Topic 2: A simulation model for credit schemes and sustainable behaviour

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Simulation Problem

The main goal of the project is to simulate the **transport choices** of employees.

Modelling each person's choice depending on a credit scheme is very subjective:

How does a credit scheme affect the choices of a particular person?

- A practical study would need to be performed in order to obtain meaningful results
- A credit scheme will only result in sustainable behaviour if we define it as so
- We chose to directly change the transport choices behaviour, basically assuming the changes came from the application of specific credit schemes

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Simulation Problem

The goal is to analyse the consequences of a given transport choice behaviour, mainly focused on the **carbon footprint**.

Our what-if analysis is based on two types of simulation models:

- **Prescriptive Model**: Necessary transformations to the system to achieve a sustainable outcome
- **Speculative Model**: Make use of non-existent operation policies and configurations of the system to analyse it in terms of performance

The main questions we are looking to answer are:

- For a specific company, do the transport choices of its employees lead to a sustainable outcome?
- Does it meet a specific CO_2 budget cap?

Simulation Model

Input variables:

- Number of workers per company
- Number of companies with each policy
- Budget cap of CO_2 emissions
- Transport choices distribution

Output variables:

- Average CO_2 per company type/policy
- CO_2 emissions per employee
- Total CO_2 emissions
- Average transport costs

Data requirements:

- The approximate CO_2 emission in g/km of cars and electric scooters
- The approximate cost in €/km of cars and electric scooters
- Graph networks of the streets in Paranhos, extracted with Open Street Maps

Performance Metrics:

- CO_2 emissions
- Efficiency of the budget cap value
- Cost-benefit to the workers

Simulation Model

Scenarization:

- Base Scenario
  - Simplified commute
  - Randomly distributed workers and companies
  - Transport selection based solely on travel distance (home -> work-> home)
- Scenario 1 (+ sustainability-conscious companies)
  - majority of workers and companies still operate as in the base scenario
  - subset of companies now prioritize sustainability: their employees will likely favour more eco-friendly transportation options
- Scenario 2 (+ companies with varying CO_2 emission budget caps)
  - New dimension of constrained decision-making: distance remains a factor, but companies must now balance their employees' commute preferences with their environmental targets

Implementation Details - Tools
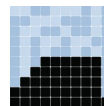
Programming Language: Python

Libraries:

- **Mesa**: simulation
- **OSMnx**: loading and handling graphs
- **Solara**: visualisation
- Others (pandas, matplotlib, etc.): handling and plotting data

Implementation Details - Graph

The graphs are loaded using **OSMnx**, with a bounding box of 5 km around FEUP.

- **Companies**: random locations within a small bounding box of the center (1km)
- **Employees**: random home locations within the complete graph

Use 3 different graphs – drive, bike and walk:

- Workers choose a transport, then navigate inside the corresponding graph
- Ensures better fidelity to real world: for instance, cannot drive in certain locations

For each worker and graph type, shortest paths are calculated with OSMnx to obtain the distance from home to work and back.

Implementation Details - Agents

Workers:

- Choose transport to travel from home to work and back based on the total distance, and on defined sustainability factor (chosen daily)
- Move one edge at a time on the graph

Companies:

- Have an assigned total CO_2 budget, based on the number of employees
- May change employees' sustainability factors (simulation of applying a credit scheme)

Implementation Details - Visualisation

Implemented on *Solara*, with support from *mesa.visualization*

Parameters modification:

- Allows changing some parameters of the model and resetting the simulation

Graph visualisation:

- Real-time visualisation of the graph and workers' movement
- The graphs are merged for better visualisation and to allow placing agents in nodes
- If the graph is too large to visualise: only shows a partial graph (includes company locations)

Plots visualisation:

- Real-time visualisation of the plots as data is generated
- Current transport choices, CO_2 emissions in comparison to company's budget plot, ...

