Efficient area of operation planning for free-floating electric car sharing systems

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Why do AoO optimization?

Free-floating car sharing companies allow their users to pick up and return cars **anywhere** within their chosen **area of operation** (AoO).

Choosing the right AoO is therefore paramount to their success.

- QoS dependent on high vehicle density
- expensive vehicles
- car sharing demand dependent on travel patterns

Problem definition

- **subdistrict** graph $G = (V, E)$
- **cost** $c_i, \ \forall i \in V$
- **budget** B
- expected **revenue** $p_{ij}, \ \forall i, j \in V$

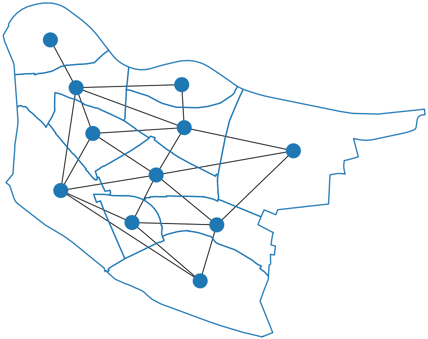

Figure: Example graph for Vienna's 3rd district

Goal: Selecting a **connected subset** of subdistricts $S \subseteq V$ **without "holes"** within the given **budget** as area of operation (AoO) that **maximizes** the **revenue** between the selected subdistricts.

ILP formulation

- $y_i \in \{0, 1\}$: include $i \in V$ in AoO
- $x_{ij} \in \{0, 1\}$: collect revenue from $i \in V$ to $j \in V$

$$\begin{aligned}
\max \quad & \sum_{i \in V} \sum_{j \in V} p_{ij} x_{ij} & & (1) \\
\text{s.t.} \quad & x_{ij} \leq y_i & \forall i, j \in V \quad & (2) \\
& x_{ij} \leq y_j & \forall i, j \in V \quad & (3) \\
& \sum_{i \in V} c_i y_i \leq B & & (4) \\
& (\textit{connected area}) & & (5) \\
& (\textit{no ``holes''}) & & (6)
\end{aligned}$$

Note: (5) and (6) are modeled as separate **flow systems** in G

Case study: Vienna

We planned **expansion strategies** for the electric car sharing company **ELOOP**.

- 250 official subdistricts of Vienna
- **cost** $c_i \propto$ subdistrict **area**
- expansion **budget**: expand current AoO by $X\%$
- **revenue** forecast based on
  - Austrian **mobility survey**
  - historical **taxi trips**

Results

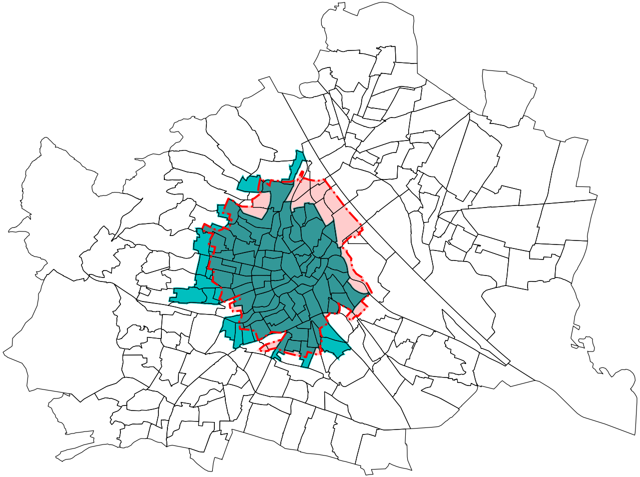

Figure: Vienna, Taxi trips, $B = 100\%$ (of current AoO)

Results

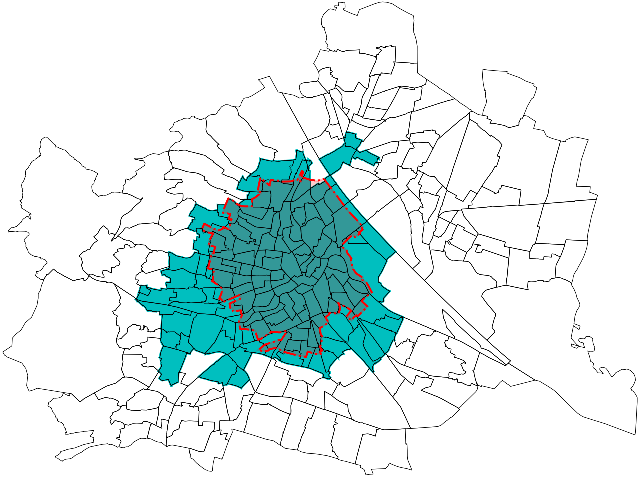

Figure: Vienna, Taxi trips, $B = 200\%$ (of current AoO)

