Distribution of EV Charging Stations
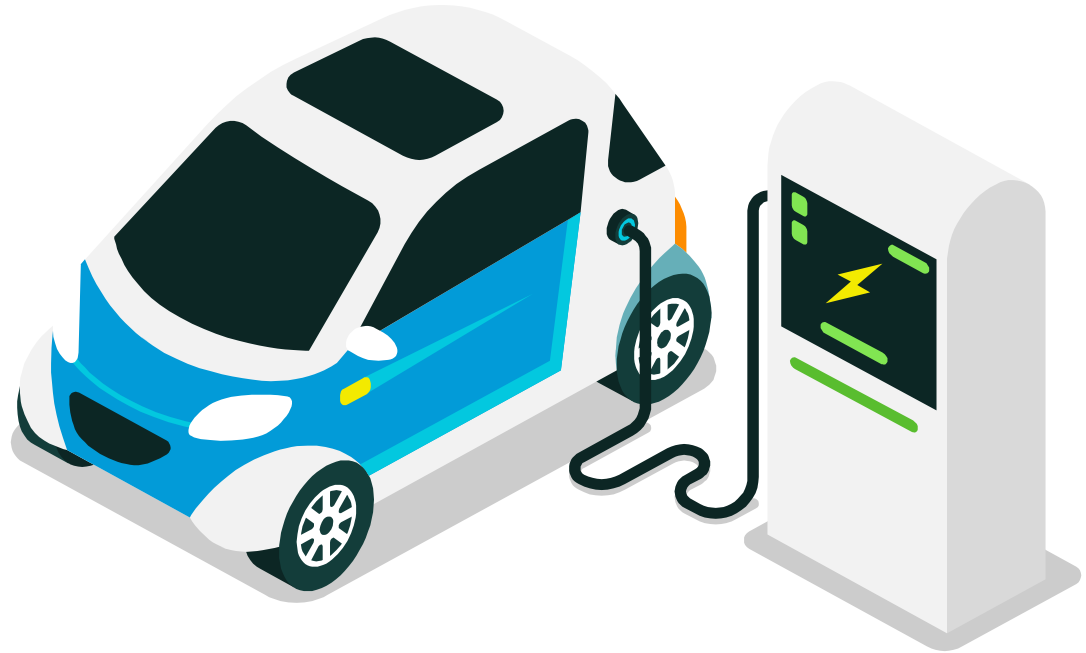
Modeling & Simulation

Group WG_21

Diogo Silva (202004288)
Henrique Silva (202007242)
Tiago Branquinho (202005567)

Simulation Problem

Description

Challenge:

- Growing adoption of **electric vehicles** (EVs)
- Recharging infrastructure efficiency in **Porto**
- Waiting times and peak demand

Problem scope:

- **Optimal placement -** location of charging stations within a city
- **Adequate capacity** - charging points per station

Key objectives:

- Minimize **waiting times** - especially during rush hours
- Balance **demand/supply** across regions
- Optimize infrastructure - varying **traffic flows** and user behavior
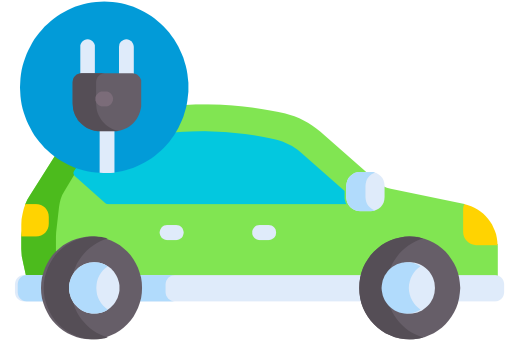
Simulation Model

Variables

- **Charging station capacity** - charging points per region

- **Vehicle battery levels** - to determine charging needs

- **Traffic patterns** - influenced by time of day (rush hour, lunch, etc.).

