IMPACTS ON EMISSIONS BY CHANGING THE TOTAL COSTS OF HIGHWAY TOLLS – A CASE STUDY

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1. INTRODUCTION

In Portugal the main contributor for Greenhouse Gases (GHG) is the transport sector (24%), also representing a big share of the energy consumed, around 37% (APA, 2018). By 2014, negative externalities associated with the transport sector accounted for 2% of the Portuguese Gross Domestic Product (GDP) (Tafidis et al., 2018). A large portion of this externalities occur in intercity corridors, in 2017 65% of the kilometers travelled by passengers were made in rural roads, motorways and highways (EMISIA, 2019). The European Union (EU) promotes a more efficient usage of the existing infrastructures to reduce the externalities of road traffic (EC, 2011), and has been encouraging the EU members to adapt their road pricing systems in a more fair and efficient way, mainly by promoting the "polluter pays" principle (Transport & Environment, 2017).

Congestion based road pricing systems, usually applied in urban centers have been studied around Europe, those systems usually consist in charging a certain monetary value to enter in a specific zone of the city, usually the city center (Morton et al., 2017). While some studies show that these systems lowered the total of the externalities associated (Croci, 2016), other state that these systems did not improve the air quality in some points (Percoco, 2013). Dynamic road pricing schemes have showed that they have an impact in terms of traffic congestion, emissions and overall, the negative externalities associated with road transport (Zhong et al., 2012). The localization of the toll may change the total externalities associated with a traffic system (Rodriguez-Roman and Ritchie, 2015). The price of the toll can also change the traffic flows, thus making the externalities of the transport system increase or decrease (Kutsukake et al., 2019, Fontes et al., 2015). Taking this into account, the objective of this short paper is to present the daily fluctuation of the total emissions, which is an external cost, by changing the number of tolls and their price in an intercity corridor, while checking, using a particular case study, if the highway is a better option than the national road in terms of CO_2 emissions. This work is part of a Doctoral thesis, which has the main objective of developing new tools and methodologies to assess dynamic and innovative ways of pricing intercity corridors with the goal of reducing the total externalities of the transport system.

2. METHODOLOGY

The case study proposed to achieve the objective is the intercity corridor between Aveiro and Albergaria-a-Velha. Aveiro is a municipality with 78.500 inhabitants and Albergaria-a-Velha has around 25.250 inhabitants. There are around 9.200 trips per day between these two cities, being 91% made by private transportation (TiS, 2014). The main roads that connects both cities are one highway (A25) and one national road (N109). The highway has three tolls, which values for a passenger vehicle are 0,65€, 0,50€ and 0,50€. The travel time by the national road is around 30 minutes and by the highway is around 21 minutes (Google Maps, 2019).

The methodology to achieve the objective proposed can be seen in the next figure.

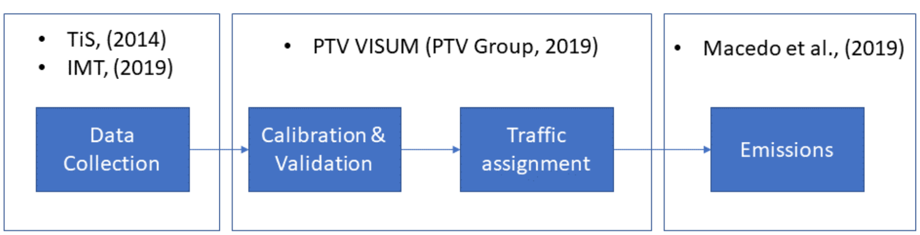

Figure 1 - Methodology used.

Firstly, data collection is performed, mainly by consulting national and regional reports (Tis, 2014, IMT, 2019). The information needed is mostly related to traffic flows. This information will be crucial to perform the calibration and validation of the model to do the traffic assignment using the software for macroscopic modelling, PTV VISUM (PTV Group, 2019). The emission model used is a macroscopic approach that uses the average speed of each link to estimate the CO_2 emissions of a typical Portuguese diesel vehicle (Macedo et al., 2019). In Figure 2, it is possible to see the baseline scenario, with the three tolls represented: "T1", "T2" and "T3".