Main Results
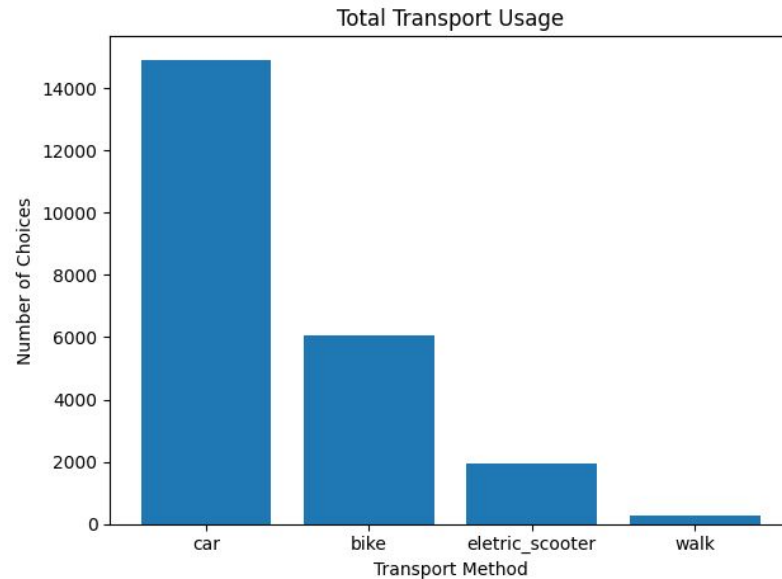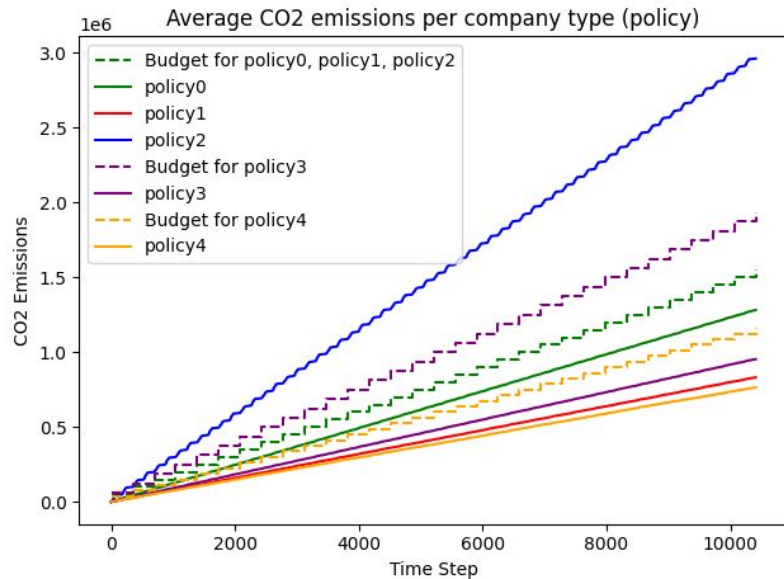
Conclusion

- The values used were completely standard, and sometimes it showed that some variables need to be adjusted specifically according to the company or agent's situation
- A CO_2 budget cap can help achieve sustainability goals. However, it needs to be adjusted to the circumstances of each company (inaccurate values can lead to poor sustainability)
- The cost-benefit to workers is an important aspect to consider when looking at sustainable transport options
- Future work could include expanding the model to other geographical areas and incorporating additional transport types, especially public transit

localhost:8765

90%

Sustainability Model

Controls

RESET ▶ STEP

Model Parameters

Number of workers per Company

Base CO2(g) Budget Per Employee

Number of companies with policy0

Number of companies with policy1

Number of companies with policy2

Number of companies with policy3

Number of companies with policy4

Information

Step: 0

Total CO2 Emissions over time

CO2 Emissions

0.04

0.02

0.00

-0.02

-0.04

-0.04   -0.02   0.00   0.02   0.04

Time Step

--- car
--- bike
--- walk
--- electric_scooter
--- Total

Current Transport Usage

Number of People

40

35

30

25

20

15

10

5

0

car   bike   electric_scooter   walk

Transport Method

Average CO2 emissions per company type (policy)

CO2 Emissions

1.0

0.8

0.6

0.4

0.2

0.0

0.0   0.2   0.4   0.6   0.8   1.0

Time Step

CO2 Emissions Per Employee Over Time

1040

1020

—— Mean CO2 Emissions
Std Dev
--- Base Budget Per Employee

This website runs on Solara