A MATSim modeling framework
to simulate the impacts of extreme rainfall events in the UK

David Alvarez Castro, Daniel Bell, Alistair Ford
Newcastle University (UK)

INTRODUCTION

Despite the implementation of transport decarbonisation measures to reduce greenhouse gas emissions, the effects in the climate are already noticeable. With infrastructure and users facing more intense and frequent extreme weather events, transport strategies to mitigate the impact of climate change must be considered. This work proposes an on-going methodology to simulate the impact of extreme rainfall events to the transport network and the travelling public, providing spatio-temporal emerging responses of synthetic individuals affected by flash floods during their daily routines. Risk is analysed from economic, social and environmental perspectives, and adaptation strategies are also considered to quantify the risk reduction and estimate the resilient dividends that can be achieved when compared to a scenario without interventions. The proposed methodology is tested at urban scale in the Tyne and Wear region (UK), although methodology can be applied anywhere in the UK.

METHODOLOGY

The developed framework firstly identifies the weather hazard in space and time using dynamic rainfall simulations (green box in Figure 1) from the UK meteorological agency (MetOffice), using data at 2.2 km grid resolution. Secondly, the vulnerability of the transport systems to the rainfall events is estimated using a dynamic hydrological model (blue box) (CityCAT) (Birkinshaw et al., 2024), where water depths of each road link are quantified at different time intervals (e.g., 10 minutes), taking into account buildings, impermeable areas, green areas and ground gradients. These time-dependent outcomes are converted into maximum vehicle velocities based on the relationship between depth of standing water and vehicle speed (Pregnolato et al., 2017), assuming safe driving behaviour from the public. The above time-variant changes in maximum speed are incorporated into a MATSim model (dark blue box) (Axhausen, Horni and Nigel, 2016) using the “NetworkChangeEvent” class to simulate the impact of the dynamic extreme event to the transport demand (purple box).

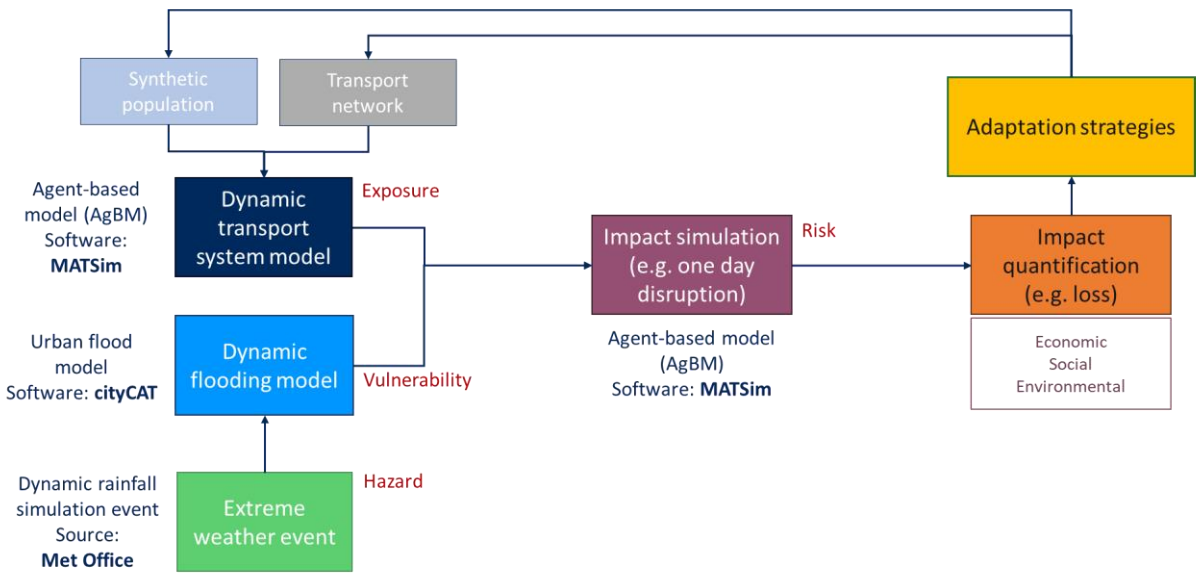

Figure 1. Methodology developed to simulate the impact of extreme rainfall events to the transport sector and travelling users, using Agent-Based Modelling (AgBM) techniques.