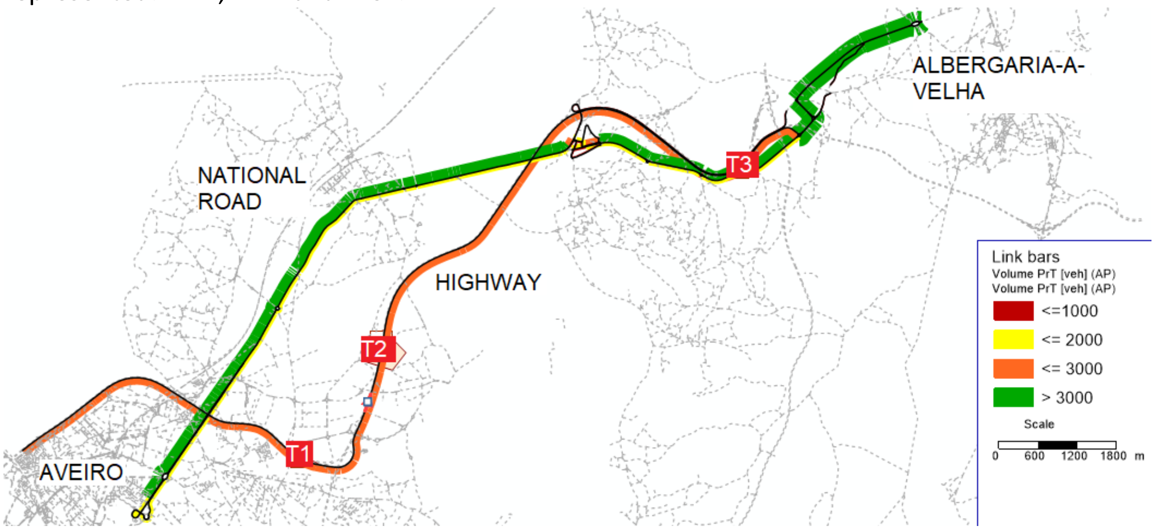

Figure 2 - Graphical representation of the baseline scenario Aveiro - Albergaria-a-Velha.

Five different scenarios are proposed and compared: 1) Baseline scenario; 2) Withdrawal of T3; 3) Withdrawal of T1; 4) Withdrawal of all tolls; and 5) Reduction of all tolls price by half.

3. PRELIMINARY RESULTS / DISCUSSION

The preliminary results are shown on the next table.

Table 1 - Preliminary results and the relative difference when compared to the baseline scenario.

Scenario	Emissions (ton. CO_2)	Difference to the baseline scenario (%)
1	21,7	0
2	22,7	5
3	24,1	12
4	26,3	21
5	24,4	13

All proposed scenarios consisted in reducing the total toll costs of the trip between Aveiro and Albergaria-a-Velha, and in all of them, emissions increased. By reducing the total cost of the tolls in the highway, the traffic flow is diverted to the highway. In this case, the national road presents less total CO_2 emissions associated, when compared to the highway. When travelling through the national road, a single vehicle emits 2,5 kg CO_2 while through the highway this value rises to 3,3 kg CO_2.

4. CONCLUSIONS

The objective of this short paper is to demonstrate, for a particular case study, how the emissions may vary depending on the total cost of tolls between an Origin-Destination pair.

The results show that the emissions may increase 21% in the more extreme scenario, where all the tolls are removed. By removing or decreasing the toll costs, the traffic flow is diverted to the highway; this translates in higher CO_2 emissions. Although the results show that it is better in terms of CO_2 emissions to travel through the national road, this does not necessarily mean that these options are the optimal choice in terms of sustainable road use. This study does not consider other pollutants (such as NO_x, $PM_{2,5}$) and the population exposed to them. The national road goes through more densely populated areas and that means that more people will be exposed to the pollutants. Also, this study does not take into account the noise exposure and road safety nor traffic congestion in peak hours. It is then proposed in the next steps to:

- Externalise the costs in a single indicator that represent emissions, safety and noise (External Costs);
- Internalise the costs in a single indicator that considers the perceived (travel time) and actual (energy and tolls) costs by the user (Internal Costs).

