Urban Mobility Metrics Backend System Documentation

1. Project Background

Urban mobility is determined by the structure of the street network, directly influencing residents' travel modes, traffic efficiency, and spatial urban organization. Analyzing urban street networks is essential for improving transportation systems and supporting urban planning.

This project, based on OpenStreetMap (OSM) street network data, develops a backend system to store and manage urban street graphs and mobility metrics, enabling comparative analysis between cities based on street network characteristics.

2. System Description

The backend system consists of a database and a web service, aimed at storing, processing, and managing urban street network data, while also computing mobility indicators and providing data access through APIs.

Main Features

- **Data Preparation & Processing**: Receives and processes street network data, converts formats, simplifies graphs, and stores results in the database.
- **Data Storage & Management**: A well-designed database structure stores city metadata, computed mobility indicators, and simplified street networks, supporting visualization and analysis.
- **API Endpoints**: Provides CRUD operations for cities, street networks, and metric data. Also supports GeoJSON downloads for integration with frontend and WebGIS applications.
- **Automated Pipeline**: Automatically extracts and processes OSM data, computes mobility metrics, and shares results via web services for comparative analysis.

The system ensures a standardized workflow and reusable interface services, providing a stable data platform for urban mobility studies.

3. Technology Stack

The backend is developed using the Django framework, with PostGIS for spatial data storage and management, and a set of spatial and graph analysis libraries for metric computation.

Backend Technologies

- **Django 5.1.7** – Web backend and REST API framework
- **GeoDjango** – Spatial extension for Django ORM
- **PostgreSQL 12.x + PostGIS** – Spatial database for geometry data
- **GDAL 3.8.4** – Geospatial data format support
- **psycopg2 2.9.10** – PostgreSQL adapter for Python

Spatial & Network Analysis Libraries

- **OSMnx 2.0.2** – Extract and simplify OSM street networks
- **NetworkX 3.4.2** – Graph structure and topological analysis
- **GeoPandas 1.0.1** – Geospatial operations on tabular data
- **Shapely 2.0.7** – Geometry construction and spatial computation
- **pyproj 3.7.1** – Coordinate reference system transformations

4. Database Design

4.1 Architecture

The system uses PostgreSQL with PostGIS extension to manage spatial data, with the following core tables:

- **GeoAreaMapping** - Geographic region classification
- **City** - Urban settlement metadata
- **Metric** - Mobility metric definitions
- **MetricValue** - Computed metric results
- **Node** - Street network intersections
- **Edge** - Connections between nodes

4.2 Data Models

GeoAreaMapping

Stores geographic region classifications.

Field	Type	Description
`geo_area`	CharField (PK)	2-letter region code (e.g. "EU")
`full_name`	CharField	Full region name

City

Contains urban settlement metadata with spatial boundaries.

Field	Type	Description
`name`	CharField (Unique)	City name
`country`	CharField	Country name
`geo_area`	ForeignKey	Links to GeoAreaMapping
`population`	PositiveIntegerField	Optional population count
`area_km2`	FloatField	Total administrative area
`built_up_area_km2`	FloatField	Urbanized land area
`geom`	MultiPolygonField	City boundary geometry (SRID 4326)

Metric

Defines mobility metric types and categories.

Field	Type	Description
`name`	CharField	Metric identifier (e.g. "CIR")
`type`	CharField	Category: `walk` (Walkability) or `bike` (Bikeability)

Constraints:

- Unique combination of `name` and `type`

MetricValue

Stores computed metric results for cities.

Field	Type	Description
`metric`	ForeignKey	Links to Metric
`city`	ForeignKey	Links to City
`value`	FloatField	Computed metric value
`datetime`	DateTimeField	Calculation timestamp

Constraints:

- Unique combination of `metric` , `city` , and `datetime`

Node

Represents street network intersections.

Field	Type	Description
`city`	ForeignKey	Parent city reference
`osm_id`	BigIntegerField	Optional OSM node ID
`elevation`	FloatField	Optional elevation (meters)
`geom`	PointField	Spatial coordinates (SRID 4326, geography)

Edge

Connects nodes with attributed street segments.