- **Region vehicles** - based on population, income, EV adoption

- **Vehicle speed** - average speed of all vehicles traveling

Simulation Components:

- **Regions (nodes)** - city areas with charging stations

- **Roads (edges)** - distances between regions

- **Clock/time** - simulates daily traffic flow dynamics
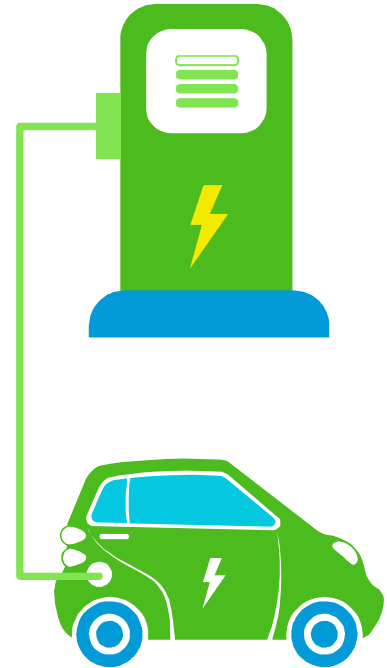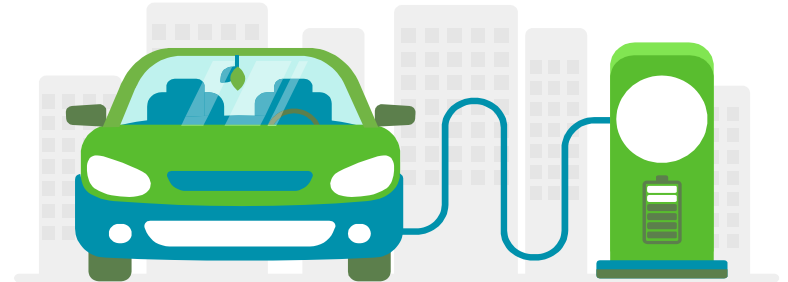
Simulation Model

Performance Metrics

- **Average waiting time** - time EVs wait for a charging point

- **Regional imbalance** - standard deviation regarding charger utilization across regions

- **Stress level** - demand per region available chargers

$$\text{stress\_level} = \text{(available\_chargers / chargers)} + \text{а} * \text{(queue / chargers)}$$

Objectives

- Evaluate system efficiency and understand how to:

  - reduce **waiting** times

  - prevent station **overcrowding**

  - ensure reliable **access**

Simulation Model

Scenarios

Scenario 1 - Current Infrastructure:

- baseline simulation
- existing station locations and capacities

Scenario 2 - Increased EV Demand:

- future growth in the EV market
- detect infrastructure bottlenecks

Scenario 3 - Varying Station Capacities:

- adjusting the capacity of region stations
- based on previous scenario needs

Goal:

- explore diverse conditions and **strategies**
- identify optimal station **placement** and **capacity**
- ensure **charger availability** at all times:
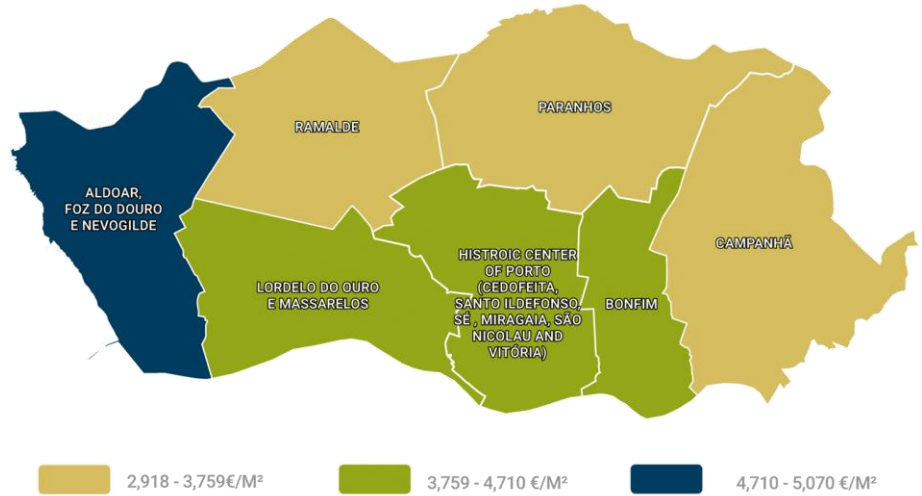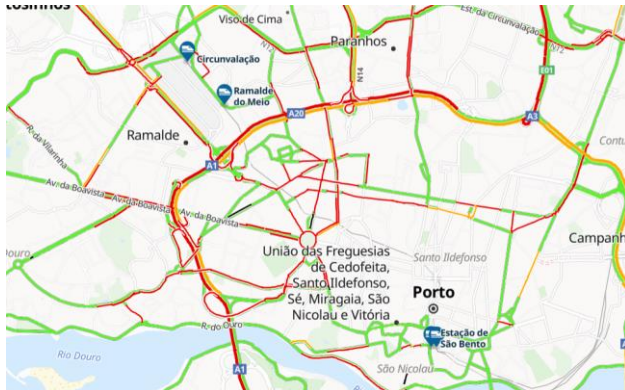 - while minimizing the investment needed