Solution stability – Bootstrapping

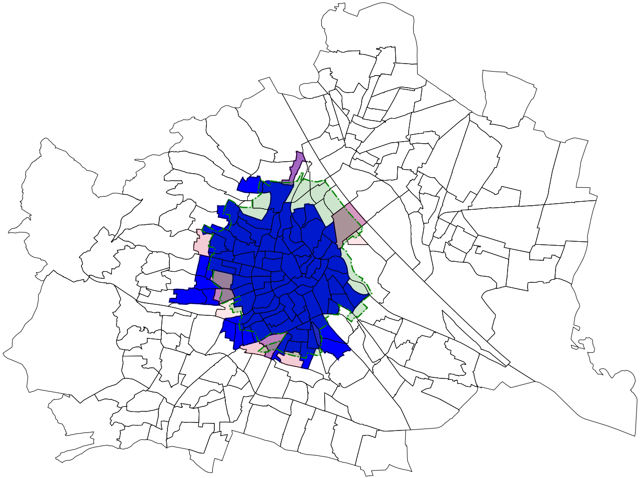

Figure: Vienna, Taxi trips, $B = 100\%$, 10 instances

Solution stability – Bootstrapping

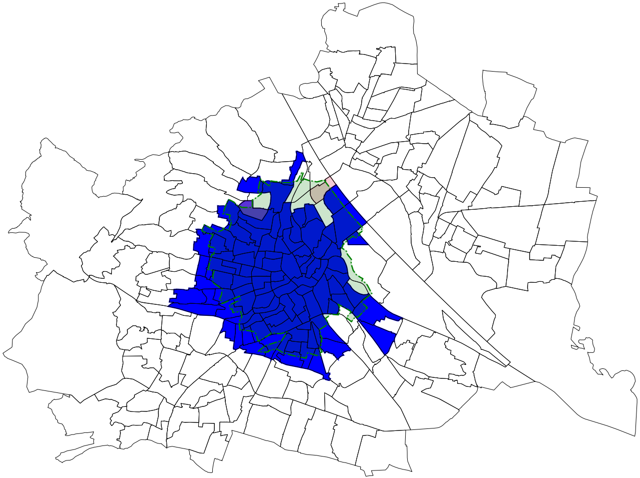

Figure: Vienna, Taxi trips, $B = 125\%$, 10 instances

Solution stability – Bootstrapping

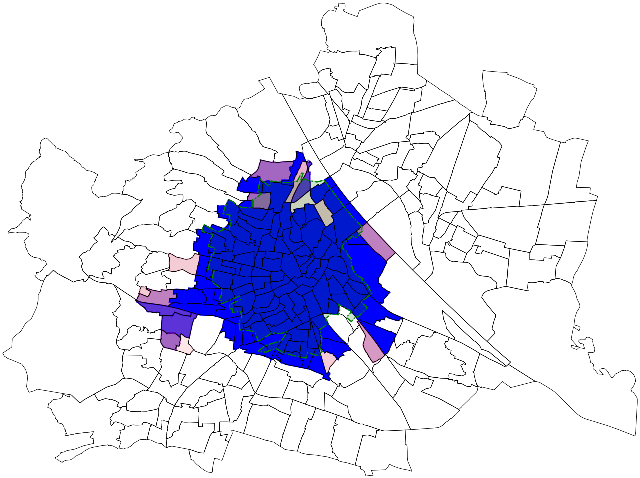

Figure: Vienna, Taxi trips, $B = 150\%$, 10 instances

Solution stability – Bootstrapping

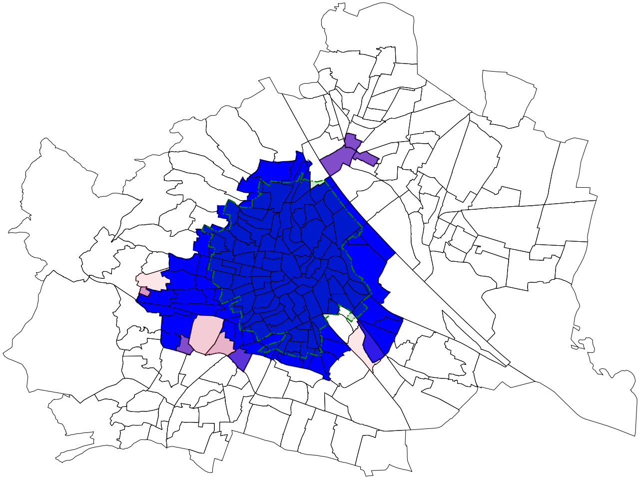

Figure: Vienna, Taxi trips, $B = 175\%$, 10 instances

Solution stability – Bootstrapping

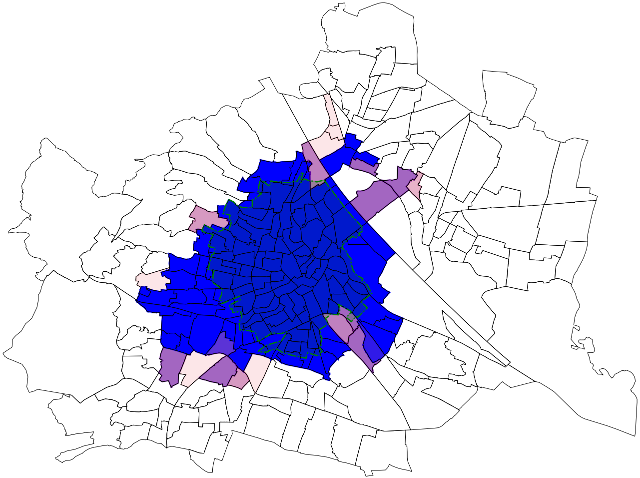

Figure: Vienna, Taxi trips, $B = 200\%$, 10 instances

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Thank You!