Analysing all these factors, it will be possible to have a close representation and future optimization of the network with the objective of reduction of the external costs by optimization of the internal costs. It will be also important to analyse hourly peak traffic because of capacity constraints which will change the external and internal costs. Public transport will also be considered.

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REFERENCES

Agência Portuguesa do Ambiente (APA). (2018). Relatório do Estado do Ambiente. Retrieved 3 of July of 2019, from https://rea.apambiente.pt/

Croci, E. (2016). Urban Road Pricing: A Comparative Study on the Experiences of London, Stockholm and Milan. Transportation Research Procedia, 14, 253–262. https://doi.org/10.1016/j.trpro.2016.05.062

EMISIA. (2019). COPERT Countries data. Retrieved from https://www.emisia.com/utilities/copert-data/

European Commission (EC). (2016). White paper 2011 [Text]. Retrieved 22 of May of 2019, from Mobility and Transport—European Commission website: https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en

Fontes, T., Pereira, S. R., Bandeira, J. M., & Coelho, M. C. (2015). Assessment of the effectiveness of fuel and toll pricing policies in motorway emissions: An ex-post analysis. Research in Transportation Economics, 51, 83–93. https://doi.org/10.1016/j.retrec.2015.07.010

Google Maps. (2019). Albergaria-a-Velha a Aveiro—Google Maps. Retrieved 16 of December of 2019, from https://www.google.pt/maps

IMT (Instituto da Mobilidade e dos Transportes). (2019). Relatório de Tráfego na Rede Nacional de Autoestradas—1o Trimestre de 2019.

Kutsukake, T., Mohri, Y., & Kaneko, S. (2019). Analysis of Toll Discounts on Nationwide Expressway in Japan. Presented at World Conference on Transport Research (WCTR) 2019 26-31 May, Mumbai, India.

Morton, C., Lovelace, R., & Anable, J. (2017). Exploring the effect of local transport policies on the adoption of low emission vehicles: Evidence from the London Congestion Charge and Hybrid Electric Vehicles. Transport Policy, 60, 34–46. https://doi.org/10.1016/j.tranpol.2017.08.007

Macedo, E., Tomás, R., Fernandes, P., Coelho, M.C., & Bandeira, J.M. (2019). Quantifying road traffic emissions embedded in a multi-objective traffic assignment model. Presented at EURO Working Group on Transportation Meeting (EWGT) 2019 18-20 September, Barcelona, Spain.

Percoco, M. (2013). Is road pricing effective in abating pollution? Evidence from Milan. Transportation Research Part D: Transport and Environment, 25, 112–118. https://doi.org/10.1016/j.trd.2013.09.004

PTV Group. (2019). PTV Visum. Retrieved 16 of December of 2019, from http://vision-traffic.ptvgroup.com/en-us/products/ptv-visum/

Rodriguez Roman, D., & Ritchie, S. G. (2017). Accounting for population exposure to vehicle-generated pollutants and environmental equity in the toll design problem. International Journal of Sustainable Transportation, 11(6), 406–421. https://doi.org/10.1080/15568318.2016.1266423

Tafidis, P., Macedo, E., Teixeira, J., Coelho, M. C., & Bandeira, J. (2018). Evaluation and comparative analysis of road transport emissions evolution in different European countries: The case studies of Portugal, Romania, Spain, and Sweden. Proceedings of 7th Transport Research Arena TRA 2018, Vienna. Retrieved from https://ria.ua.pt/handle/10773/23714

TiS. (2014). Plano Intermunicipal de Mobilidade e Transportes da Região de Aveiro—Relatório de Síntese. Retrieved from https://www.regiaodeaveiro.pt/regiaodeaveiro/uploads/document/file/1354/relat_c3_b3rio_20sintese_20final_20_n_c3_a3o_20t_c3_a9cnico_.pdf

Transport & Environment. (2017). Road charging for cars: What the European Commission should do Transport & Environment. Retrieved 22 of May of 2019, de https://www.transportenvironment.org/publications/road-charging-cars-what-european-commission-should-do

Zhong, R., Sumalee, A., & Maruyama, T. (2012). Dynamic marginal cost, access control, and pollution charge: A comparison of bottleneck and whole link models. Journal of Advanced Transportation, 46(3), 191–221. https://doi.org/10.1002/atr.195