EVALUATION OF IMPACTS ON INTERCITY CORRIDORS FOR EFFICIENT AND SUSTAINABLE MOBILITY – INNOVATIVE WAYS TO ADDRESS CORRIDORS PRICING

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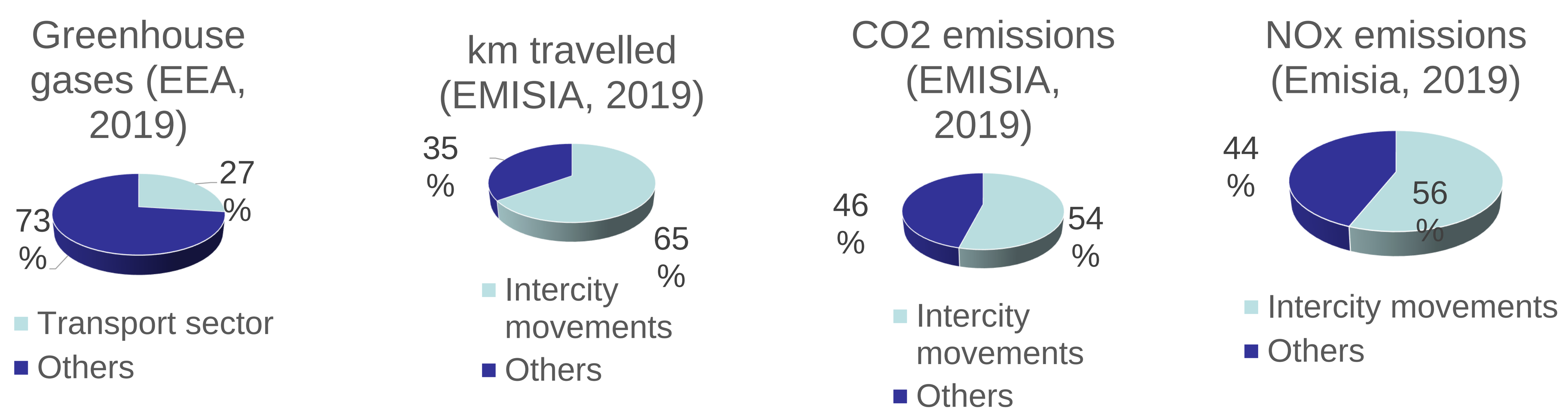
1. INTRODUCTION & OBJECTIVES

The negative externalities associated with regional transport and intercity trips represent a significar part of the total of negative externalities related with transport sector.



The purpose of this work is to develop tools and methodologies to implement smart and dynamic prices to perform traffic assignment and mitigate negative externalities associated with intercity corridors. Central research questions:

- Evaluate how an **optimal traffic distribution** in intercity corridors may contribute for the **reduction of transport-related externalities**;
- Estimate how new smart and dynamic tolls and fares may contribute to **optimal traffic solutions**.

The following topics will be addressed:

- **Optimal traffic distribution** for the reduction of externalities;
- Estimation of key variables (emissions, noise, accidents) and their external costs;
- Achieving **optimal traffic solutions** using new smart and dynamic tolls and public transport fares.

