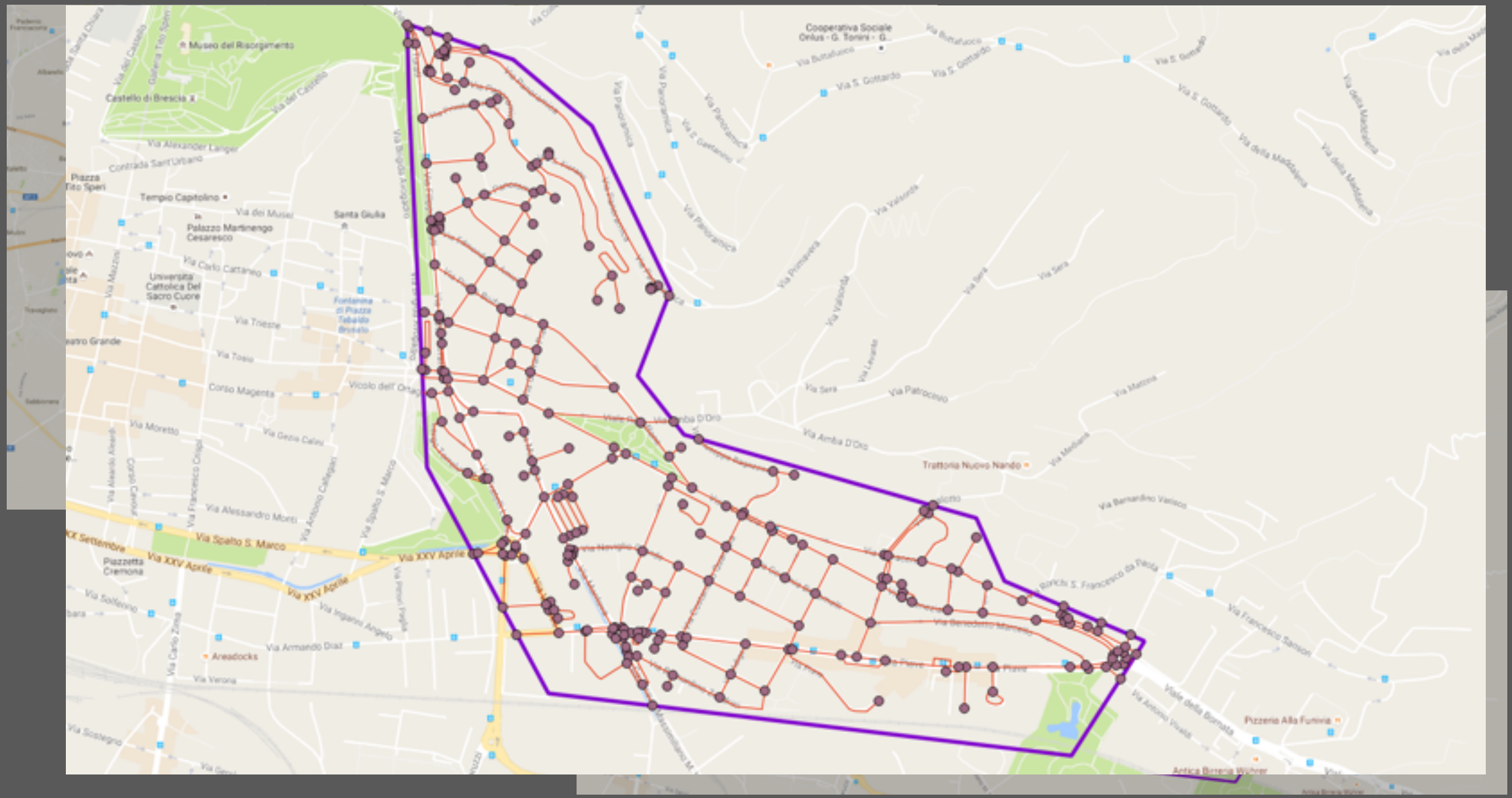


Study area


Museo del Risorgimento
Castello di Brescia
Via del Castello
Via Alexander Langer
Contrada Sant'Urbano
Piazza Tito Speri
Tempio Capitolino
Via dei Musei
Palazzo Martinengo Cesaresco
Santa Giulia
Via Carlo Cattaneo
Università Cattolica Del Sacro Cuore
Via Trieste
Via Tosio
Corso Magenta
Vicolo dell'Orso
Via Moretto
Via Gezia Calini
Via Alessandro Monti
Via Spalto S. Marco
Via XXV Aprile
Via XX Settembre
Piazzetta Cremona
Via Solferino
Via Carlo Zima
Via Armando Diaz
Via Verona
Via Sostegno
Areadocks
Via Ingarani Angelo
Via Francesco Crispi
Via Antonio Cattaneo
Via Alberto Alberti
Via Mazzini
Cooperativa Sociale Onlus - G. Tonini - G...
Via Bunaiuolo
Via S. Gottardo
Via Panoramica
Via S. Gaetano
Via Pastorgnica
Via Primavera
Via Valsorda
Via Sera
Via Levrano
Via Patrocinio
Via Mattina
Via Amba D'Oro
Via Mediana
Via Bernardino Varisco
Trattoria Nuovo Nando
Via della Maddalena
Via della Maddalena
Via Francesco Samson
Viale della Bornata
Via Antonio Vivaldi
Pizzeria Alla Fumiva
Antica Borgia Wicher