The impact of the extreme rainfall event is then quantified from three different perspectives (orange box) (i.e., economic (e.g., costs of journey delays), social (e.g., who are the most affected people) and environmental (e.g., increased vehicles' emissions)), which could help policymakers and practitioners to better understand the potential consequences of extreme rainfall events in the study area to the transport flow and public. Lastly, hard and soft adaptation strategies (yellow box) (e.g. changes to physical infrastructure such as flood prevention or changing to behaviour such as home working on disrupted days) are simulated to estimate their efficiency in reducing the risks and inform policymakers on where and to what extent the transport systems should be upgraded to handle these extreme scenarios. Figure 1 summarises the proposed methodology.

RESULTS

The previous described methodology was applied to the Tyne and Wear region, using Alvarez Castro et. al (2024) MATSim validated model and data from the *Toon Monsoon* flash flood event, where 50mm of rain fell in just two hours in June 2012, the same amount as expected in a month time. Comparisons were made between two extreme scenarios. The first shows how the synthetic individuals behave as on a normal day (i.e., without the possibility of adapting their behaviours to the consequences of the extreme weather event) and, the second when they are allowed to learn through a set of iterations, where modifications to their activity plans (e.g., the use of different transport modes, followed routes and starting time) were allowed. While the former shows the consequences faced by the synthetic individuals without the ability to adapt their mobility patterns (i.e., worst case scenario), the latter shows how individuals avoid, when possible, flood-affected or highly congested areas. However, the results from the latter could not be considered as a genuine behaviour, as individuals adapted their behaviours based on previous gained knowledge through the iterations. Results obtained must be seen as the ideal population response to identify efficient routes and avoid the most affected areas. Therefore, the obtained outcome could act as a proxy for a situation where early warning about flood impacts is provided.

