Healthcare Accessibility Evaluation Method

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Method Overview

Composite accessibility index integrating:

- Travel time (ORS API)

- Doctor load per facility

- Population size

- Urban/rural legal classification

This method introduces a composite approach to evaluate healthcare accessibility across settlements using open geospatial data, travel time routing, and weighted scoring. It combines advantages of classical spatial accessibility models (e.g., PPR, 2SFCA) with dynamic routing and density-aware center estimation.

Method Description (Detailed)

Integrated Healthcare Accessibility Evaluation

This method calculates a composite accessibility index for each settlement by combining:

- **Travel Time to Facilities** using OpenRouteService (ORS) API
- **Doctor Load Factor**: Population served per physician
- **Population Factor**: Weights based on total population
- **Legal Status Factor**: Urban vs. Rural classification

Steps:

1. **Extract residential buildings** from OpenStreetMap
2. **Apply Kernel Density Estimation (KDE)** to find actual centers of population per settlement
3. **Classify healthcare facilities** from OSM data into standardized categories (e.g., Hospital, Clinic, Pharmacy)
4. **Route from each population center to nearest facilities** using ORS API (by car, optionally walking)
5. **Compute composite accessibility score** using weighted formula
6. **Visualize outputs**: maps, histograms, tables

Comparison of Existing Methods

No	Method	Code/Formula Sketch	Key Features / Limitations
1	PPR	Pop / Providers	Simple; ignores distance
2	Shortest Path	min(NetworkDistance(center, facility))	One-to-one, ignores competition
3	Isochrone	ServiceArea(15min)	Fixed buffer; no competition
4	2SFCA	See Luo & Wang (2003)	Accounts for supply-demand in two steps
5	Enhanced 2SFCA	Adds Gaussian/Kernal weighting	More accurate but complex
6	MCLP	Integer optimization	Needs scenario setup
7	P-Median	Minimize weighted distance	Used in allocation planning
8	MHV3SFCA	Probabilistic, distance-decay model	Sophisticated but less interpretable
9	Composite Index	Varies by study (e.g., Neutens et al., 2010)	May include cost, time, satisfaction, etc.
☑	**Our Method**	Composite of 4 factors (Time, Load, Pop, Law)	Flexible, interpretable, spatially precise

Novelty Compared to Existing Methods

No	Method	Key Limitation	Our Improvement
1	Population-to-Provider Ratio (PPR)	Ignores distance/travel time	Adds travel-time via routing and facility capacity normalization
2	Shortest Path	One-to-one mapping only	Aggregates multiple nearby facilities per center
3	Service Area (Isochrone)	Fixed threshold zones	Dynamic per-route time with weight factors
4	2SFCA	Assumes uniform population	Uses KDE to define true centers of population
5	Enhanced 2SFCA	High complexity	Simplifies through travel-time weights, no kernel tuning needed
6	MCLP	Optimization-focused, requires scenario setup	Our method evaluates current accessibility, not optimal allocation
7	P-Median / P-Center	Needs integer optimization	Avoids model-fitting, uses empirical spatial data
8	MHV3SFCA	Probabilistic & complex	Simpler score function with interpretable components
9	Composite Healthcare Accessibility Index (CHCA)	May use non-spatial data, subjective weights	Keeps weights explicit and modular, spatially driven

Strengths and Possible Improvements

Strengths:

- KDE-based density centers: better than geometric centroids
- Multilingual OSM classification
- Actual travel time (ORS API)
- Composite index: time, load, population, legal status
- Tunable weights
- Interactive + static visualization

Can be improved:

- Real doctor counts instead of default=1
- Add walk/bike & road quality
- Time-of-day or seasonal access
- Scenario modeling (e.g., elderly, emergencies)

Workflow Overview

Step 1: Load and Preprocess Administrative Boundaries

```
adm_gdf = gpd.read_file("path_to_admin_boundary.geojson")
adm_gdf["center_density"] = adm_gdf.geometry.centroid
```

Step 2: Extract Residential Buildings
Use OSM or existing shapefile of residential buildings. KDE (Kernel Density Estimation) is then applied to identify true population centers.

```
# Assuming buildings_gdf is loaded
centers_gdf = calculate_true_density_centers(adm_gdf, buildings_gdf)
```

Step 3: Calculate KDE-based Population Centers

```
med_gdf = get_medical_facilities(adm_gdf)
```