Field	Type	Description
`city`	ForeignKey	Parent city reference
`start_node`	ForeignKey	Origin node (related_name: 'start_edges')
`end_node`	ForeignKey	Destination node (related_name: 'end_edges')
`geom`	LineStringField	Street geometry (SRID 4326, geography)
`data`	JSONField	Road attributes:

Field	Type	Description
		- `name` : Street name
		- `length` : Segment length (m)
		- `mode` : Travel mode
		- `speed_limit` : km/h
		- `edge_type` : Road classification

Constraints:

- Unique combination of `city` , `start_node` , and `end_node`
- Spatial index on `geom`
- `length` : must be a number (int or float), optional
- `speed_limit` : must be a number (int or float), optional
- `mode` : must be one of ['pedestrian', 'driving', 'cycling', 'public_transport'], optional
- `edge_type` : must be one of ['highway', 'urban', 'rural', 'alley'], optional

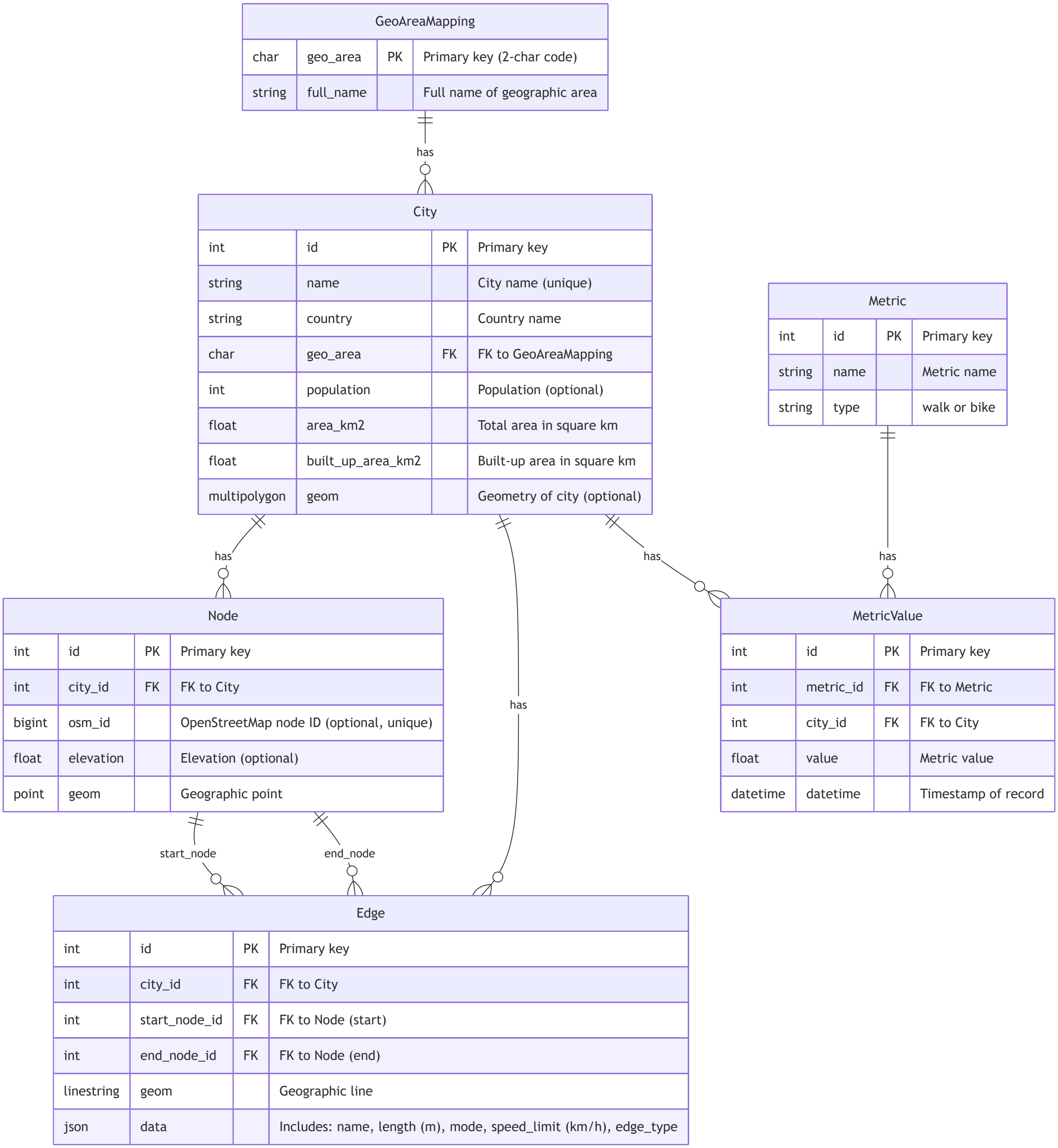
Methods:

- `set_data()` : Validates and stores edge attributes in JSON field

4.3 Entity Relationships

Key relationships:

- One GeoAreaMapping contains multiple City records
- One City contains multiple Node, Edge, and MetricValue records
- Each Edge connects exactly two Node records (directional)
- MetricValue joins City with Metric through time-series data



GeoAreaMapping

char	geo_area	PK	Primary key (2-char code)
string	full_name		Full name of geographic area

City

int	id	PK	Primary key
string	name		City name (unique)
string	country		Country name
char	geo_area	FK	FK to GeoAreaMapping
int	population		Population (optional)
float	area_km2		Total area in square km
float	built_up_area_km2		Built-up area in square km
multipolygon	geom		Geometry of city (optional)

Metric

int	id	PK	Primary key
string	name		Metric name
string	type		walk or bike

Node

int	id	PK	Primary key
int	city_id	FK	FK to City
bigint	osm_id		OpenStreetMap node ID (optional, unique)
float	elevation		Elevation (optional)
point	geom		Geographic point

MetricValue

int	id	PK	Primary key
int	metric_id	FK	FK to Metric
int	city_id	FK	FK to City
float	value		Metric value
datetime	datetime		Timestamp of record

Edge

int	id	PK	Primary key
int	city_id	FK	FK to City
int	start_node_id	FK	FK to Node (start)
int	end_node_id	FK	FK to Node (end)
linestring	geom		Geographic line
json	data		Includes: name, length (m), mode, speed_limit (km/h), edge_type

5. API Design

API Overview

This API provides endpoints for managing urban metrics data including cities, measurement metrics, network nodes, and edges.

Base URL: `http://localhost:8000/api/`

All responses are in JSON format.

Key Features

- Manage city records
- Access and manage street networks (`Node` , `Edge`) with spatial queries and downloads
- Manage mobility metrics (`Metric` , `MetricValue`)
- Support filtered queries and categorized metric retrieval

Example API Endpoints

POST /api/cities/

URL: `http://localhost:8000/api/cities/`
Creates a new city entry in the database.

Request Body:

```
{
    "name": "Berlin",
    "country": "Germany",
    "population": 3600000,
    "area_km2": 891.8,
    "built_up_area_km2": 310.4,
    "geom": null,
    "geo_area": "EU"
}
```

GET /api/metric-values/

URL:
`http://127.0.0.1:8000/api/metric-values/?city_name=Milan&start_date=2025-05-01&end_date=2025-05-12`
Retrieves filtered list of metric values.

Query Parameters:

- `city_name` : Milan
- `metric_name` : CIR
- `metric_type` : walk
- `start_date` : 2025-05-01

- `end_date` : 2025-05-12

GET /api/nodes/

URL: `http://127.0.0.1:8000/api/nodes/?city=1`
Returns nodes filtered by city ID.

Query Parameters:

- `city` : 1

GET /api/edges/

URL: `http://127.0.0.1:8000/api/edges/?city=1`
Returns edges belonging to specified city.

Query Parameters:

- `city` : 1

Postman Collection

A full Postman collection is provided for testing and reproducibility.

Available Endpoints

City Endpoints

- `GET /api/cities/` - Get All Cities
- `POST /api/cities/` - Create City
- `PUT /api/cities/{id}/` - Update City
- `DELETE /api/cities/{id}/` - Delete City

Metric Endpoints

- `GET /api/metrics/` - Get All Metrics
- `POST /api/metrics/` - Create Metric
- `PUT /api/metrics/{id}/` - Update Metric
- `DELETE /api/metrics/{id}/` - Delete Metric

MetricValue Endpoints

- `GET /api/metricvalues/` - Get All Metric Values
- `GET /api/metricvalues/filtered/` - Get Filtered Metric Values
- `POST /api/metricvalues/` - Create MetricValue
- `PUT /api/metricvalues/{id}/` - Update MetricValue
- `DELETE /api/metricvalues/{id}/` - Delete MetricValue

Node Endpoints

- `GET /api/nodes/` - Get All Nodes
- `GET /api/nodes/city/{city_id}/` - Get Nodes by City
- `POST /api/nodes/` - Create Node
- `PUT /api/nodes/{id}/` - Update Node
- `DELETE /api/nodes/{id}/` - Delete Node

Edge Endpoints

- `GET /api/edges/` - Get All Edges
- `GET /api/edges/city/{city_id}/` - Get Edges by City
- `POST /api/edges/` - Create Edge
- `PUT /api/edges/{id}/` - Update Edge
- `DELETE /api/edges/{id}/` - Delete Edge

Access the collection:
Postman Collection Link