2. METHODOLOGY

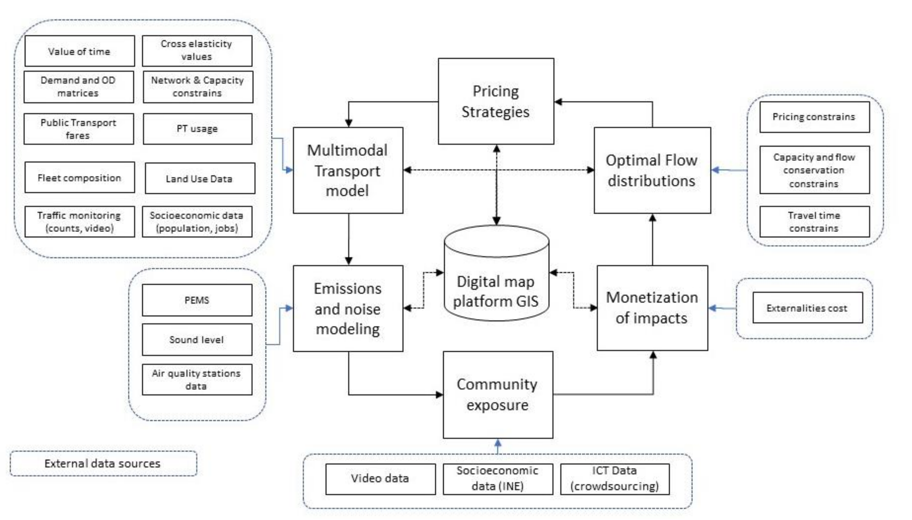


Figure 1 Methodology overview

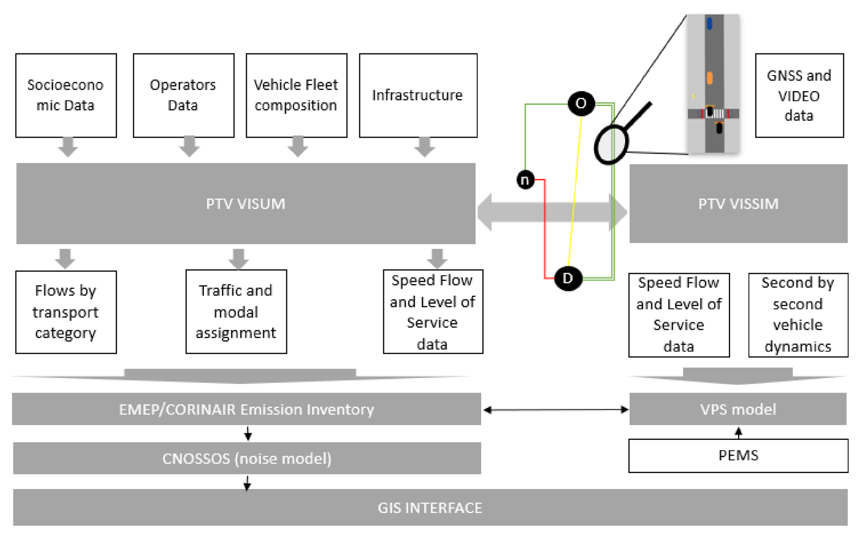


Figure 2 Model development overview

1) **multimodal transport model**, some external data sources will be needed such as value of travel time, public transport usage, among others. The goal is to have information of the variables needed and the development of the multimodal transport model that will be the base for the methodology.
2) **emissions and noise modelling** using real data gathered from Portable Emissions Monitoring Systems (PEMS), sound level meter and air quality stations to calibrate the models that will be used.
3) **community exposure** to adjust the levels of emissions and noise level regarding people exposed.
4) **monetization of impacts,** External Costs will be estimated using van Hessen et al. (2019).
5) **optimal flow distributions** and the study of:
6) **pricing strategies** will be executed as the final step of the research plan. The optimization will take into account: **a) External Costs:** externalization of the costs in a single indicator that represent emissions, safety and noise; and **b) Internal Costs:** internalization of the costs in a single indicator that considers the perceived (travel time) and actual (energy and tolls) costs by the user. All the variables will be displayed in a **digital map platform GIS.**

2.1. Estimation of emissions-related external costs

The CO_2 and NO_x emissions factors (g/km) are given for a typical Portuguese diesel and petrol passenger car. For a petrol vehicle (Macedo et al., 2020):

$$CO_2 = \begin{cases} 0.072s^2 - 7.530s + 360.424, & s \leq 50kph \\ 0.016s^2 - 2.382s + 232.506, & 50 < s \leq 90kph \\ -0.013s^2 + 4.063s - 118.60, & s > 90kph \end{cases}$$

$$NO_x = \begin{cases} 0.0003s^2 - 0.0281s + 1.3511, & s \leq 50kph \\ 0.0001s^2 - 0.0142s + 1.0232, & 50 < s \leq 90kph \\ -0.001s^2 + 4.0334s - 1.5687, & s > 90kph \end{cases}$$

where *s* is the average speed (kph) of the road segment.