Step 4: Extract and Classify Medical Facilities
This uses tags in multiple languages to categorize facilities (e.g., hospital, clinic).

```
routes_df_prepared = prepare_data(routes_df)
routes_df_prepared['access_index'] = routes_df_prepared.apply(calculate_final_accessibility, axis=1)
```

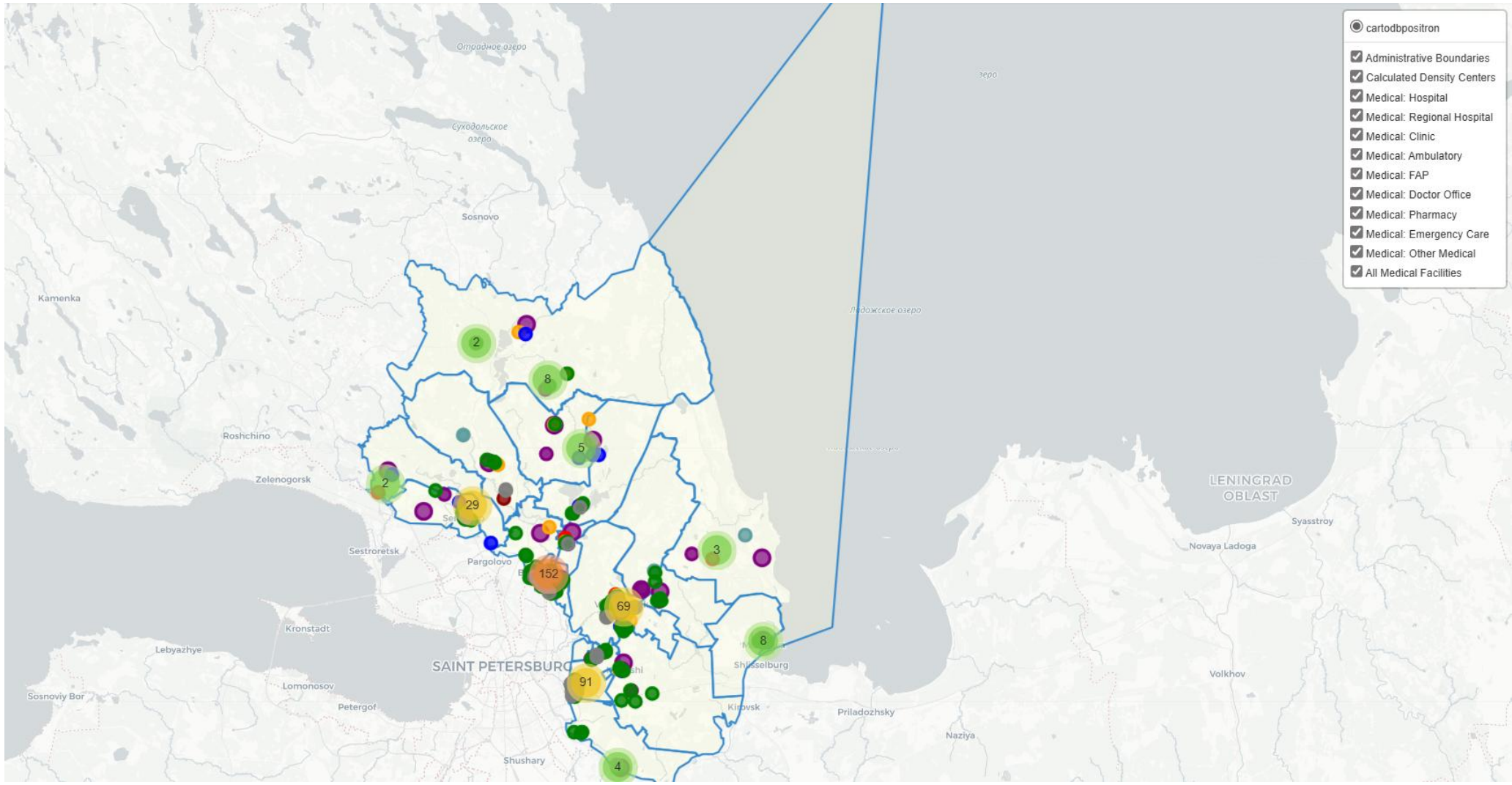
Step 5: Compute Travel Routes
This will calculate travel time from population centers to facilities using OpenRouteService.