The model

$$\min \sum_{(i,j)\in A} c_{ij} x_{ij}$$

$$\text{s.t.} \quad x_{ij} + x_{ji} \geq 1 \quad (i,j) \in A$$

$$\sum_{(i,j)\in\delta^+(\{h\})} x_{ij} = \sum_{(i,j)\in\delta^-(\{h\})} x_{ij} \quad h \in V$$

$$x_{ij} \in \mathbb{N} \quad (i,j) \in A$$

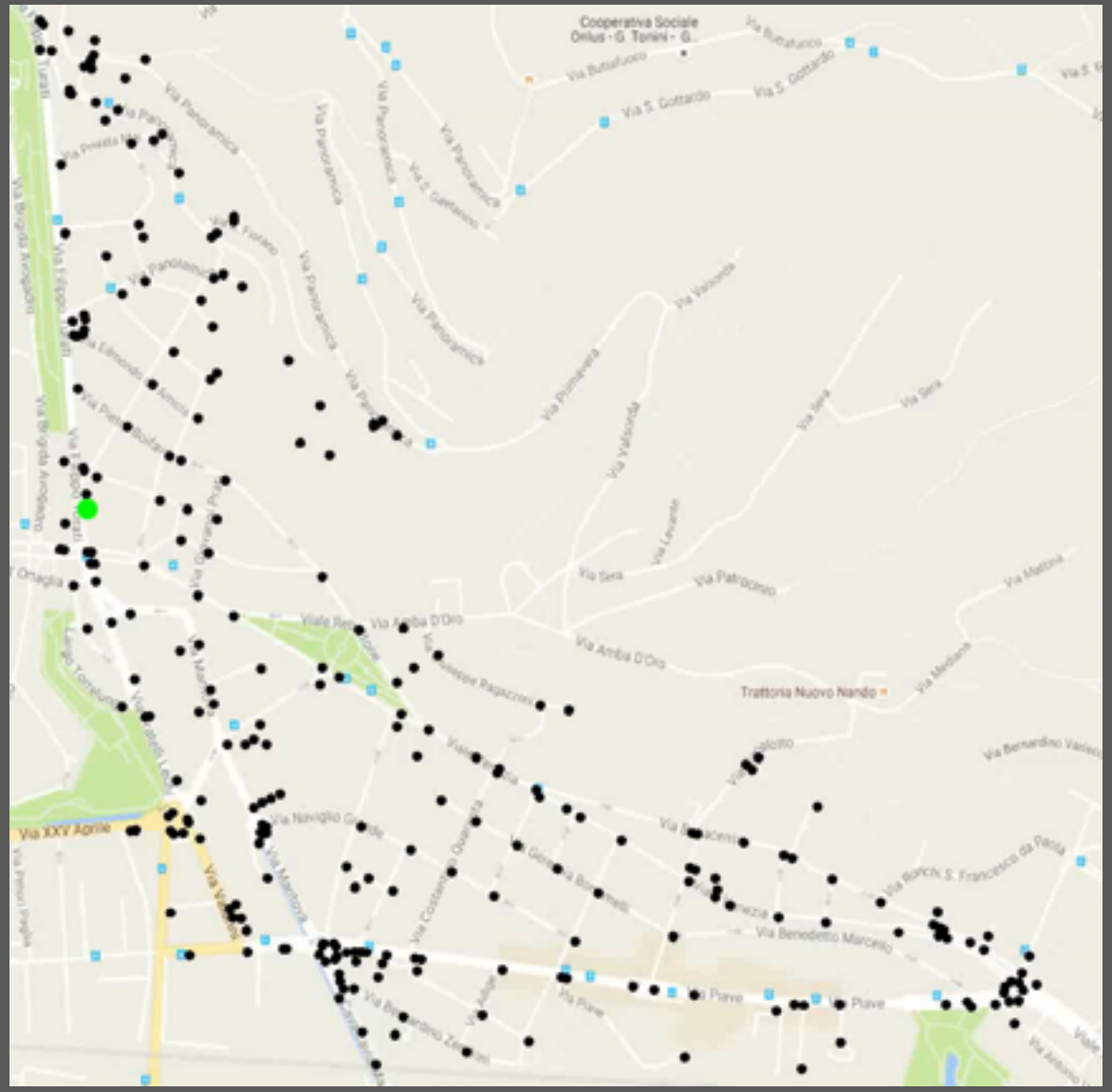
Implementing the algorithm

VS

Used software: MPL


```
TITLE
        Waste_collection;

INDEX
        i := DATAFILE("nodes.txt");
        j := DATAFILE("nodes.txt");

DATA
        cost[i,j] := DATAFILE("distances.txt");

VARIABLES

        x[i,j] WHERE cost[i,j] > 0;

MODEL
        MIN  SUM(i,j: x[i,j] * cost[i,j])

SUBJECT TO

        arc_passing[i,j]:       x[i,j] + x[i:=j,j:=i] >= 1;

        flow_conservation[i]:   SUM(j: x[i,j]) - SUM(j: x[i:=j,j:=i]) = 0

INTEGER

        x[i,j]

END
```

The solution



The solution

Study area ~ **1km^2**. The optimal (shortest) route is **36 km** long!

