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POPULATION NOISE EXPOSURE MODELLING USING LARGE SCALE MULTI-AGENT SIMULATION

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ABSTRACT

Modelling the noise exposure for a given population is essential in order to assess its potential environmental health issues and to guide authorities in their urban planning or transportation policies. This paper introduces a new method for evaluating noise exposure of large-scale populations based on MATSim, an open- source agent-based transportation simulator. A list of agents, i.e. a synthetic population, is generated using available census and travel surveys, and are used in the transport simulation. The description of the agents includes their socio-professional profile. The resulting vehicle movements are then used in NoiseModelling, an open-source CNOSSOS-EU implementation for noise emission and propagation, to compute the noise levels every time step, typically every 15mn. Agents are then followed in their daily schedule and a noise level is assigned to them every time step. The result is a 24h noise level time history for every agent. Opportunities for analysis are discussed, such as the detailed population exposure assessment and the investigation of environmental justice issues. A case study is presented and some use cases are explored. Finally, a similar coupling for air pollutants (CO2, NOx, ...) using the HBEFA emission database and the SIRANE dispersion model is under development that will enable multi-exposure assessments.

Keywords: *multi-agent, noisemodelling, matsim, exposition, pollution*

1. INTRODUCTION

Since the Environmental noise directive (END) 2002/49/EC, metropolitan areas across Europe have to produce noise maps of their territories for the 3 main traffic sources (plane, road and railway) and the concerned local authorities have to publish an evaluation of the noise exposure of their population. The official method for producing the noise maps and for calculating populations exposure is standardized in the CNOSSOS-EU [1] model and its use is mandatory since 2019. Amongst the many specificities of the directive, we can note that the noise maps are only calculated for 3 periods (Day, Evening and Night) and that for the assessment of noise exposure, only the residential location of the population are used.

A method that uses an activity based multi-agent traffic simulator, MATSim [2], coupled with NoiseModelling [3] [4], a noise emission and propagation software implementing the CNOSSOS-EU model, is presented here. It improves the temporal resolution of the noise evaluation beyond the DEN periods as well as the spatial precision of the exposure, by

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taking the population movement into consideration. Finally, it enables socioeconomical analysis of noise and pollution exposures, as it relies on an explicit description of the population.

2. METHOD

Our method for estimating the noise exposure of populations relies on:

- generating a synthetic population;
- running a traffic simulation;
- calculating the traffic noise.

In this section the tools that are used to estimate the population noise exposure and their purpose are presented.

2.1 EQASIM: Synthetic population generator

The first step of the method is to have an explicit representation of the population. The idea is to have a representative list of synthetic persons, also called agents, with associated socio economical characteristics. Each agent is assigned a typical day activity chain, that is a list of geolocated activities such as 'home', 'work', 'leisure', 'shopping', etc.
The Eqasim project [5] is used to generate these synthetic population. It's a project mainly aiming at French regions but can be used anywhere. It is a pipeline of processing stages that use various population census and surveys as well as aggregated population statistics to produce a synthetic population. It has been used successfully to represent the entire Ile-de-France population [6].

2.2 MATSim: Multi-Agent traffic simulator

With the synthetic population, the list of agents with their activity plans, MATSim [2], the multi-agent traffic simulator is used to compute the vehicle movements throughout the simulated day. More specifically, the Discrete Mode Choice [7] model is used. In the model, agents try to optimize their daily schedule by trying different modes of transport and evaluating the result with various cost or utility functions. The simulation converges to an equilibrium after about a hundred iterations.

2.3 NoiseModelling: Noise Emission and Propagation

NoiseModelling [3] [4] is a noise emission and propagation software that implements the CNOSSOS-EU model. The coupling between NoiseModelling and MATSim is detailed in [8]. One key step here is to aggregate the traffic flow and average speed by small time periods, typically 15min or 1h. The noise emission for every road segment is then directly by applying the CNOSSOS emission formulas.
From there, the noise propagation is computed and the result is a noise map every time period.

2.4 HBEFA / SIRANE: Air Pollution

As with noise pollution, the traffic air pollution is computed from the MATSim simulation. The HBEFA database [9] is used with the MATSim 'emission' contribution [10] in order to compute the traffic pollutants emissions.
For pollutants propagation in the area, the SIRANE [11] software is used. It combines a street canyon model with an atmospheric model for particles propagation and includes chemical reactions as well.
The result is, similarly to noise, a map of pollutant concentration for various particles (PM10, PM2.5, NOx, Pb etc.)

2.5 Agents Exposures

To calculate a single agent exposure, we can follow his movements throughout the simulated day. The noise level at the activity's receiver is assigned to every agent while they are at the activity's location. Tracking the agent's position every time step yields a time series of pollution exposure.
In the end the population exposure to noise (or air pollution) can be computed directly as the sum of very agent's exposures.

3. USE CASE: THE L63V AREA IN LYON

To demonstrate the potential of this method we'll use an area in the city of Lyon, France. This area includes the 3rd and 6th districts of the city of Lyon as well as the city of Villeurbanne.
The synthetic population of the department, with a 20% downscale, is generated before selecting the L63V area. **Figure 1** is a way to represent the synthetic population by mapping the repartition of HOME activities (rescaled to 100% of the population).

