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Determination of Optimal Locations for ATM Network Service Points

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Subject of research

The object of the study is a network of ATMs
The subject of the study is the effectiveness of customer service by points of the ATM network

Key problems:

- lack of an integrated approach to solving the problem of placing network service points,
- simplification of optimization tasks,
- difficulty in assessing the effect of the techniques used

Goal and tasks

The goal is to find the most effective algorithm for constructing a complex network of service points (ATMs)

Tasks:

- key research models' identification,
- formation of the model structure, including mathematical formulation,
- implementation of algorithms,
- assessment of the effectiveness of the applied methods,
- general conclusions' formulation

Demand maximization model

Source: OpenStreetMap

ATMs on the working population density map

$$\max \sum_i f_i\big(d(x_i, X)\big)$$

where
d is the fixed demand at each point
x_i from thetotal set (*X*),
i = 1,2,...,n are the possible locations of each point of sale,
f is a function that maximizesthe fixed demand at the point of sale *i*

$$f_x(X) = \omega_x e^{-X^2} \qquad d(x_i) = \frac{N_{x_i} + P_{x_i}}{\beta_{x_i}}$$

N_{x_i} – resident population,
P_{x_i} – working population,
β_{x_i} – number of ATMs at the point x_i

Combined model

Source: OpenStreetMap

- **Points** are priority locations for ATM placement according to the mini-sum distance model,
- **Polygons** are priority locations for ATM placement according to the market share maximization model,
- **Heat map** – working and living population

- **Local population:**

$$max \sum_i f_i\big(d(x_i, X)\big)$$

+ setting weight using PageRank method

- **Passers-by customers:**

$$max \sum_{p \in P} f_p \cdot g(D(Y, p))$$
$$Y \in G_i |Y|$$

$G = (N, A)$ – branch network, N – network nodes, A – graph edges, Y – possible points for placing branches on the network G (placement is possible both on nodes and on edges).
P – non-empty network client paths, $p_i \in P$ – set of non-empty paths at a node i, f_P – flow of potential clients along any route $p \in P$, D – distance, g – distance minimization function