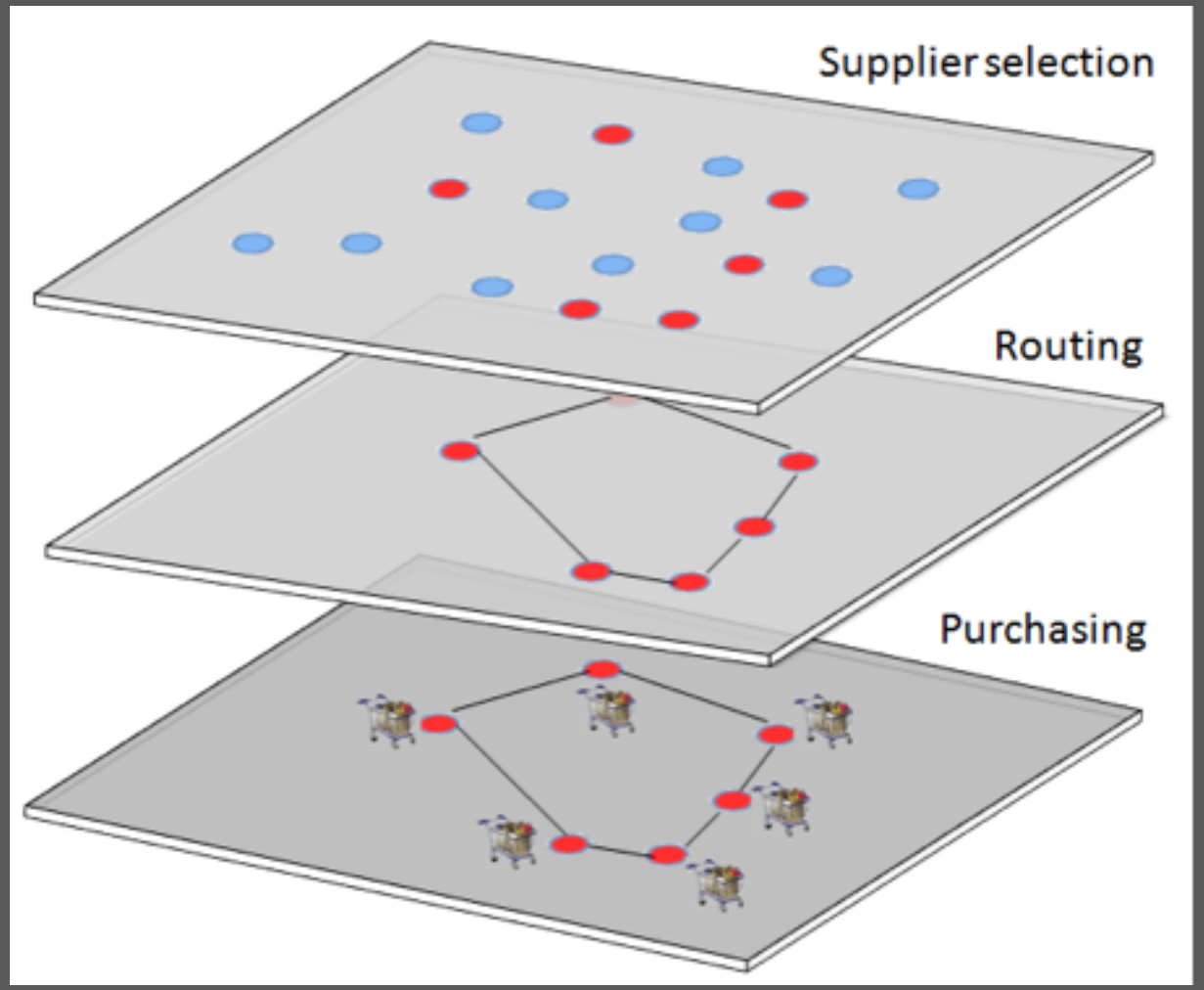
However, with respect to a not optimal implemented route, with our solution we can save about 400km annually!
Brescia is about 90.34 km^2 so do the math!