Implementation Details

Computing Data Estimates

Region Traffic

- Traffic **intensities** for each region
- City graph to calculate region values:
  - **edges** - roads/connections with different traffic weights

2,918 - 3,759€/M²   3,759 - 4,710 €/M²   4,710 - 5,070 €/M²

Car Seeding

- EV generation for each region pre-simulation
- Based on regional **income** distribution and affordability
- **Car tier** filtering:
  - percentage of income willing to be spent

Implementation Details

Simulation Flow

Simulation Logic

- Day divided into **segments** (rush hour, lunch, ...)
- **Step execution**:
  - 1 step = 1 minute
  - car/region updates
- **Visualization** refreshed at each step:
  - vehicle locations
 - region metrics

Car Logic

- **States** - idle, traveling, charging, in-queue, etc.
- Actions based on **day time**:
  - likelihood of traveling
- **Movement**:
  - average velocity
  - battery depletion
- **Region selection**:
  - for traveling
  - for charging
- **Home charging:**
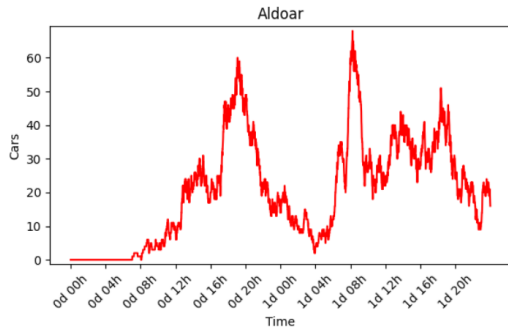 - option to leave halfway

Region Logic

- **Charging system**:
  - cars either charge or wait - availability
- **Metric calculation** and updates, tracking:
  - wait time for queued cars
  - average car autonomy
  - charger utilization
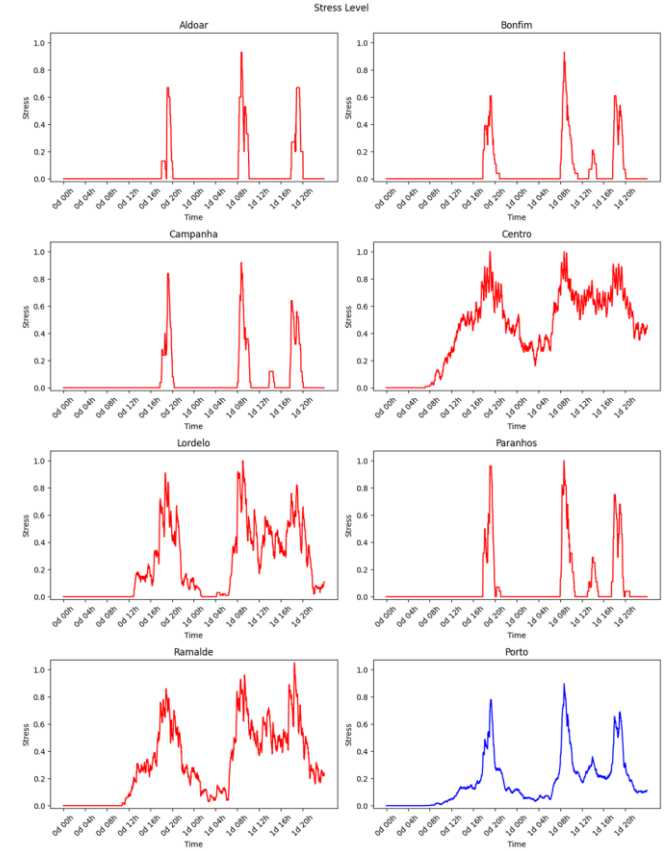 - cars currently in region

