Estimating the socio-environmental impacts of car substitution by bicycle and public transit using open tools

Rosa Félix[1*], Filipe Moura[1] and Robin Lovelace[2]

[1*]CERIS - Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal, 1049-001, Av Rovisco Pais 1.
[2]Institute for Transport Studies, University of Leeds, Leeds, United Kingdom, LS2 9JT, 34-40 University Rd.

*Corresponding author(s). E-mail(s): rosamfelix@tecnico.ulisboa.pt;
Contributing authors: fmoura@tecnico.ulisboa.pt; r.lovelace@leeds.ac.uk;

Abstract

In metropolitan areas, car trips can be replaced by a combination of public transit and cycling for the first-and-last mile. This approach requires interventions to make cycling more appealing, and the resulting public investments can have significant social and environmental benefits. This paper focuses on estimating the potential for cycling + PT as a substitute for car trips in the Lisbon metropolitan area and assessing its socio-environmental impacts using open data and open source tools.

To achieve the cycling targets set by the Portuguese cycling strategy, the Department of Transport introduced *biclaR*, a decision support tool that facilitates the design and development of a metropolitan cycling network. A scenario of intermodality introduced, and its socio-environmental impacts were assessed using the *HEAT for Cycling* and the *HEAT as a Service* tools. Additionally, we estimated the impacts of shifting car trips to PT and monetize them with the EU Guide to cost-benefit analysis.

The results indicate that 20% of the current trips can be made with the bicycle + PT combination, with an additional 12% of PT trips being potentially replaced. Shifting to cycling for the first-and-last mile can reduce annual CO2eq emissions by 6,000 to 15,000 tons/day, and the 10-year socio-environmental benefits account

for €230 to €590 million, depending on the cycling targets. For the PT leg, the transfer from car results in the avoidance of 8,500 to 20,800 tons of CO2eq emissions per year.
The provided information on socio-economic benefits can support policymakers in prioritizing interventions to reduce the reliance on individual motorized transportation and effectively communicate their decisions.

Keywords: Active transport, Intermodality, First and last mile, Health economic assessment, Environmental impacts, Open data and methods

1 Introduction

The Introduction section should explain the background to the study, its aims, a summary of the existing literature and why this study was necessary.

In metropolitan areas, car trips can be replaced by a combination of public transit (PT) and cycling for the first-and-last mile. This approach requires interventions and programs to make bicycling more appealing, and the resulting public investments can have significant social and environmental benefits. This paper focuses on estimating the potential for cycling + PT as a substitute for car trips in the Lisbon metropolitan area (LMA) and assessing its socio-environmental impacts using open data and open source tools.

According to the latest mobility survey conducted in 2018, the LMA registered a total of 5.3 million daily trips, with only 0.5% by bicycle. Car modal share is 58.4%, while PT accounts for 15.5%. To achieve the cycling targets set by the Portuguese national cycling strategy for 2025 and 2030 (4% and 10%, respectively), the Department of Transport introduced biclaR, a decision support tool that facilitates the design and development of a metropolitan cycling network.

The intermodality scenario considers trips that can combine PT and cycling for the first-and-last legs. Conservatively, we considered the sum of first-and-last legs up to 5 km. Furthermore, we restricted PT use to unimodal trips without transfers (although they can be included in future modeling). Finally, we only included PT modes that can

practically accommodate bicycles, such as trains, ferries, trams, and intermunicipal bus lines with bike racks (Figure 1).

To obtain reliable results, we used the OpenStreetMap road network and GTFS data. The r5r R package estimated the trip duration and distance for both the original modes and the bicycle + PT combination, while the od jittering R package estimated the OD locations based on a centroid-based OD matrix.

Socio-environmental impacts were assessed using the HEAT for Cycling and the HEAT as a Service tools, from the WHO. Additionally, we estimate the impacts of shifting car trips to PT for the second leg of the journey with EMEP/EEA's COPERT methodology and monetize them with the EU Guide to cost-benefit analysis.

The results indicate that 20% of the current trips can be made with the bicycle + PT combination, with an additional 12% of PT trips being potentially replaced. Shifting to cycling for the first-and-last mile can reduce annual CO2eq emissions by 6,000 to 15,000 tons/day, and the 10-year socio-environmental benefits account for €230 to €590 million, depending on the cycling targets. For the PT leg, the transfer from car results in the avoidance of 8,500 to 20,800 tons of CO2eq emissions per year, or €1.4 to €3.5 million over 10 years, with trains offering the greatest potential for substitution (88%).

By making the research process publicly accessible in a code repository, this study enables the replication of similar estimates for socio-environmental impacts resulting from a modal shift from cars to bicycles + PT in other metropolitan areas. The provided information on socio-economic benefits can support policymakers in prioritizing interventions to reduce the reliance on individual motorized transportation and effectively communicate their decisions.

The Introduction section, of referenced text Campbell and Gear (1995) expands on the background of the work (some overlap with the Abstract is acceptable). The introduction should not include subheadings.