Problem 2:
Management of complex operations in procurement logistics

Procurement logistics

A buyer has to determine

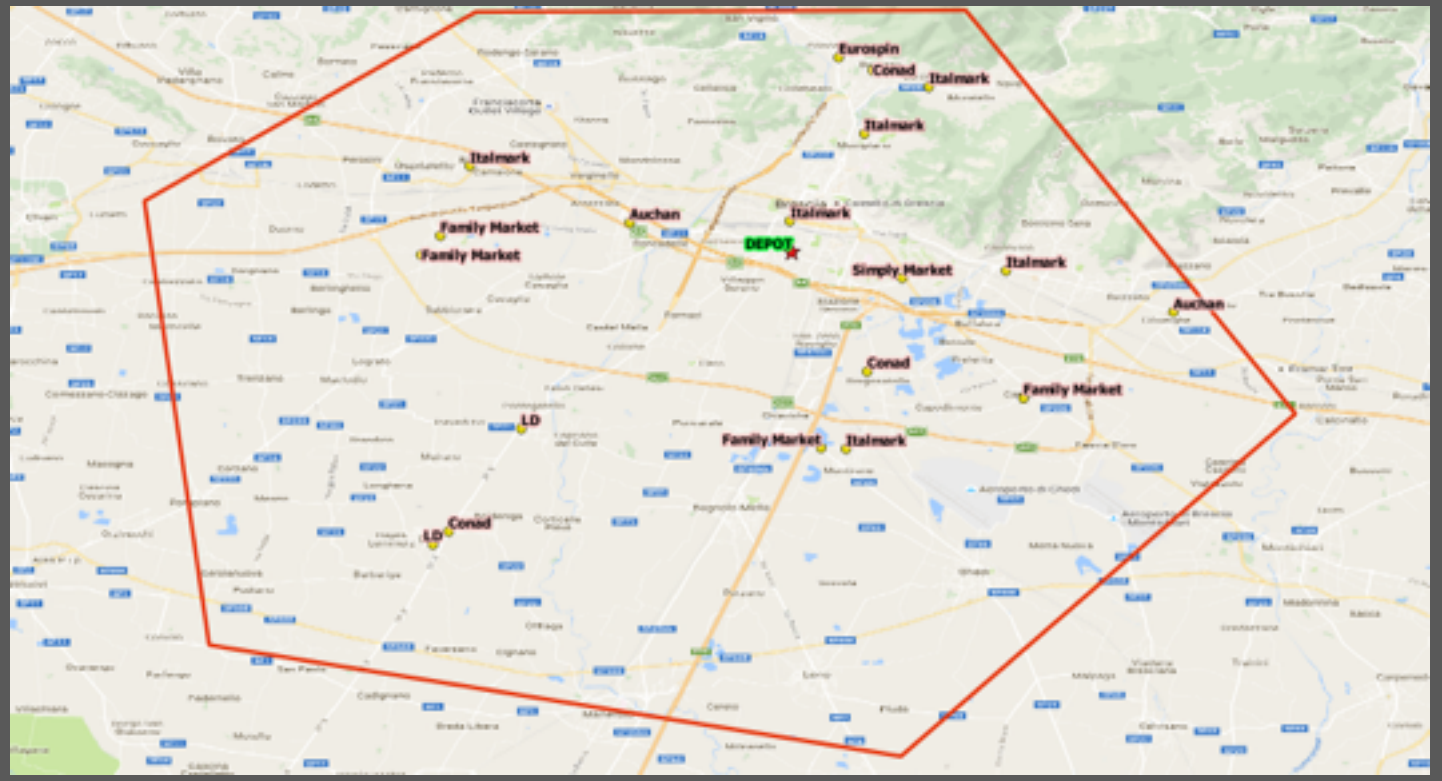
- Optimal suppliers selection;
- Optimal routing;
- Optimal purchasing planning.



Study area

We have a shopping list. We can buy from 19 supermarkets (M) using a set of trucks, each one with a maximum capacity Q. We start from the depot and we want to return there.
50 different goods (k), offered differently by each supermarket. Some goods can not travel together.

We want to buy everything at the minimum travelling and purchasing cost.



The model

$$\min \sum_{v \in F} \sum_{(i,j) \in A} c_{ij} x_{ij}^v + \sum_{k \in K} \sum_{i \in M_k} \sum_{v \in F} p_{ik} z_{ik}^v \tag{1}$$

$$\text{s.t.} \quad \sum_{i \in M_k} \sum_{v \in F} z_{ik}^v = d_k \quad k \in K \tag{2}$$

$$\sum_{(i,j) \in \delta^+(\{h\})} x_{ij}^v = \sum_{(i,j) \in \delta^-(\{h\})} x_{ij}^v = y_h^v \quad h \in M, v \in F \tag{3}$$

$$u_i^v - u_j^v + |M| x_{ij}^v \leq |M| - 1 \quad i, j \in M, i \neq j, v \in F \tag{4}$$

$$\sum_{k \in K} \sum_{i \in M_k} z_{ik}^v \leq Q \quad v \in F \tag{5}$$

$$z_{ik}^v \leq q_{ik} y_i^v \quad k \in K, i \in M_k, v \in F \tag{6}$$

$$\sum_{v \in F} z_{ik}^v \leq q_{ik} \quad k \in K, i \in M_k \tag{7}$$

$$w_k^v + w_g^v \leq 1 \quad (k, g) \in B, v \in F \tag{8}$$

$$w_k^v \leq \sum_{i \in M_k} z_{ik}^v \leq d_k w_k^v \quad k \in K, v \in F \tag{9}$$