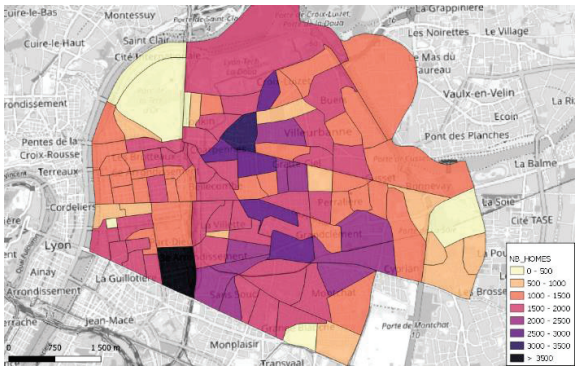

Figure 1. Number of HOME activities per IRIS in the studied area.

Then MATSim is used and the vehicle movements are analyzed per road segments every 15 minutes. A snapshot of the vehicle positions in the simulation can be seen in **Figure 2**.

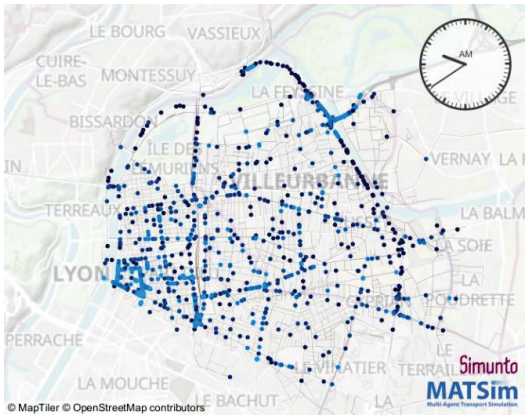

Figure 2. Vehicle positions at 09:39 in the MATSim simulation

From there the NoiseModelling emission and propagation modules are used to get sound levels at agents' activities positions. NoiseModelling can be used to get a classic traffic noise map, every 15 minutes, as illustrated in **Figure 3**.

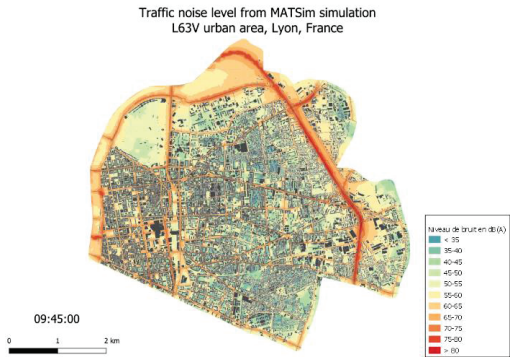

Figure 3. Traffic noise map in L63V from the MATSim simulation.

Then, as shown in **Figure 4**, every agent is followed during his simulated day and a noise level is assigned every 15 min.

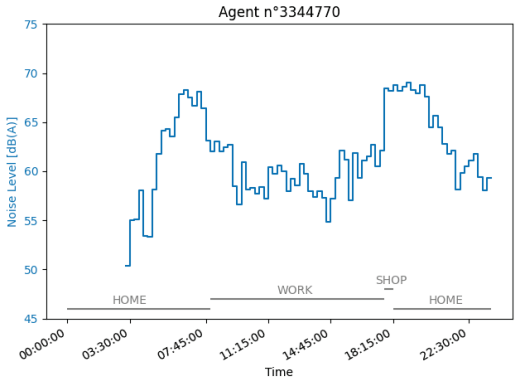

Figure 4. Agent daily noise exposure.

If we consider the exposure of the agents a simple energetic sum of their noise levels. We can start looking at, for example, the age categories of agents exposed to more than 65dB(A) in their simulated day, as shown in **Figure 5**.

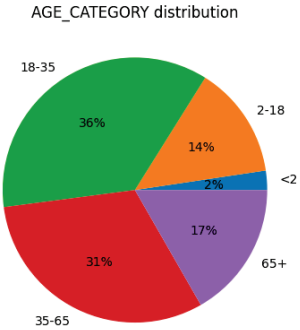

Figure 5. Age categories of agents exposed to more than 65dB(A)

It illustrates the possibilities provided by the presented method.

4. DISCUSSION

As highlighted with the L63V use case, the proposed method offers a finer, more detailed population exposure model than what the standard methods offers.
Computing the traffic flow of vehicles from the MATSim simulation every 15minutes, we can use the CNOSSOS emissions model provided by NoiseModelling to get noise time varying noise emissions on the network. From there, using NoiseModelling to propagate noise to population position, we can estimate noise exposition every 15 minutes.

It enables advanced analysis like looking at socioeconomical distribution of pollution exposure, and therefore, at environmental injustice in urban areas for example. The method can be used by urban planners and policy makers to evaluate the impact of their projects on the population, and guide their decision.
However, as is expected with a composition of so many models, limitations need to be acknowledged. A detailed listing of these limitations can be found in [8], but a brief summary is presented here.
The first limits come from the input of the whole method, the synthetic population.
The traffic model can also be improved in many ways: freight traffic is omitted and motorcycles vehicles are not considered for example.
Finally, the attribution of noise level at activity locations can be discussed. It is likely that assigning a noise level to a residential house doesn't have the same implication as assigning a noise level to a shopping center.
Estimating the accuracy of the process is complex and still needs to be evaluated.

5. CONCLUSION

In conclusion, this paper has presented a new approach for evaluating noise exposure in large-scale populations using the MATSim transportation simulator and NoiseModelling. The proposed method results in an agent-based noise and pollutants exposition, which enables a detailed population exposure assessment and opportunities for investigating environmental justice issues. The presented case study demonstrated the potential of the proposed approach, and various use cases were explored. This paper contributes to the development of effective measures for mitigating noise exposure and improving environmental health in urban areas. The proposed approach can be used by policymakers, urban planners, and researchers to evaluate the impact of transportation policies and guide urban planning decisions.

6. ACKNOWLEDGMENTS

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