Faculty of Engineering of the University of Porto

Modelling and Simulation - Checkpoint 1

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1 Problem Formulation

Our project is based on an AYR credit scheme, where the main goal is to incentivise more sustainable behaviours and to influence people to reduce their carbon footprint. The group will create a simulation model and test it on a social simulation platform.

We will use a *What-if* analysis and two different models in order to build a valid, coherent, and precise simulation. The two models we are going to use are:

- **Prescriptive Model:** In our project, we will study what transformations we can make in order to improve our system. In our specific case, study the different credit schemes or incentives that can be implemented by private companies in order to make their employees more sustainable and reduce the overall carbon footprint.
- **Speculative Model:** This model will also be very important because we will use different scenarios to test the new operation policies and different configurations of our system and analyse them in terms of performance. Furthermore, the scenarios to be simulated correspond to systems that do not exist yet.

The *What-if* analysis will also be crucial to our project. It will allow us to inspect the behaviour of our complex system and assess how changes in a set of independent variables (such as the scheme implemented by the companies) impact a set of dependent variables (like transport usage or CO_2 emissions).

1.1 Problem description

Some companies are aiming to encourage their employees to adopt more sustainable commuting habits by introducing a benefits or credit scheme designed to incentivise eco-friendly travel choices.

1.2 Goals of the simulation project

Here are some key questions we aim to address with our model:

- Which policy leads to higher decreases in the carbon footprint?
- Which policy leads to higher adhesion to sustainable transports (public transports, bicycles, walking)?
- Which company policy is the most cost-effective for convincing workers to take more sustainable transportation from home to work?
- Which is the most used transport for each policy?
- Which type of population is most affected by a given policy?

1.3 Main entities

In this section, we define the key entities that interact within the system. These entities represent the primary objects of interest and will drive the behaviour and outcomes of the model.

- **Workers** (employees)

  - Dynamic behaviour: Workers are the primary dynamic objects in the simulation. They can make decisions regarding their mode of transport and change their preferences based on company policies, affecting the overall carbon footprint.
  - Attributes:
    * Type (e.g., conservative, environmentally conscious, cost-sensitive). This affects how likely they are to react and change their behaviour based on the company's policy.
    * Preferred mode of transport: private car, bicycle, public transport, walking.
    * Company: the specific company the worker belongs to.

- **Companies**
  - Influence worker behaviour through their sustainability policies, but do not actively make decisions in the simulation.
  - Reward employees based on their transport choices.
  - Provide means of sustainable transport for their employees (e.g., bicycles).
  - Attributes:
    * Employees that work in the company.
    * Policy used: This affects how likely employees are to change their behaviour, as well as how much cost the policy entails for the company.

1.4 Variables of the system

Variables represent key characteristics of the whole simulation system and are not specific to any entity. These variables influence the behaviour and outcomes of the entire system, either directly shaping the decision-making of entities or evolving as a consequence of system dynamics.

Some input variables are controllable, allowing us to adjust specific inputs, while others are uncontrollable and represent inherent characteristics of the population or environment.

For the output variables, we need to keep in mind that they represent the complete information to be obtained at the end of a simulation, and should be enough to answer the questions posed in Section 1.2.

Input variables:

- Distribution of the population ."types"[1] (e.g., 20% conservative, 20% environmentally conscious, ...).
- Type of credit scheme used and company policies[2].

Output variables:

- Percentage of adhesion to the credit scheme (increase in sustainable transports), by tracking transport usage.
- Total carbon footprint.
- Approximate financial cost for the companies.

[1] Uncontrollable variable: We cannot change society's characteristics.
[2] Controllable variable: We can implement a different credit scheme.

1.5 Operation policies (Scenarios)

In this project, we will begin by applying a baseline scenario, followed by a series of increasingly complex scenarios where the level of complexity will escalate after each simulation. It's important to note that each modification will build upon the previous scenario, allowing for a more direct comparison between the different simulations we conduct.

In all of our scenarios, when a policy is in place, employees get points by choosing more sustainable ways of transport. These points could be traded in for benefits, e.g., to receive an extra day of holidays or services offered by partners.

- **Base case**: We have a city with some streets and public transport options, and there are a few companies. In this simplest case, the companies don't implement any sustainability schemes or benefits.
- **Scenario 1**: One of the companies implements a policy that benefits only the top 5 more sustainable employees. The rest of the companies will not implement any policies.
- **Scenario 2**: One of the companies implements a policy that benefits all sustainable employees. The rest of the companies will not implement any policies.
- **Scenario 3**: Multiple companies implement policies that benefit sustainable employees. Different companies might implement different policies.
- **Scenario 4**: Similar to Scenario 3. In addition, employees might have different personalities that impact their willingness to adopt companies' policies.

1.6 Key performance indicators and decision criteria

Key performance indicators directly represent the success of a given simulation, providing an accurate view of the system under study.

In this project, we will use the following key performance indicators:

- **Reduction of CO_2 emissions**: Measure the total amount of CO_2 emitted.
- **Percentage of employees that opted to be more sustainable**: Percentage of people that opted for more sustainable transports instead of using their own private car.
- **Usage of public transports**: Number of people that opted for specific public transports.
- **Cost-benefit of the program.**

Besides that, we will have different **decision criteria**, such as:

- **Impact on urban mobility**: Analyse how the changes of behaviour (from the employees) affect the total carbon footprint.
- **How flexible the program is**: Evaluate the capacity of the program to adapt itself to different organisational cultures and different employees. This is based on the percentage of employees that adapted to new policies.

- **Efficiency of the incentives**: Evaluate which incentives are more efficient when it comes to promoting more sustainable behaviour (e.g., public transportation usage).
- **Ease of Implementation and financial costs**: Analyse the cost associated with the different implementations of incentive programs and their financial viability.

1.7 Data requirements

To increase the potential of our speculative model, we intend to add values that approximate the real world, such as:

- Graph networks of the streets in Paranhos, extracted with Open Street Maps[3].
- The location of public service stops, using Open Street Maps.
- Public transport timetables.
- The approximate CO_2/km emission value of cars.
- Total population of Paranhos in 2021.
- Number of people that work in Paranhos.

1.8 Simulation tools, environments and languages

During the project, the programming language we will use is Python, with Mesa[4] as the simulation tool. Additionally, OSMnx[5] will be used to import graph networks of designated cities.

[3] https://www.openstreetmap.org/#map=18/41.178466/-8.597239
[4] https://mesa.readthedocs.io/stable/
[5] https://osmnx.readthedocs.io/en/stable/