$$x_{ij}^v, y_i^v, w_k^v \in \{0, 1\} \qquad z_{ik}^v, u_i^v \geq 0$$

Used software: CPLEX

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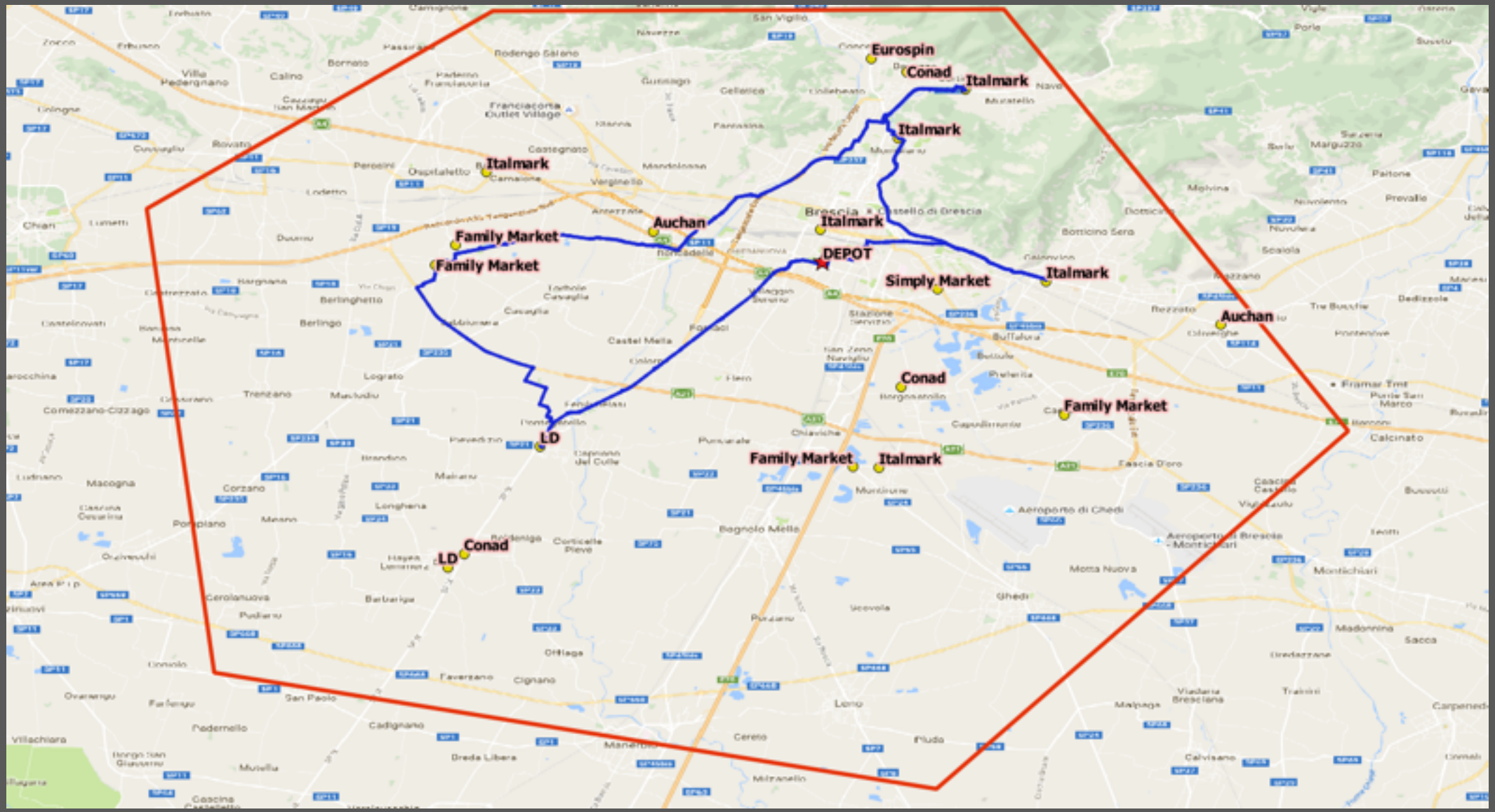
We implemented a model, using all these constraints, but…..

After 10 minutes we were still far from the optimal solution!!

We had to reason and develop a dynamic inclusion of more powerful constraints to speed up the resolution.