Each pollutant is then multiplied by the factor 0.1 €/kg CO_2 and 1.7 €/kg NO_x. (van Hessen at al., 2019)

2.2. Estimation of noise-related external costs

The methodology uses the average speed of each road segment and the current traffic flow. Firstly, the following model is used to predicts noise cost exposure according to different levels of noise (Leq) (Sampaio et al., 2019):

$$NCE = 2.108E^{-5}L_{eq}^2 - 1.855E^{-3}L_{eq} + 4.1077E^{-2}$$

The model to estimate the noise costs per person exposed can be expressed as follows:

$$NC = 1.34E^{-6}Q + 5.17E^{-5}v - 1.24E^{7}v^2 + 5.30E^{4}$$

- Q stands for traffic flow (number of vehicles);
- v is the average speed of the vehicle in a given road segment;
- v^2 is the average speed squared.

2.3. Estimation of congestion-related external costs

The traffic congestion-related costs were estimated considering four different levels of congestion that are translated by the Volume to Capacity Ratio (V/C ratio) and the road type. The values can be found in the next table (van Hessen et al., 2019).

V/C ratio	Motorway (€-cent per vkm)	Other (€-cent per vkm)
<0.8	0.0	0.0
0.8 – 1	15.9	31.2
1 – 1.2	22.6	39.6
>1.2	29.4	46.4

2.4. Estimation of safety-related external costs

The safety-related external costs (RC) considers death and injury due to an accident for the person exposed, for the relatives or the person exposed and crash cost for the rest of the society. The following expression summarizes the methodology (Fernandes et al., 2019):

$$RC_k = \frac{X_F SC_F + X_{SI} SC_{SI} + X_U SC_U}{ab(V_{LDV} + V_{HDV}) l_k}$$

- k is for each road segment;
- X_F , X_{SI} , X_U , are the annual number of fatalities, serious and light injuries, respectively;
- SC_F , SC_{SI} , SC_U , are the average social accident costs (€) for crashes involving fatalities, serious and light injuries, respectively.

3. PRELIMINARY RESULTS

The following results are for the intercity corridor between Aveiro and Coimbra in a typical peak-hour period.
The safety-related costs estimation are still under development.
The values presented are in € per VKM (vehicle-kilometer).