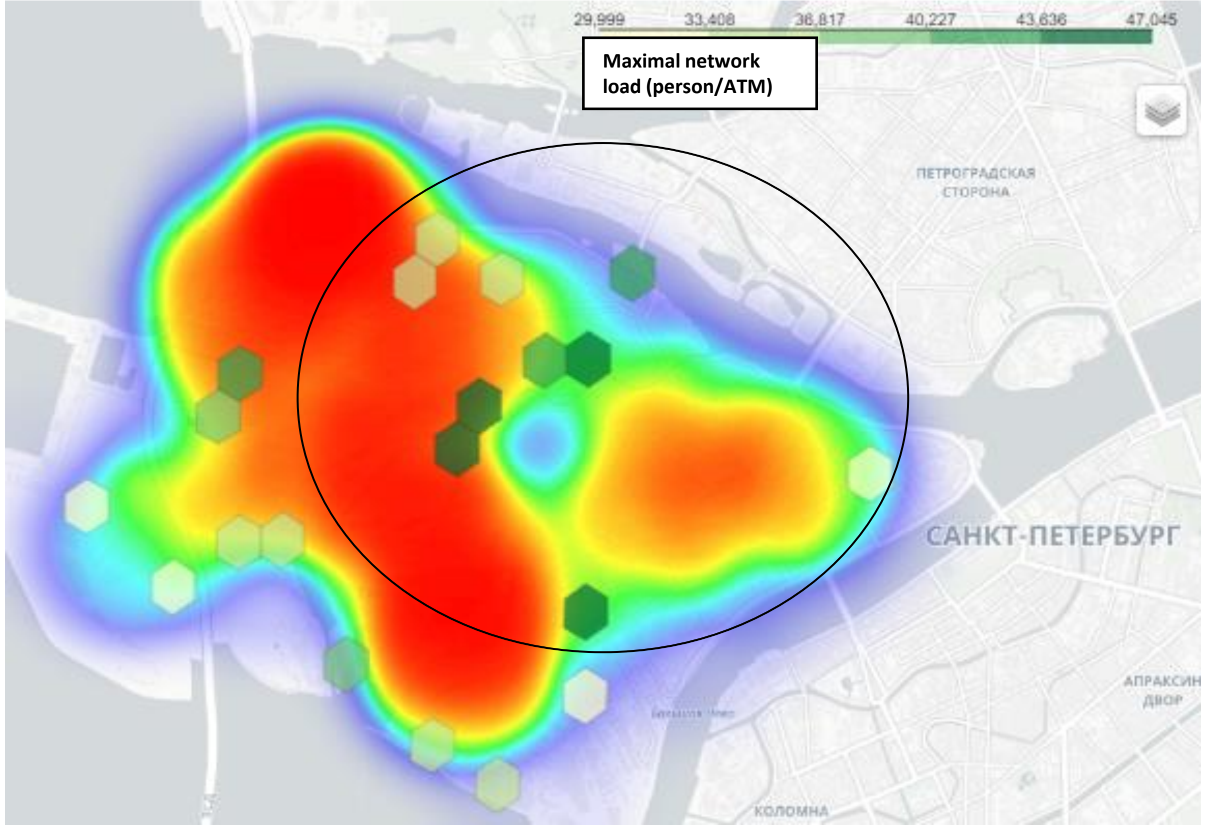
The probabilistic Huff model

$$max(C_i \cdot P_{ij}) = max\left(C_i \cdot \frac{\frac{S_j}{T_{ij}^{\lambda}}}{\sum_{j=1}^{M} \frac{S_j}{T_{ij}^{\lambda}}}\right)$$

C_i – number of buyers in district *i*,
Pij – the probability of choosing point *j* by a buyer from district *i*,
Sj – retail area of the point *j*,
T_{ij} – travel time from area *i* to point *j*,
λ – the coefficient of buyers' sensitivity to distances,
N – number of the city's districts,
M – number of service points.

Simulation result:

The building density factor influenced on the right-hand shift of service points' location



The probabilistic Huff model

Building density polygons (retail area)

Shortest paths to a certain ATM

The McFadden Model

$$max(C_i \cdot P_{ij}) = max(C_i \cdot \frac{exp(V_{ij})}{\sum_{j=1}^{M} exp(V_{ij})})$$

$$V_{ij} = \sum_{k=1}^{S} A_{ijk}$$

V_{ij} – evaluation of attractiveness,
A_{ijk} – the value of k parameter's attractiveness

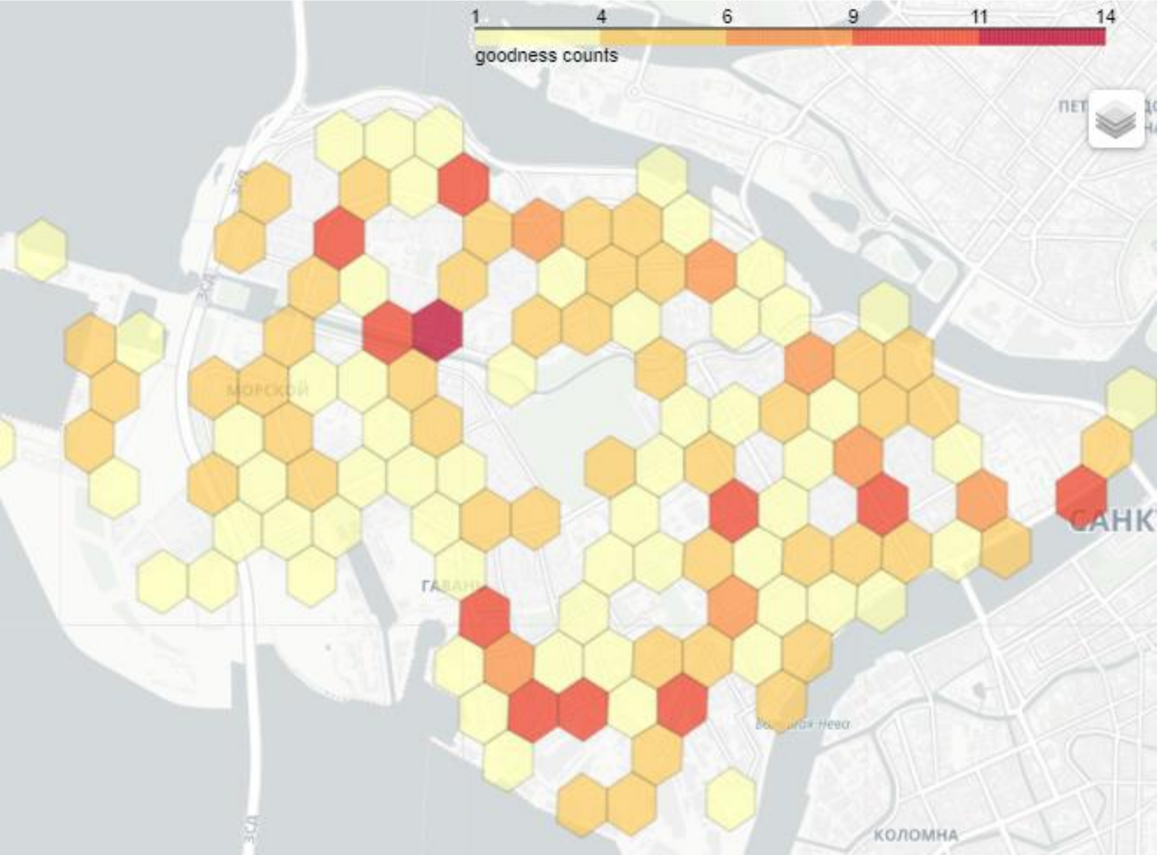
Attractiveness parameters:

- the ratio of the volume of retail space to the remoteness of ATMs,
- proximity to bus stops and shops,
- remoteness of competitors

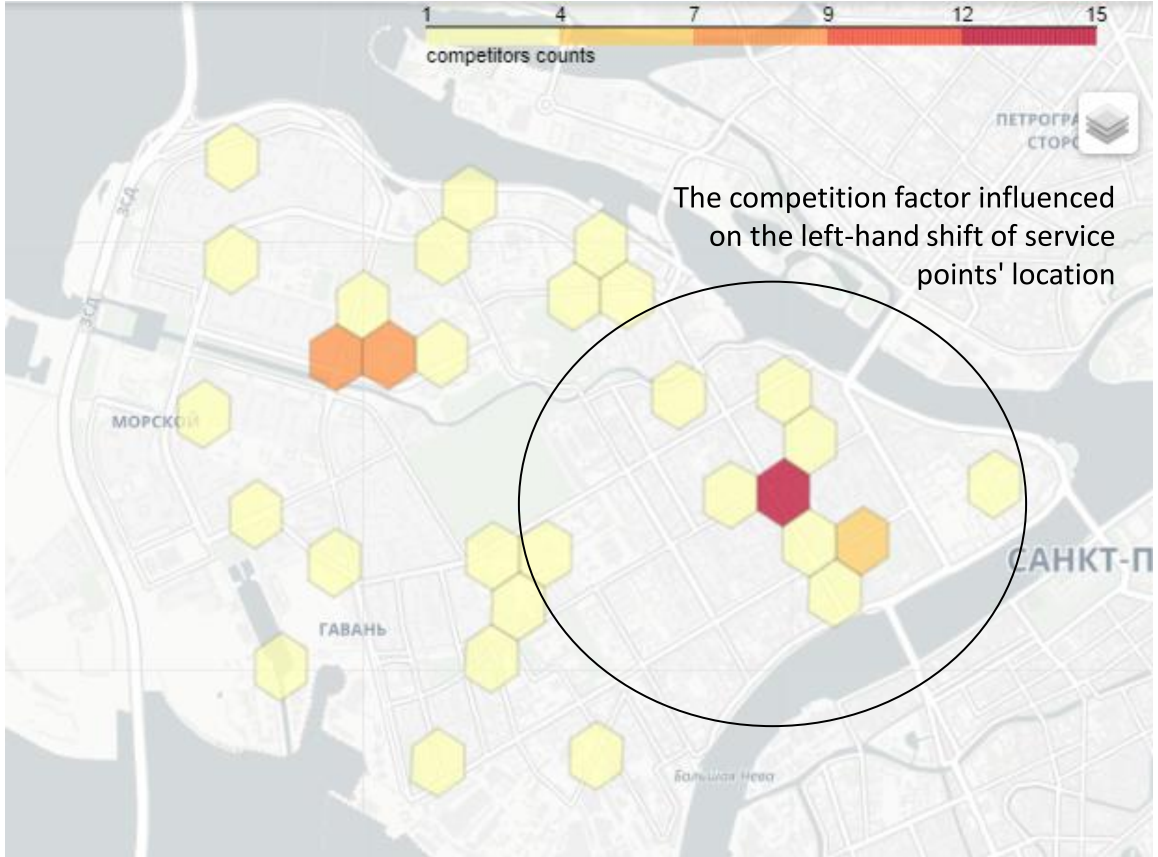
Simulation result:

The competition factor influenced on the left-hand shift of service points' location

The McFadden Model



Density of shops and bus stops

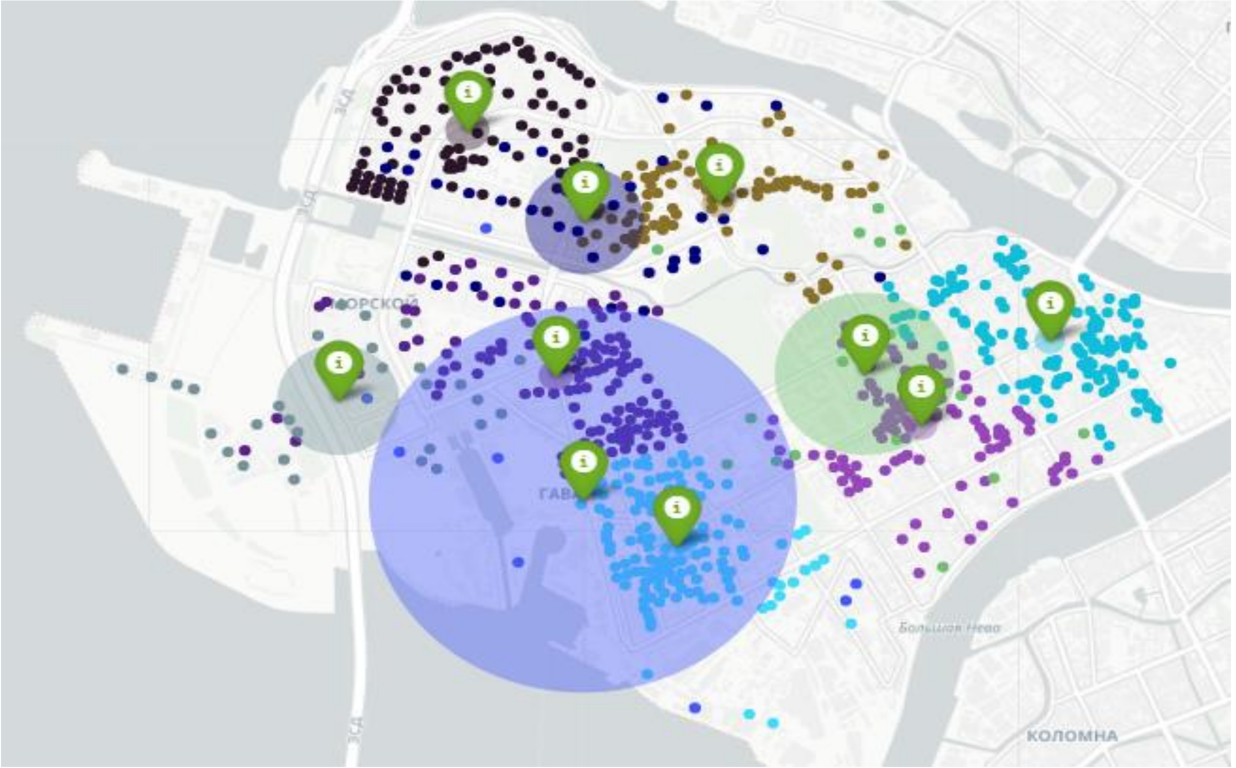


Density of competing ATMs' placement

Clustering by building density

$$argmin_S \sum_{i=1}^{k} \sum_{x \in s_i} \rho(x\mu_i)^2$$

$\rho(x\mu_i)^2$ is a distance function between x (multiple data set points) and μ_i (cluster center)