Optimal shopping plan



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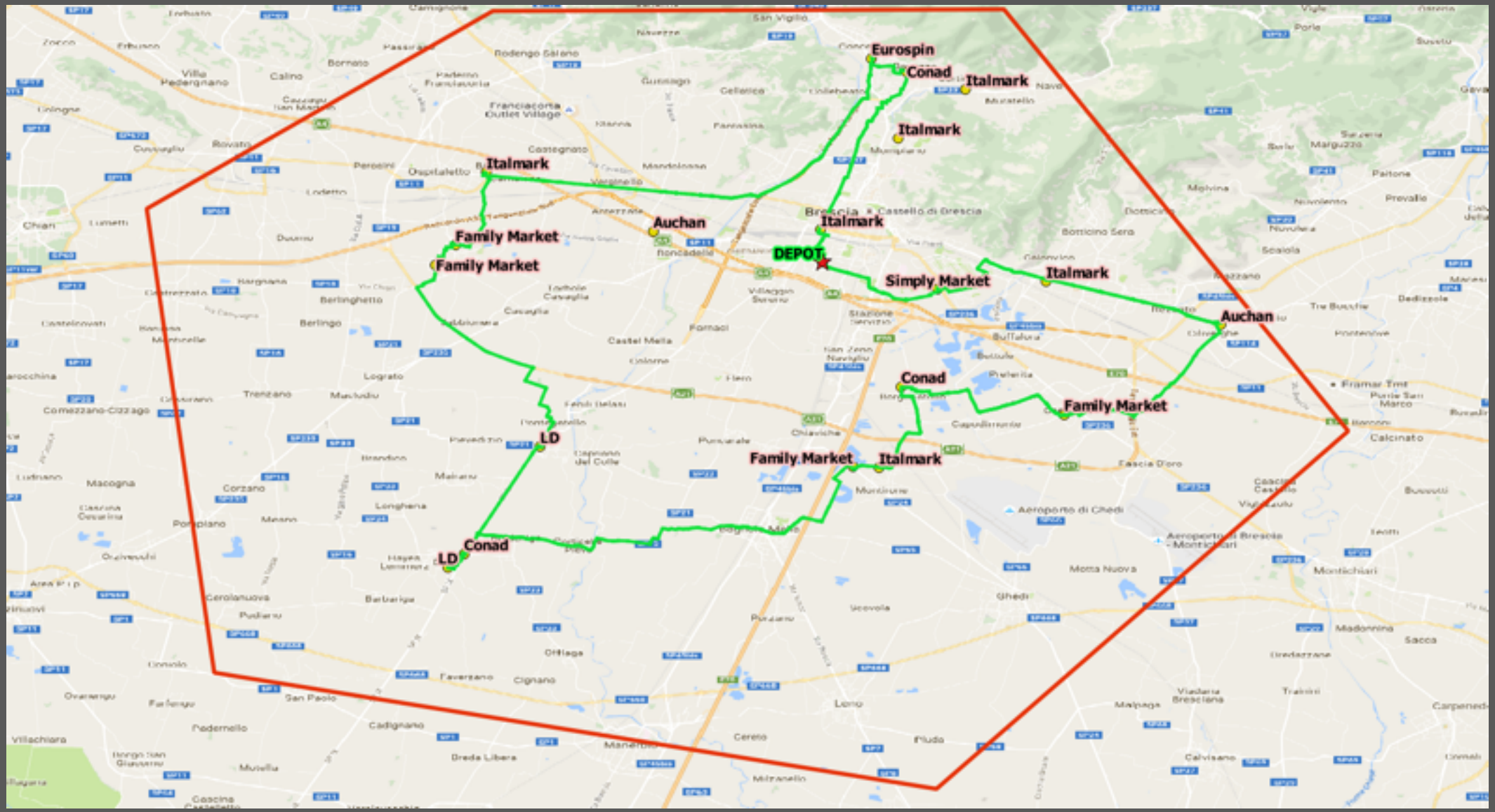