Results and Discussion - Scenario 1

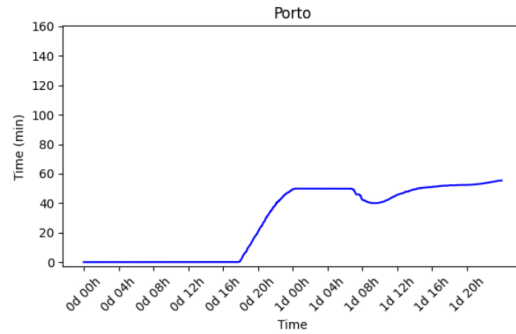## Average Queue Size
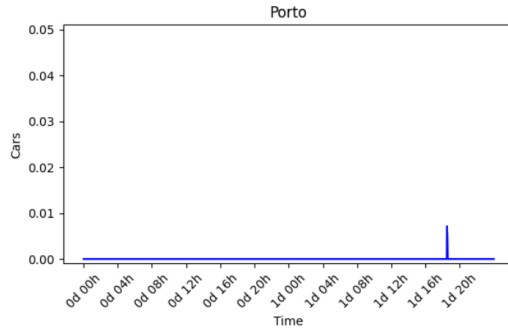
Home charging (Aldoar vs Paranhos)
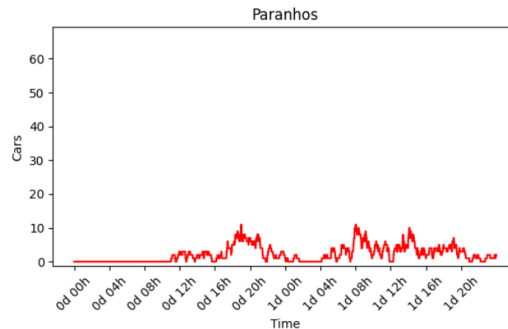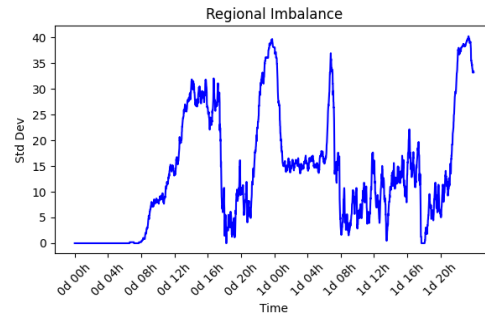

Stress levels

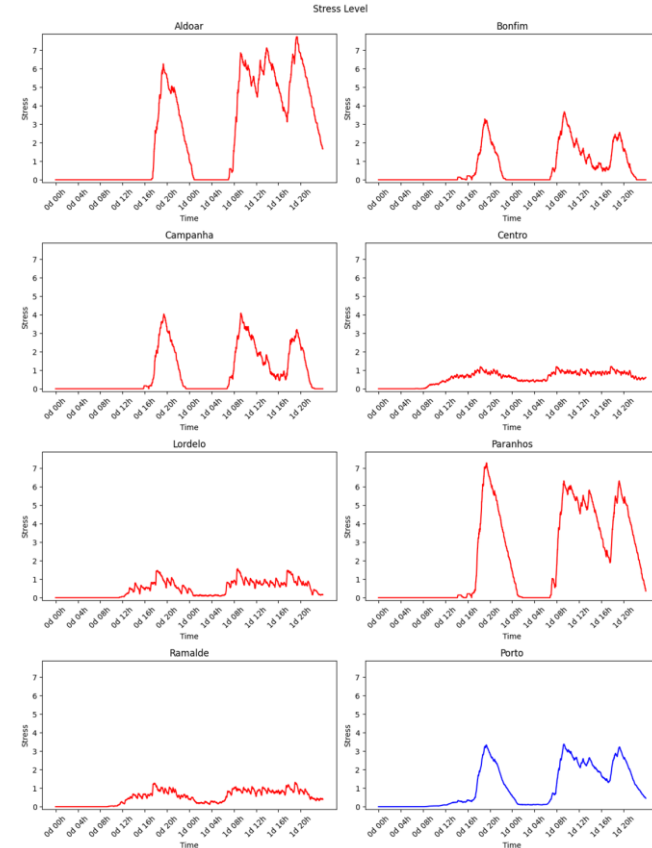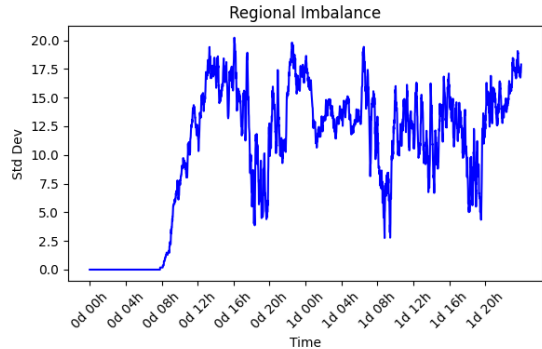# Results and Discussion - Scenario 2