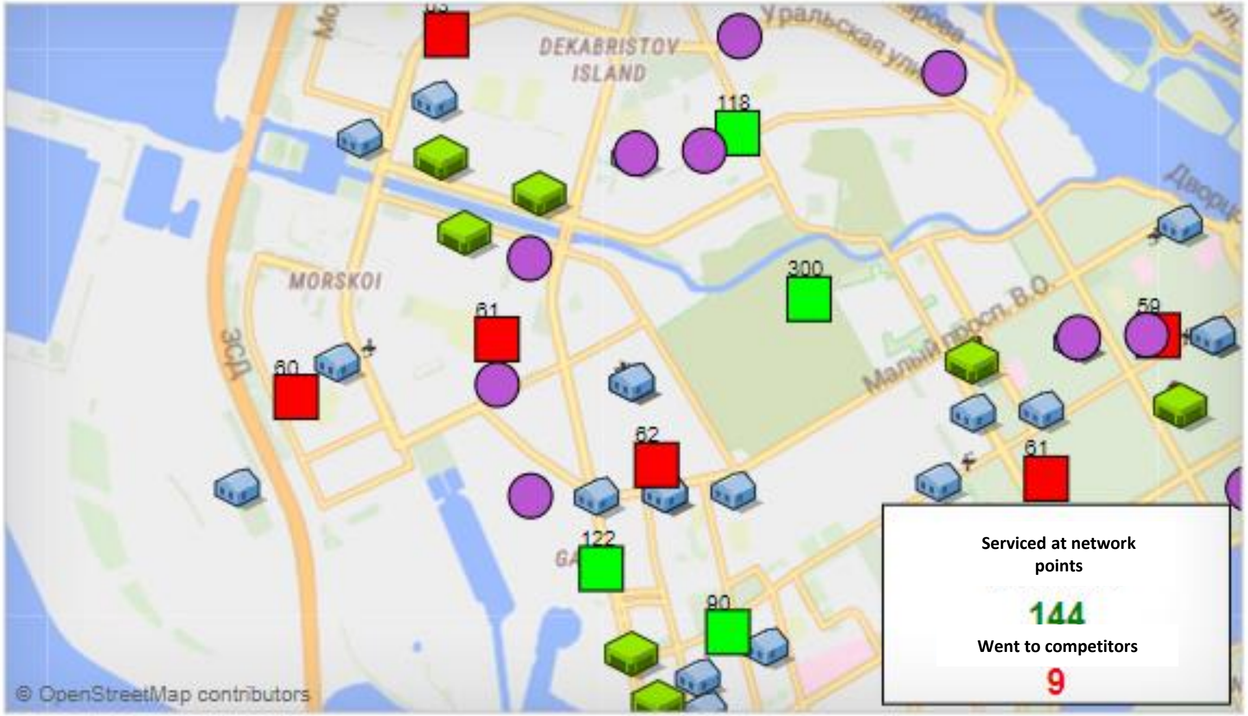


k-means

Hierarchical clustering

Simulation model

Expected result: assessment of the effectiveness of the considered models in terms of the number of clients served and those who went to competitors



Idea: modeling takes place on the basis of two types of agents - ATMs and clients.
Clients are generated by green and blue tents.
ATMs are static and shown as multi-colored squares.
In the process of imitation, the client arrives, is served, goes to the starting point, or goes to a competitor. The ATM agent monitors the readiness status of each ATM instance.

Designations:

- The ATM is free and ready to use
- ATM requires loading banknotes
- Competitor ATM
- Client generation point (residential building)
- Customer generation point (stop/store)

Final comparison

	The McFadden Model	Combined model	Clustering	The Huff Model	The Simplest Analytical Model
Number of clients served	136	142	144	143	122
The number of customers, left for competitors	5	7	9	10	14
Percentage of incoming customers' retention	96,45%	95,30%	94,12%	93,46%	89,71%

- The best model by the metric of the number of clients served is the **spatial hierarchical clustering model**. Advantages of use: ease of implementation, scalability to large data sets. Disadvantages: sensitivity to outliers that distort the average; duration of execution of the algorithm due to the iterative approach.
- In terms of incoming customer flow retention metrics, the best is the **McFadden model**. Highlighting the competition factor had a positive effect on customer retention rates.
- **The combined model** took second place in both metrics. By distinguishing two types of client flow, this model turned out to be more balanced in terms of network load.
- **The Huff model** is sensitive to assessing the parameters of the attractiveness of service points, and in **the simplest model** there is an underestimation of the influence of the spatial factor and the competition factor, therefore, for these models we see the lowest results.

Thanks for your attention