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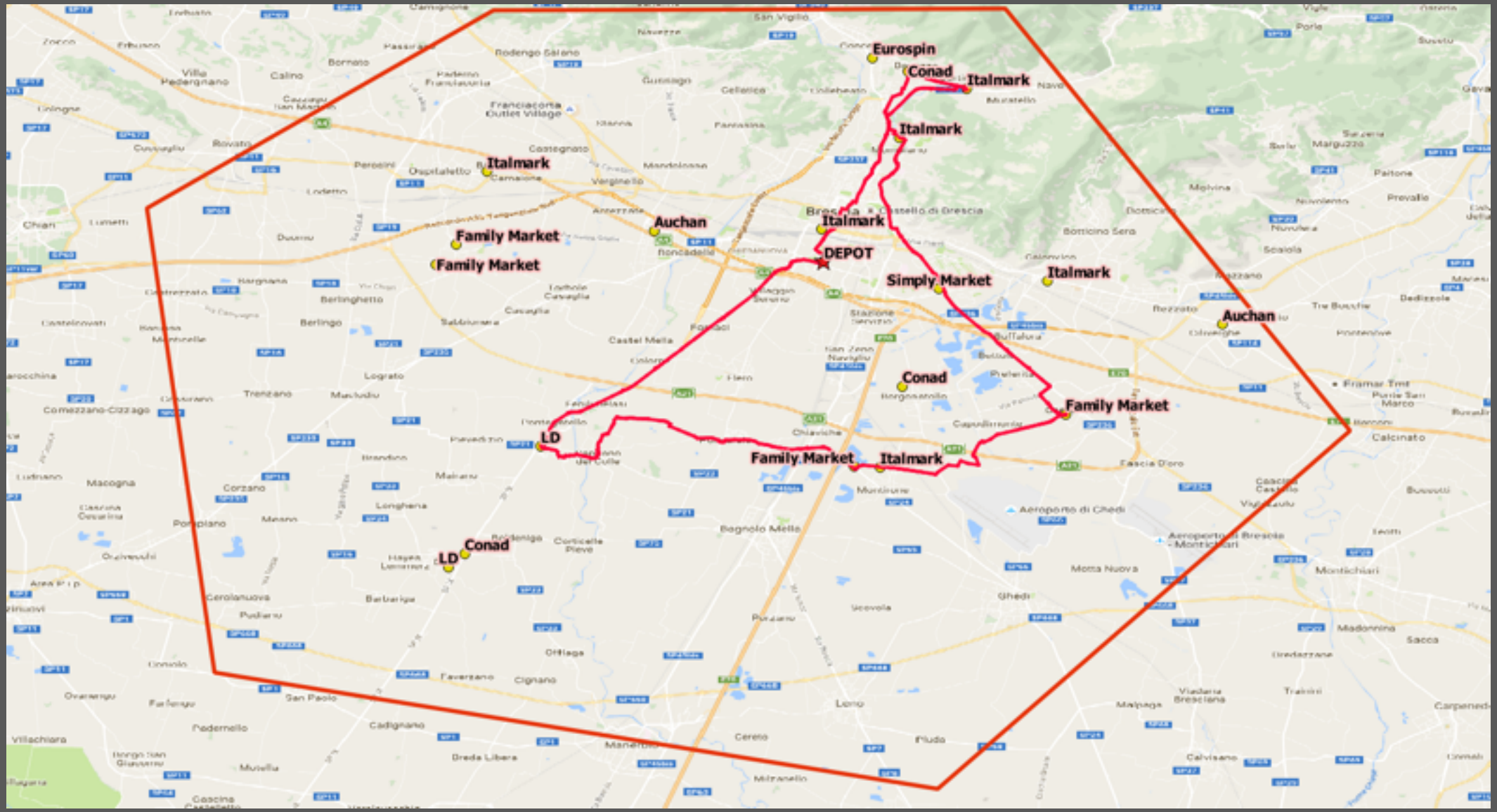

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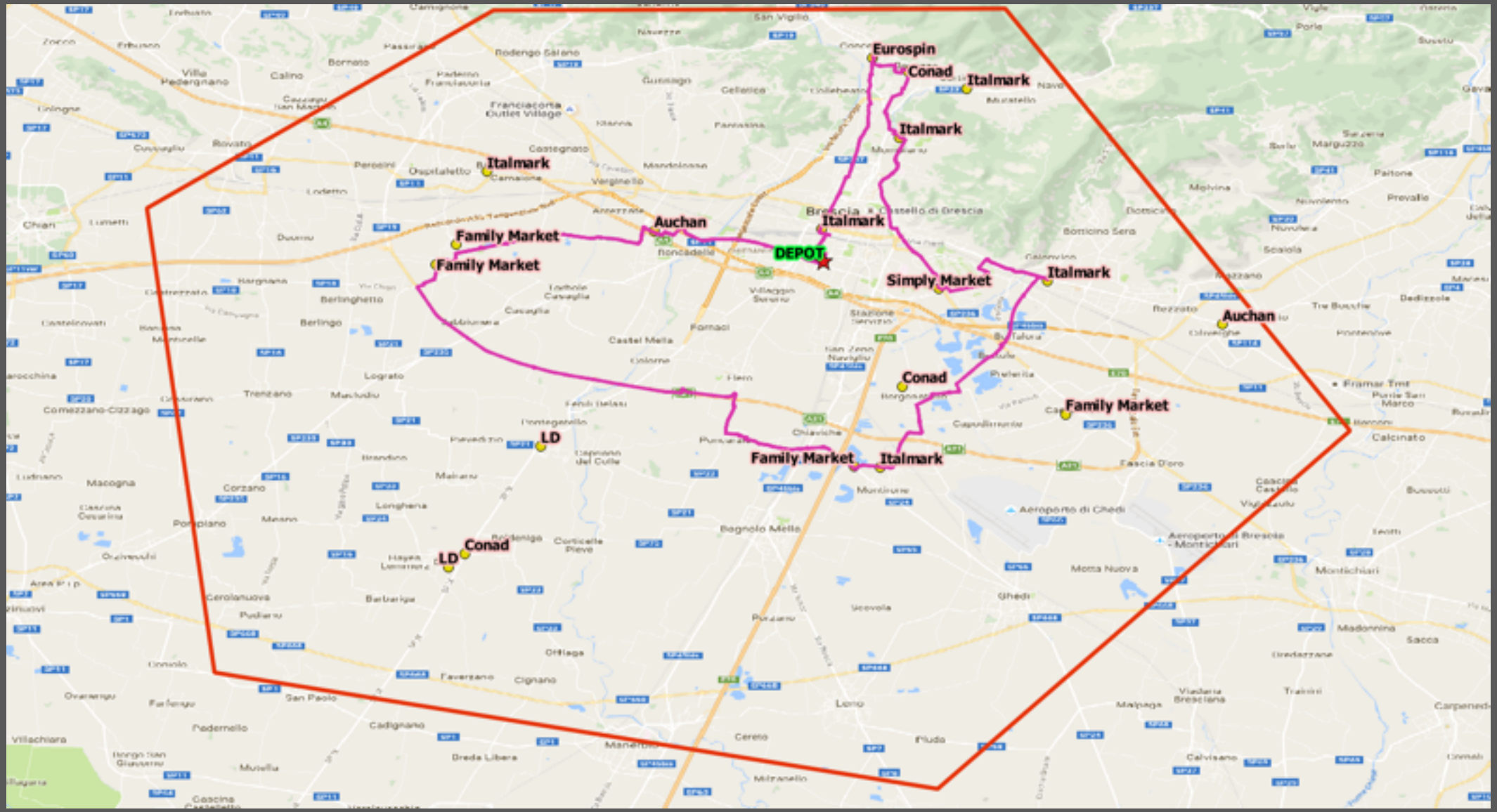