Springer Nature does not impose a strict layout as standard however authors are advised to check the individual requirements for the journal they are planning to submit to as there may be journal-level preferences. When preparing your text please also be aware that some stylistic choices are not supported in full text XML (publication version), including coloured font. These will not be replicated in the typeset article if it is accepted.

2 Methods

The methods section should include:

- the aim, design and setting of the study
- the characteristics of participants or description of materials
- a clear description of all processes and methodologies employed. Generic names should generally be used. When proprietary * brands are used in research, include the brand names in parentheses
- the type of statistical analysis used, including a power calculation if appropriate
- studies involving human participants, data or tissue or animals must include statement on ethics approval and consent

3 Results and Discussion

Topical subheadings are allowed. Authors must ensure that their Methods section includes adequate experimental and characterization data necessary for others in the field to reproduce their work. Authors are encouraged to include RIIDs where appropriate.

Ethical approval declarations (only required where applicable) Any article reporting experiment/s carried out on (i)˜live vertebrate (or higher invertebrates),

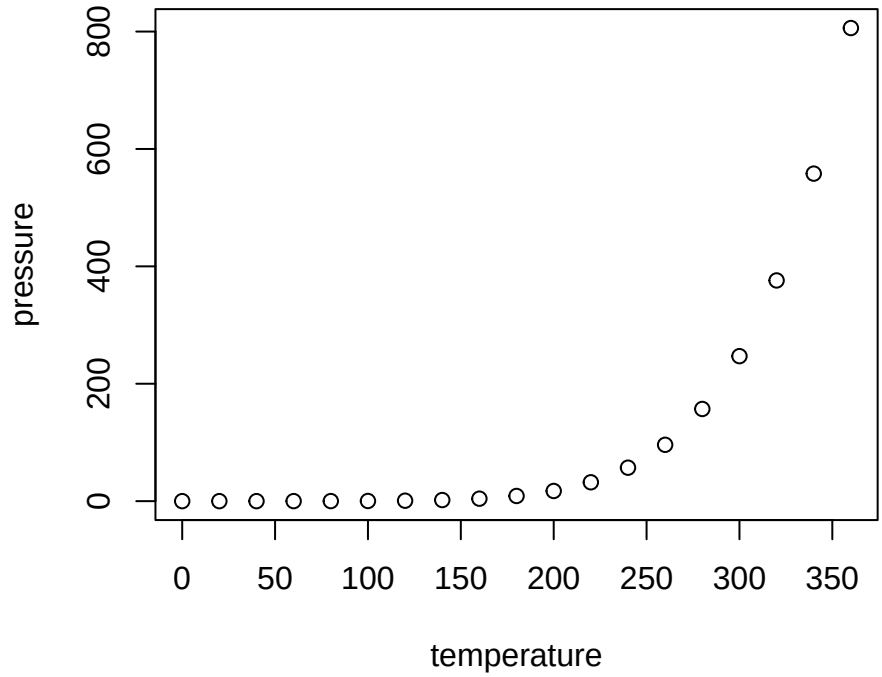

Fig. 1 This is an example of a caption

(ii)˜humans or (iii)˜human samples must include an unambiguous statement within the methods section that meets the following requirements:

1. Approval: a statement which confirms that all experimental protocols were approved by a named institutional and/or licensing committee. Please identify the approving body in the methods section
2. Accordance: a statement explicitly saying that the methods were carried out in accordance with the relevant guidelines and regulations

3. Informed consent (for experiments involving humans or human tissue samples): include a statement confirming that informed consent was obtained from all participants and/or their legal guardian/s

If your manuscript includes potentially identifying patient/participant information, or if it describes human transplantation research, or if it reports results of a clinical trial then additional information will be required. Please visit (https://www.nature.com/nature-research/editorial-policies) for Nature Portfolio journals, (https://www.springer.com/gp/authors-editors/journal-author/journal-author-helpdesk/publishing-ethics/14214) for Springer Nature journals, or (https://www.biomedcentral.com/getpublished/editorial-policies/#ethics+and+consent) for BMC.

4 Conclusion

This should state clearly the main conclusions and provide an explanation of the importance and relevance of the study to the field.

Conclusions may be used to restate your hypothesis or research question, restate your major findings, explain the relevance and the added value of your work, highlight any limitations of your study, describe future directions for research and recommendations.

In some disciplines use of Discussion or 'Conclusion' is interchangeable. It is not mandatory to use both. Please refer to Journal-level guidance for any specific requirements.

Acknowledgments. Acknowledgments are not compulsory. Where included they should be brief. Grant or contribution numbers may be acknowledged.

Please refer to Journal-level guidance for any specific requirements.

Declarations

Some journals require declarations to be submitted in a standardised format. Please check the Instructions for Authors of the journal to which you are submitting to see if you need to complete this section. If yes, your manuscript must contain the following sections under the heading 'Declarations':

- Funding
- Conflict of interest/Competing interests (check journal-specific guidelines for which heading to use)
- Ethics approval
- Consent to participate
- Consent for publication
- Availability of data and materials
- Code availability
- Authors' contributions

If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section.

References

Campbell, S.L., & Gear, C.W. (1995). The index of general nonlinear DAES. *Numer. Math.*, *72*(2), 173–196,