Average Queue Wait Time

Regional Imbalance
(charger utilization)
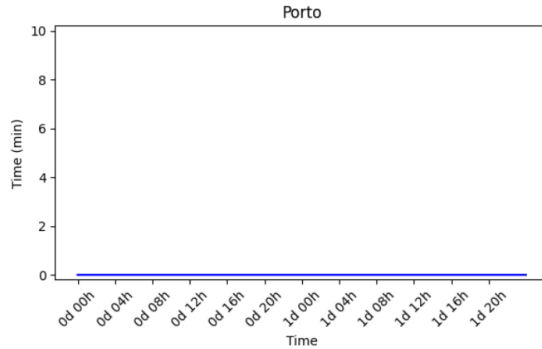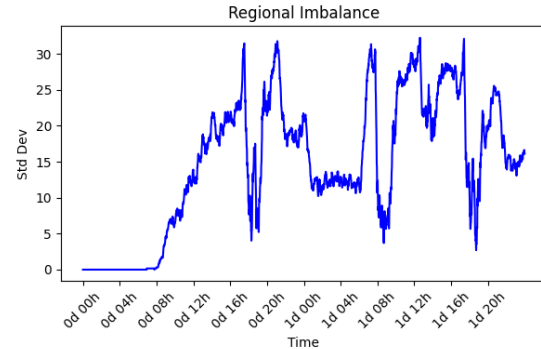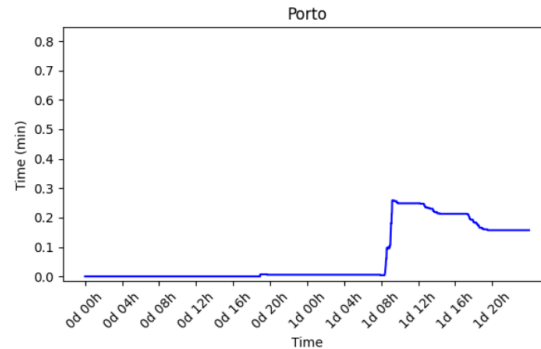