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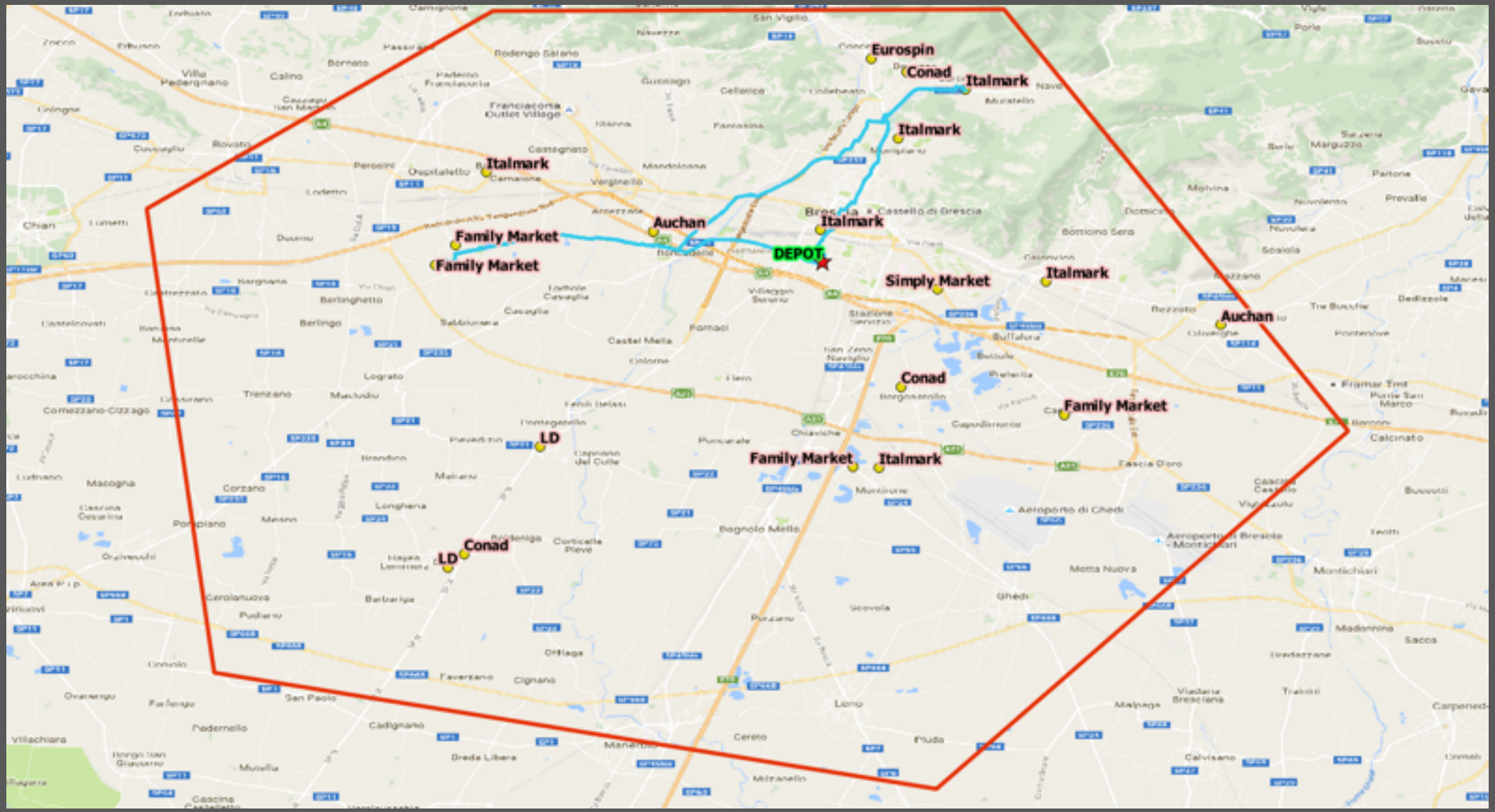

Optimal shopping plan

Final remarks

We saw very powerful instruments to solve real life problems.

Private and public bodies might (SHOULD) take advantage of these mathematical tools to improve citizens life quality, profits, sustainability, …

Thank you