TEACHING MATERIAL GUIDANCE

1) Title of the material

Kaziyeva, D.; Loidl, M.; Wallentin, G. Simulating Spatio-Temporal Patterns of Bicycle Flows with an Agent-Based Model. ISPRS Int. J. Geo-Inf 2021, 10, 88, doi:doi.org/10.3390/ijgi10020088.

https://www.mdpi.com/2220-9964/10/2/88/htm

2) Which section of the SUMP it is relevant to?

The authors in the research paper propose agent-based modelling to simulate cycling flows at a regional scale for an entire day. The spatially explicit approach to modelling individual travel behaviour presented in the paper opens up new opportunities for evidence-based planning and decision making in the broader area of cycling promotion and monitoring of cycling flows taking into account travel motivation. Therefore, the article can be linked especially to the third, fourth and eleventh parts of the SUMP circle, which deal respectively with: analyse mobility situation (in particular analyse problems and opportunities – **subsection 3.2.** but also the analysis of problems and opportunities for all modes of transport - subsection 3.2.), scenario building and joint evaluation (developing scenarios of possible futures - **subsection 4.1.** but also discuss scenarios with citizens and stakeholders with use of the model results - **subsection 4.2**), and monitor, adapt and communicate (in particular monitor progress and adapt – **subsection 11.1.** but also inform and engage citizens and stakeholders **- subsection 11.2)**.

3) Which Mobility Manager knowledge this material is the most relevant to?

It is related to Transport and mobility planning (section 1 of the Mobility Manager competencies) especially 1c (understanding of travel behaviour) as well as to Data analysis for mobility planning especially 5a (data collection and analysis), 5b (transport modelling and simulation) and 5c (traffic demand forecasting).

4) Problem approached and content overview

Problem approach - cycling infrastructure is widely planned in the absence of reliable data, and the effects of cycling promotion measures cannot be properly monitored, therefore it is necessary to use tools supporting the planning and monitoring of the effects of cycling promotion measures. Transport planning strategies consider cycling promotion as one of the ways of solving problems related to car traffic, such as limited space, congestion and pollution. However, in most cases the evidence base for optimising cycling promotion is weak, and information on cycling patterns at sufficient resolution is largely lacking. The authors of this paper proposed an agent-based modelling approach to simulate cycling flows at a regional scale for an entire day. The feasibility of the model is demonstrated using the Salzburg region in Austria as an example. The simulation resulted in clear spatial-temporal patterns of cycling traffic at high spatial (road segments) and temporal (minutes) resolution. The scenario analysis positively assesses the level of model

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complexity, where demographically parameterised cyclist behaviour outperforms stochastic null models. Validation using reference data from three sources shows a high correlation between simulated and observed cycling, with predictive power primarily related to the quality of the input and validation data. In summary, the implemented agent-based model successfully simulates the cycling patterns of 186,000 inhabitants in a reasonable time. This spatially explicit approach to modelling individual travel behaviour opens up new opportunities for evidence-based planning and decision making in the broad area of cycling promotion.

Cycling is widely considered to be an appropriate alternative to motorised traffic, without negative environmental, economic and social consequences. Therefore, administrations and policymakers aim to enhance sustainable mobility and promote cycling, especially in urban environments. Evidence from the literature shows a positive correlation between comprehensive cycling promotion and a modal shift towards active transport modes. However, data on where and when people cycle within urban transport networks are still scarce. As a consequence, cycling infrastructure is commonly planned in the absence of reliable data, while the effects of measures promoting cycling cannot be adequately monitored.

A computer model, as an abstract representation of a real system, allows researchers to study processes without the need to conduct experiments in a real environment. This paper presents a methodology for simulating the travel of a heterogeneous population over one full day with emerging cycling flows using agent-based modelling (ABM) approach. Accordingly, the paper aims to implement a context-dependent individual decision-making process resulting in cycling patterns, interpret the model results for a case study, check the model complexity and validate the model results with observational data. Decision making is supported by spatial reasoning and includes characteristics of activity type, activity duration, activity location, trip start time, mode, speed and route. Mode choice provides six transport options to facilitate mode switching in one person's daily schedule. Nevertheless, only those using a bicycle move around the simulated space, while the rest are teleported to their destinations.

The paper presents the list of data acquired for the study, followed by a description of the model and the statistical testing method. The results section presents the results of the cycling model analysis and validation.

5) Who could be interested in this material?

This article is aimed at students and others looking for inspiration for sustainable urban mobility planning using travel mapping models. Students specialised in mobility management will find information on how to model the transport behaviour of citizens. The activities described can be helpful for those developing and monitoring SUMPs.

6) What is worth mentioning as an innovative factor for the reader?

The results highlight the added value of using transport ABMs on a regional level, where spatial-temporal traffic patterns are driven by the individual behaviour of residents. The

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output helps to distinguish the usability of existing and potential cycle paths, which is essential for planning strategies and investments. Although only bicycle traffic is simulated, the simulation of mode choice includes all major modes of transport. This facilitates the potential integration of additional concepts to capture travel patterns by other modes. Furthermore, the model can facilitate the study of other urban dynamic processes as an integrated transport module.

Agent-based modelling (ABM) provides a suitable simulation environment for creating spatially and temporally explicit traffic flows. This approach simulates the actions and interactions of individual elements or agents that act individually based on their characteristic attributes and behaviours. In a mobility system, an agent represents a person who makes travel decisions according to his/her preferences, the results of his/her non-linear actions, the decisions of others and the environment. The ability of ABM to describe in greater detail the properties and behaviours of agents and the environment mimics the heterogeneity of individuals and external conditions in the real world. The result of such a complex system is an emergent pattern of motion flow at very fine spatial and temporal resolution.

Geospatial analytical functions in the ABM environment are crucial because mobility is spatial by its very nature. Basic geographical features such as distance, accessibility, connectivity, and the design of the built environment have a direct impact on mobility. Geographic Information Systems (GIS) offer concepts and tools to capture these interdependencies. The integration of spatial aspects and operations in an agent-based model solves the problem of limited time representation in native GIS environments and accelerates the modelling of spatial reasoning in human behaviour. Taken together, these studies propose agent-based models that simulate either simplified daily cycling journeys of the entire population of a city or region, ignoring planning behaviour, or abstract scenarios beyond the actual geographical location. Consequently, no research to date has yet proposed an agent-based model that simulates the entire day of the entire regional population and that results in disaggregated spatial-temporal cycling patterns.

7) Limitations

The paper identifies gaps in the quality of available input and validation data. The main problem is the risk of incompleteness, biased representation of the population or lack of necessary information. This applies to the issue of travel modelling not only in the field of ABM. Incomplete representativeness of crowdsourced mobility data may cause some discrepancies in validation results. Data collection by mobile applications depends on user participation. Users are often health-oriented people interested in recording cycling trips. Therefore, data may miss utilitarian trips to work, school and university by other groups of people. Besides, the number of journeys recorded by the apps is small (together the trajectories from both apps account for 0.17% of the average daily number of cyclists) which limits the representativeness of the group.

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