Step 6: Prepare Data and Compute Accessibility Index

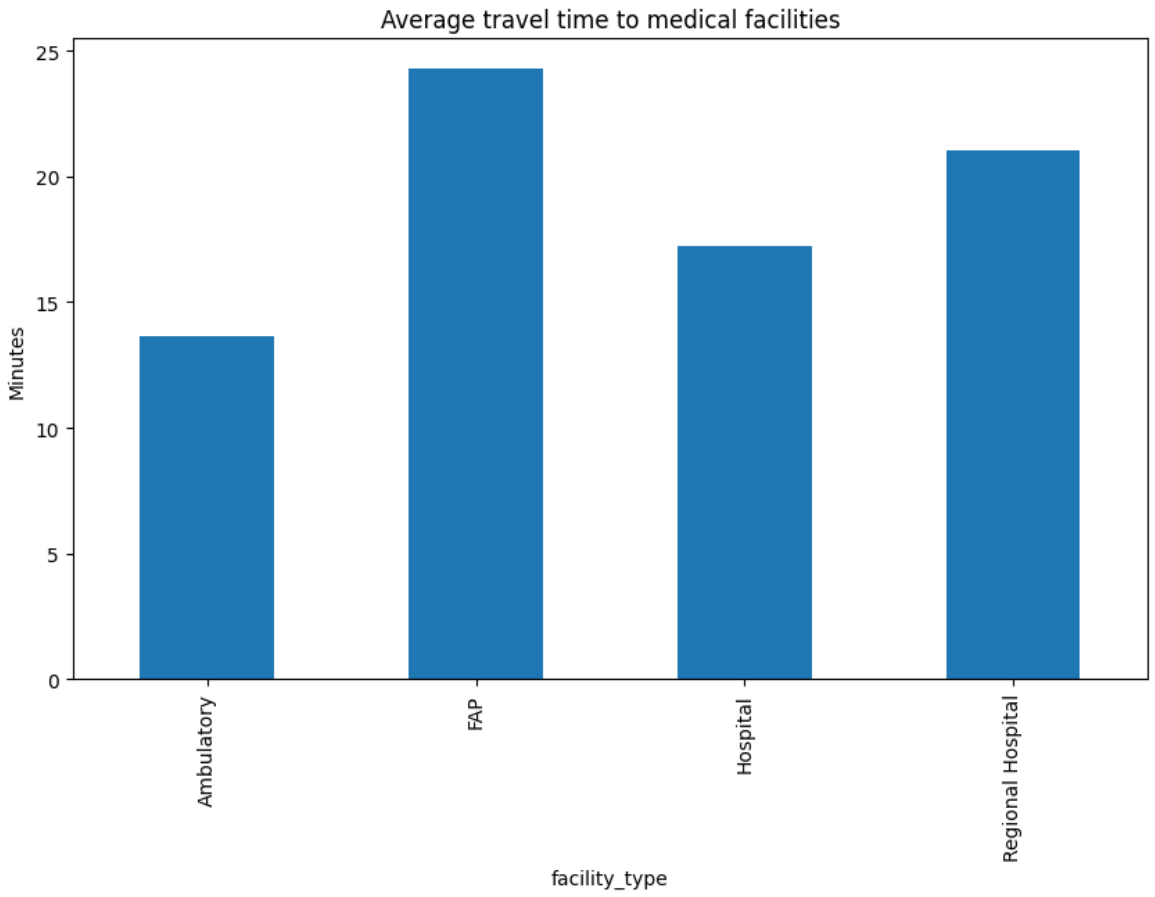
This uses a weighted composite score:

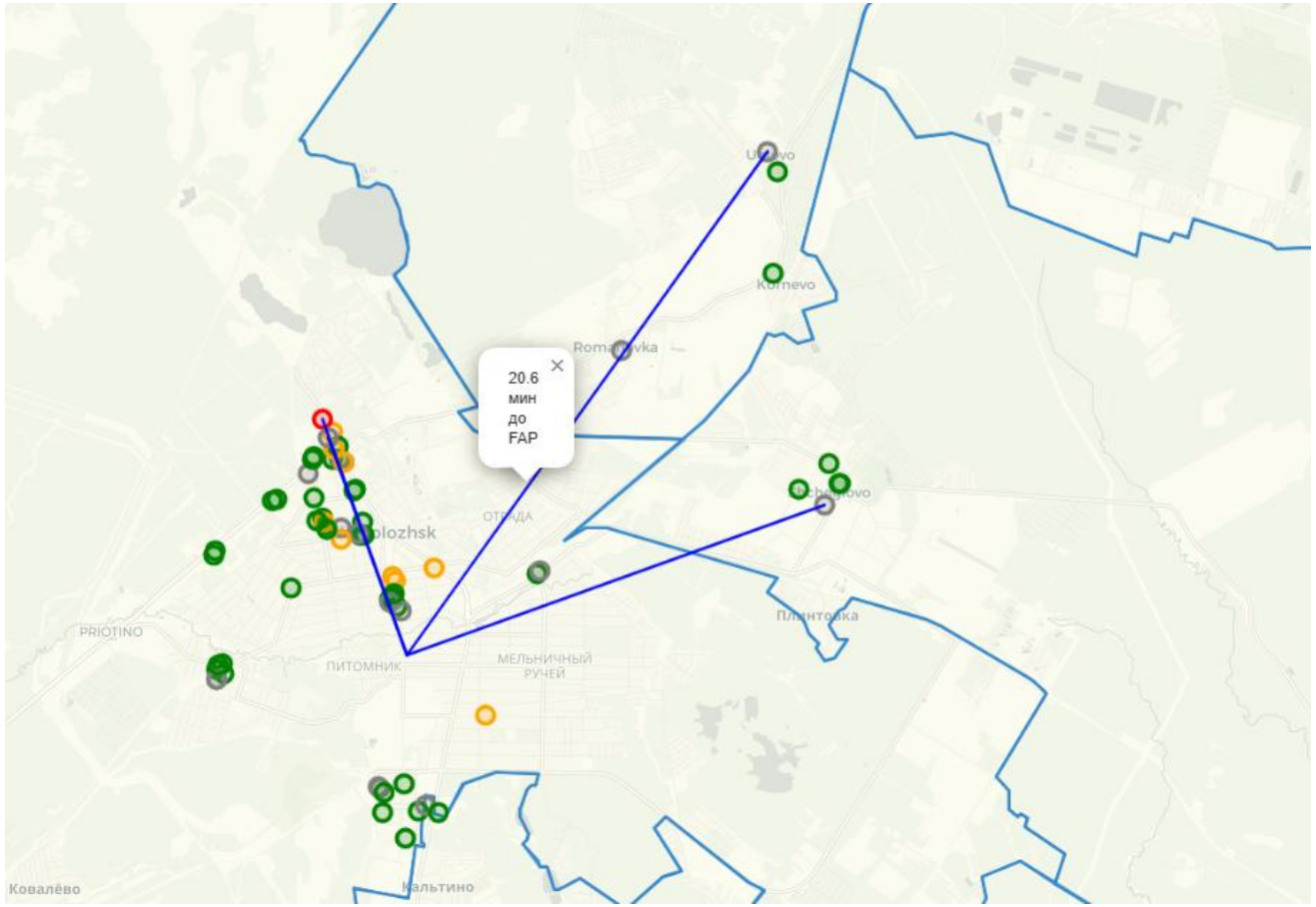
```
Accessibility Score =
  0.5 * Time Factor
+ 0.2 * Doctor Load Factor
+ 0.2 * Population Factor
+ 0.1 * Legal Urban/Rural Factor
```

Case Study: Vsevolozhsky District



Key Takeaways





Key Takeaways

Top 10 most accessible routes:

	center_name	facility_name	facility_type	duration_min	access_index
61	Toksovskoye Urban Settlement	Токсовская больница	Hospital	15.538667	77.5
35	Morozovskoye Urban Settlement	Морозовская городская больница	Regional Hospital	3.253500	77.5
45	Rakhinskoye Urban Settlement	Всеволожская КМБ, Ириновское отделение	Hospital	14.377167	77.4
21	Kuzmolovskoye Urban Settlement	Онкологический диспансер им.ЛД Романа	Hospital	4.994167	76.1
67	Shcheglovskoye Rural Settlement	Всеволожская клиническая межрайонная больница	Regional Hospital	12.056000	75.9
48	Romanovskoye Rural Settlement	Амбулатория Романовка	Ambulatory	0.871000	75.8
65	Shcheglovskoye Rural Settlement	Всеволожский роддом	Hospital	12.402167	75.7
37	Murinskoye Urban Settlement	Западное Мурино Токсовская межрайнная больница	Hospital	2.040667	75.4
64	Shcheglovskoye Rural Settlement	Амбулатория Щеглово	Ambulatory	5.674333	75.1
47	Rakhinskoye Urban Settlement	Морозовская городская больница	Regional Hospital	20.829667	74.7