Stress levels
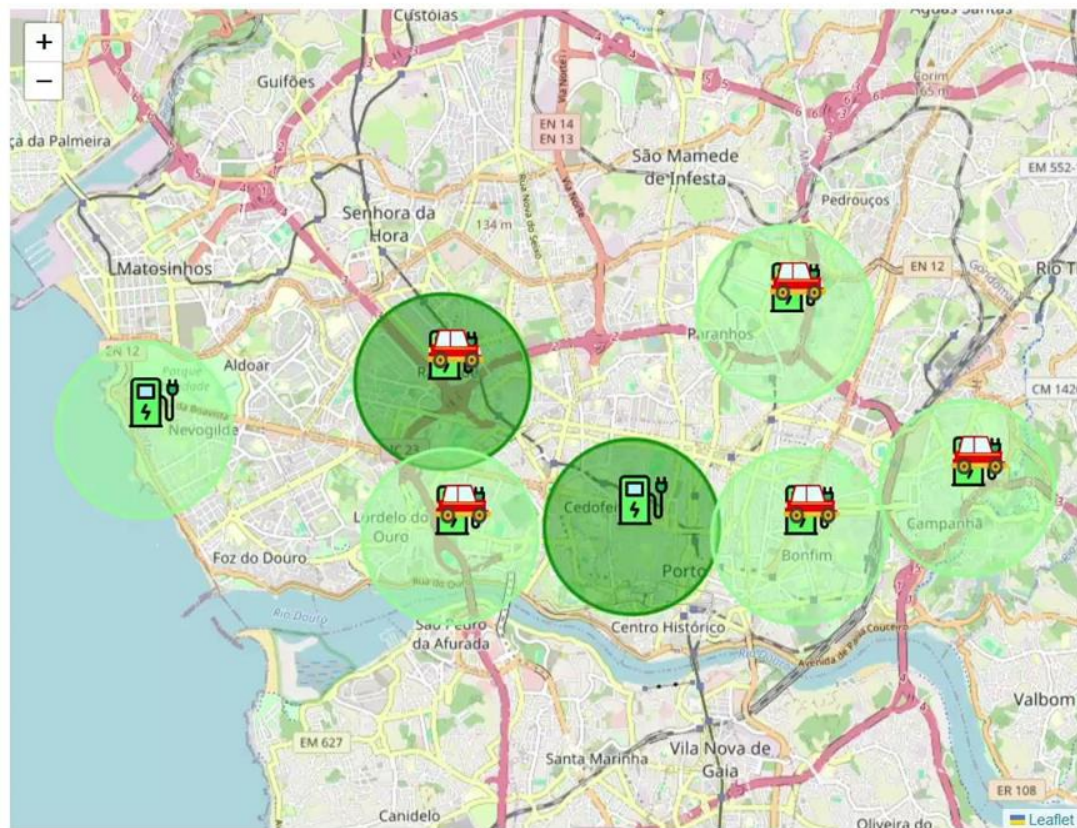
Results and Discussion - Scenario 3

Outer-focused investment

Inner-focused investment

Balanced investment
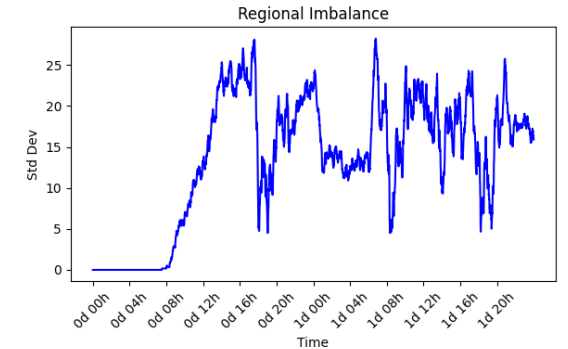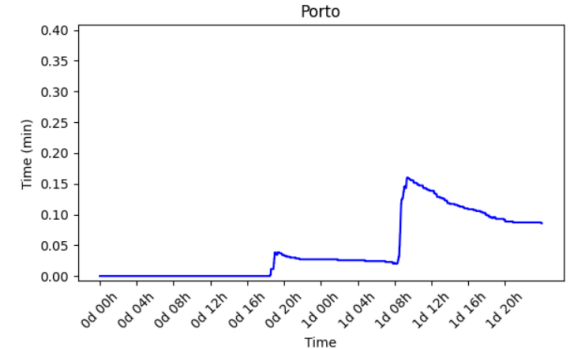
	Aldoar	Ramalde	Paranhos	Lordelo	Centro	Bonfim	Campanhã	Porto
Avg Home Charging Time (min)	33	29	31	30	30	30	29	30
Charger Utilization (%)	13	45	0	25	45	0	0	18
Regional Imbalance	-	-	-	-	-	-	-	19
Avg Queue Size	0	0	0	0	0	0	0	0
Stress Level	0.1	0.5	0	0.2	0.5	0	0	0
Avg Wait Time (min)	109	1	87	1	0	18	47	38
Avg Charging Time (min)	44	44	44	43	43	43	45	44
Cars Present	2357	2389	2257	1927	2787	1190	831	13738
Home Charging	33	1	4	3	1	1	0	43
Available Chargers	13	63	28	65	94	28	25	316
Cars Waiting	0	0	0	0	0	0	0	0
Cars Charged	135	1322	270	863	2361	168	176	5295
Avg Car Battery (%)	59	58	58	57	57	57	64	59