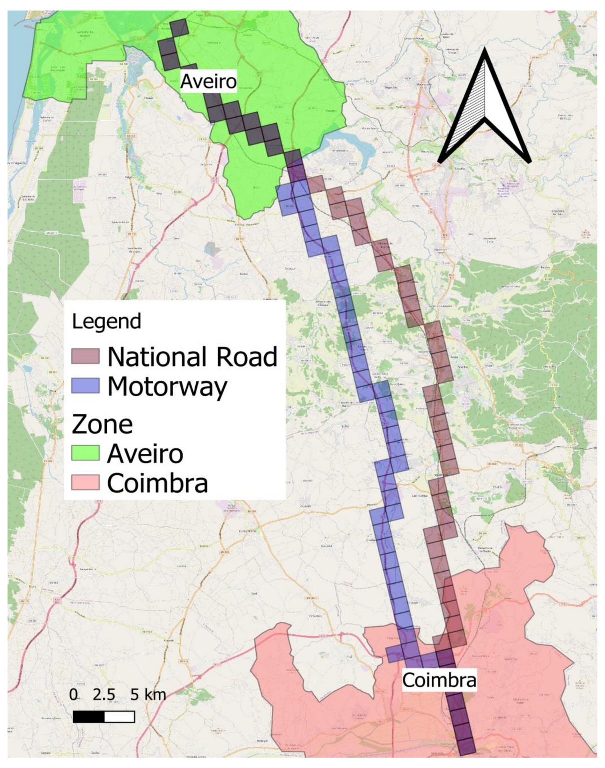


Figure 3 – Case study

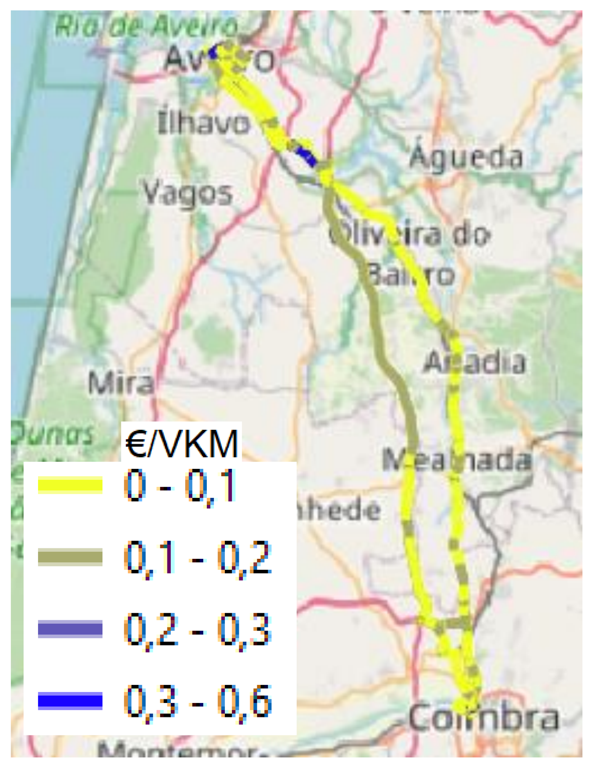


Figure 4 – Sum of all the externalities under study

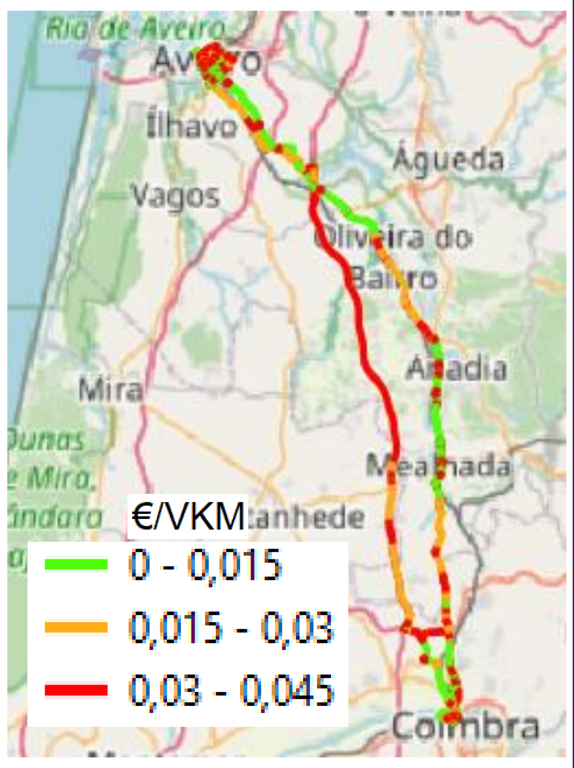


Figure 5 – CO_2-related external costs

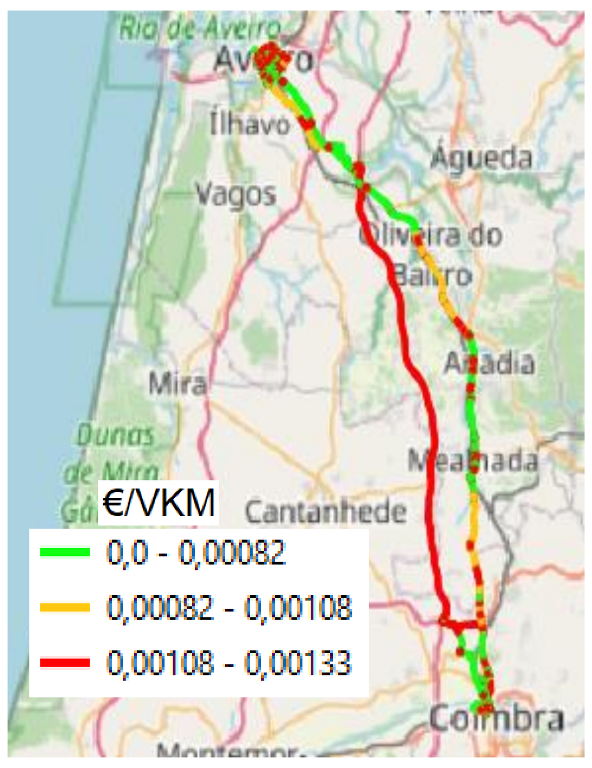


Figure 6 – NO_x-related external costs

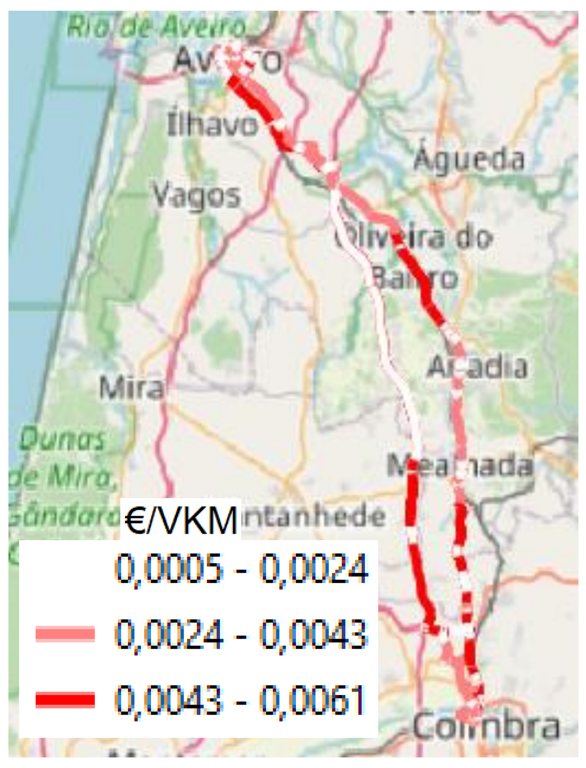


Figure 7 – Noise-related external costs

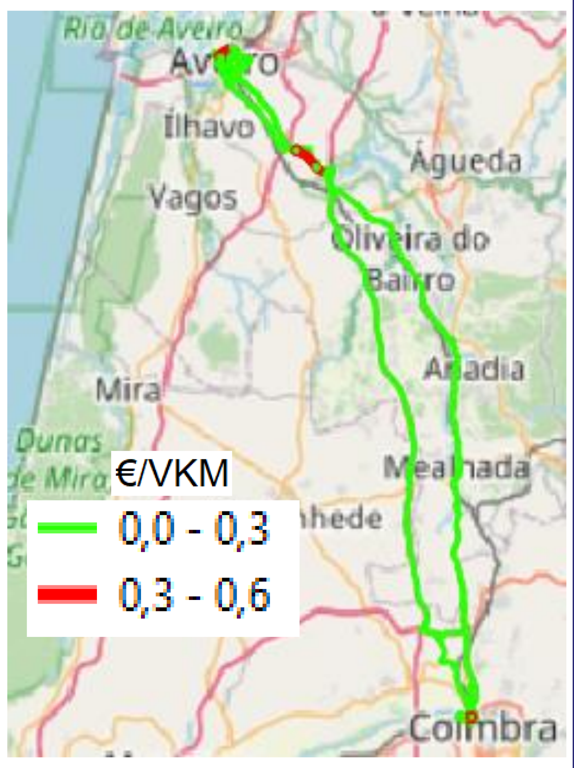


Figure 8 – Congestion-related external costs

4. FUTURE WORK

- Model **traffic related impacts,** especially the safety-related external costs.
- Characterization of the **population exposure to pollutants.**
- Design and assessment of new and **innovate ways to address corridors pricing.**
- Optimal **flow distributions** and optimal **pricing strategies.**

5. REFERENCES

- EEA (2019). **Greenhouse gas emissions from transport.**
- EMISIA (2019). **COPERT coutries data.**
- van Hessen et al. (2019). **Handbook on external costs of transport.**
- Macedo, E., Tomás, R., Fernandes, P., Coelho, M. C., & Bandeira, J. M. (2020). **Quantifying road traffic emissions embedded in a multi-objective traffic assignment model.** *Transportation Research Procedia*, *47*, 648–655.
- Sampaio, C., Bandeira, J. M., Macedo, E., Vilaça, M., Guarnaccia, C., Friedrich, B., Relvas, H., Rafael, S., Rodrigues, V., & Coelho, M. C. (2019). **A Dynamic Link-based Eco-indicator for supporting equitable traffic management strategies.** Transportation Research Procedia, 37, 43–50. https://doi.org/10.1016/j.trpro.2018.12.164
- Fernandes, P., Vilaça, M., Macedo, E., Sampaio, C., Bahmankhah, B., Bandeira, J. M., Guarnaccia, C., Rafael, S., Fernandes, A. P., Relvas, H., Borrego, C., & Coelho, M. C. (2019). **Integrating road traffic externalities through a sustainability indicator.** Science of The Total Environment, 691, 483–498. https://doi.org/10.1016/j.scitotenv.2019.07.124

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