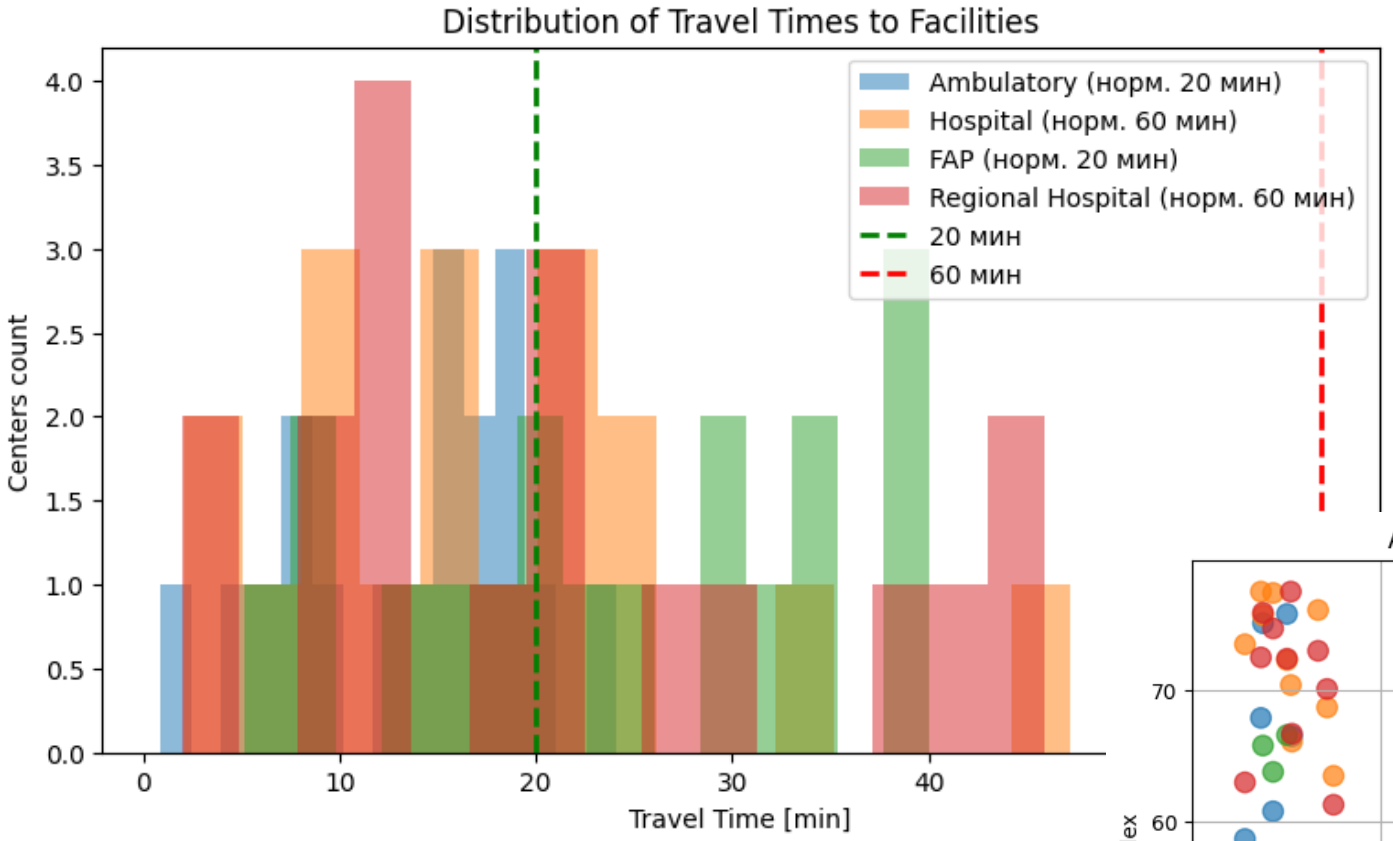
Top 5 with the least accessibility

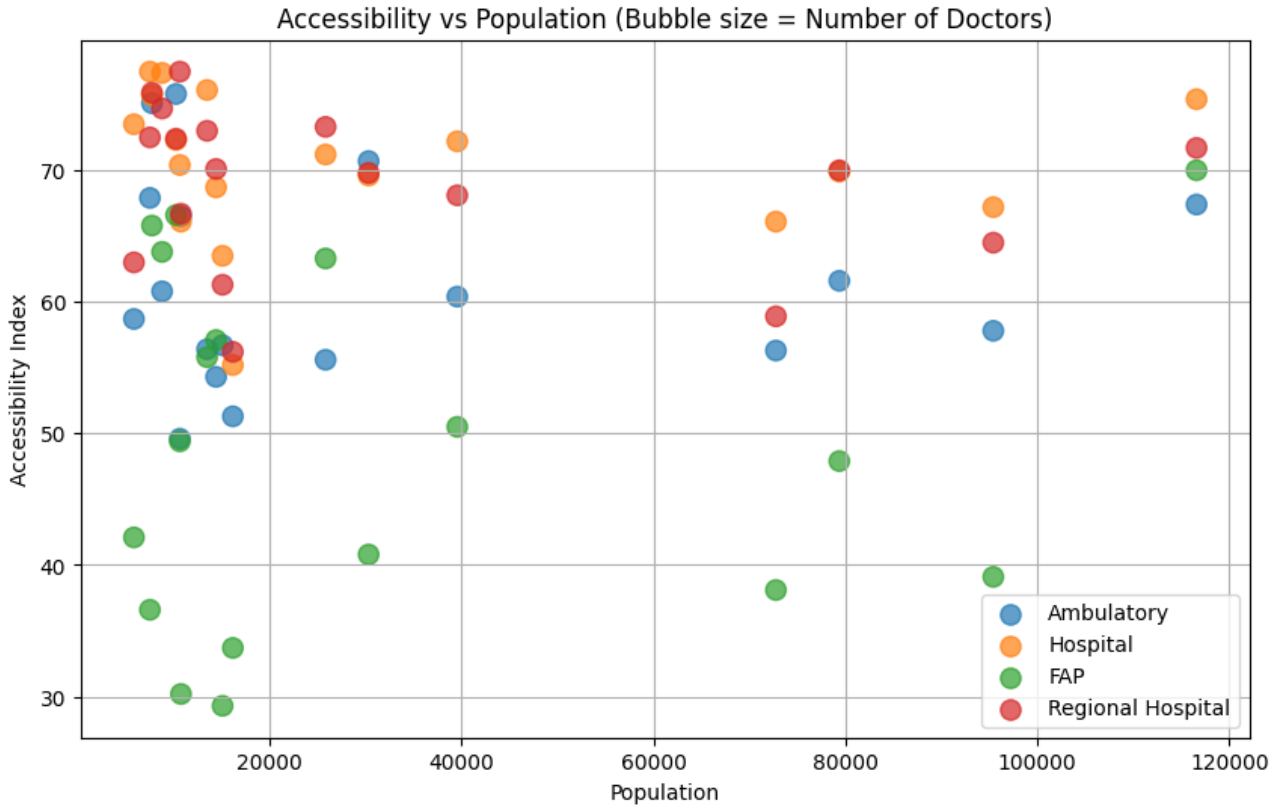
	center_name	facility_type	access_index	duration_min	num_doctors	population_2025
54	Sverdlovskoye Urban Settlement	FAP	29.3	42.723500	1	15092
30	Leskolovskoye Rural Settlement	FAP	30.2	37.993833	1	10761
26	Kuyvozovskoye Rural Settlement	FAP	33.7	33.947333	1	16166
62	Toksovskoye Urban Settlement	FAP	36.6	40.357333	1	7525
58	Sertolovskoye Urban Settlement	FAP	38.1	30.856500	1	72752

Top 5 with the most accessibility

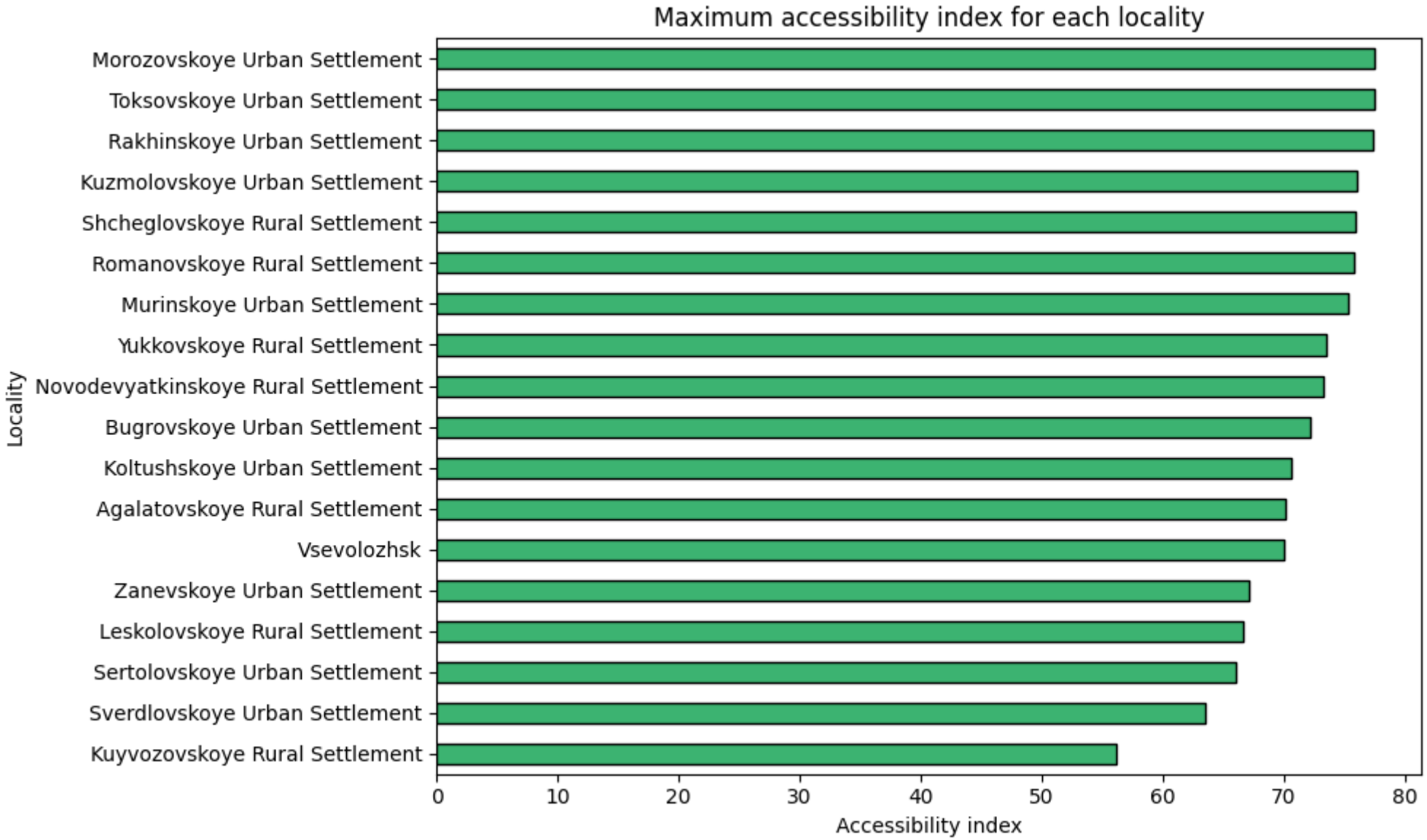
	center_name	facility_type	access_index	duration_min	num_doctors	population_2025
67	Shcheglovskoye Rural Settlement	Regional Hospital	75.9	12.056000	1	7738
21	Kuzmolovskoye Urban Settlement	Hospital	76.1	4.994167	1	13480
45	Rakhinskoye Urban Settlement	Hospital	77.4	14.377167	1	8794
61	Toksovskoye Urban Settlement	Hospital	77.5	15.538667	1	7525
35	Morozovskoye Urban Settlement	Regional Hospital	77.5	3.253500	1	10642

Key Takeaways





Key Takeaways



References & Data Sources

Scientific References:

- Luo, W. & Wang, F. (2003). Measures of Spatial Accessibility to Health Care.
- Delamater, P. (2012). Spatial Accessibility in Health Geography.
- Wan, N. et al. (2012). Enhanced Two-Step Floating Catchment Area Method.
- Neutens, T. (2010). Space–Time Accessibility.
- Church & ReVelle (1974). The Maximal Covering Location Problem.
- Hakimi, S. (1964). Optimum Distribution of Switching Centers.

Data Sources:

- OpenStreetMap (https://www.openstreetmap.org/)
- OpenRouteService (https://openrouteservice.org/)
- Population and boundary shapefiles from Ленинградская область geoportal
- IDU Lab, ITMO University — internal preprocessing scripts