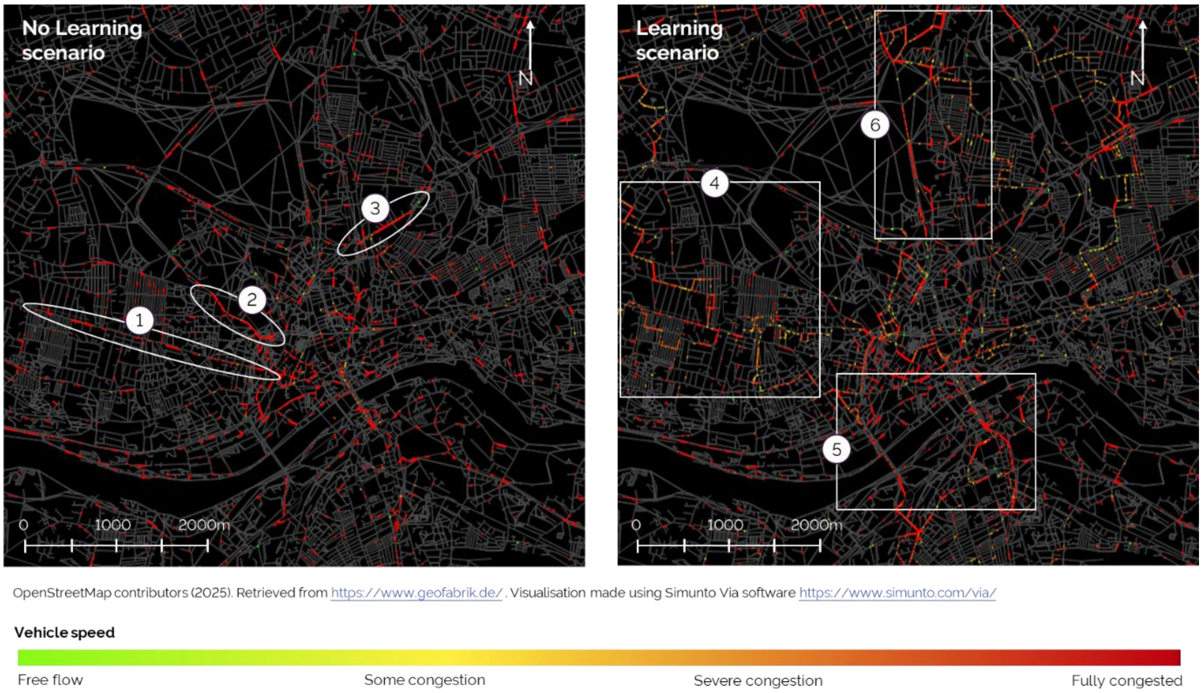

Figure 2. Result comparison between the two scenarios simulated: No learning (left) and learning scenario (right). Vehicles speeds are represented on a colour scale of green (free flow), yellow (experiencing some congestion), orange (severe congestion) and red (fully congested), showing the impact of the extreme rainfall in the transport mobility.

Preliminary results of the behavioural changes in the study area can be observed in Figure 2. Synthetic individuals located on flood-affected roads (e.g., Westgate Road (1), Barrack Road (2), and Jesmond

Road (3)), found detours to avoid these areas by using less affected routes through Arthurs' Hill and Fenham (4), Redheugh Bridge and Tyne Bridge (5), and Jesmond (6), among others, after the possibility of adapting their behaviours.

DISCUSSION

These ideal emerged behaviours have various implications and consequences for the transport network and the population. Firstly, alternative routes must absorb the detoured travel demand to ensure a smooth and resilient mobility. Secondly, several infrastructure assets (e.g., bridges, tunnels) might face a higher stress (e.g., rainfall impact, more vehicles using them), therefore their robustness and resilience need to be considered to avoid negative cascading effects (e.g., failures). Thirdly, access to critical facilities (e.g., hospitals, fire stations) must be guaranteed to always ensure their normal performance. Fourthly, several groups in society would be more affected than others based on their activity locations (e.g., house and workplaces) or their socio-demographic attributes (e.g., age, health status). Fifthly, people may be forced to travel longer distances, thus increasing their greenhouse gas emissions.

Future work will be focused on the previous highlighted analyses, the impact quantification of the potential consequences and the simulation of several adaptation measures to improve transport network resilience and reduce the risk. Additionally, a more realistic approach where agents can only adapt their behaviours based on real-time information (i.e., within replanning) will be considered.

CONCLUSION

Transport systems are critical to our current lifestyle, as they provide the nexus between daily social and economic interactions. Current failures or damages have serious consequences that can be exponentially worsened with the potential impact of more frequent and intense extreme climate events.

The analysis of extreme rainfall events on a transport network provides understanding of the possible impact to infrastructure and to the public, contributing to adaptation strategies for future preparedness. Hazard, vulnerability and risk factors are considered in the proposed methodology, providing results at a very granular level that emerge from the interactions of individuals when facing the rainfall event within MATSim. This approach will enable policymakers to make more inform decisions to reduce uncertainty about future disruptions.

REFERENCES

Alvarez Castro, D., Ford, A., James, P., Palacín, R. and Ziemke, D., (2024) A MATSim model methodology to generate cycling-focused transport scenarios in England, Journal of Urban Mobility, Volume 5, 100078, ISSN 2667-0917, https://doi.org/10.1016/j.urbmob.2024.100078 .

Axhausen, K. W., Horni, A., and Nagel, K. (2016). The multi-agent transport simulation MATSim. Ubiquity Press. https://library.oapen.org/handle/20.500.12657/32162

Birkinshaw, S., Glenis, V., O'Donnell G. and Kilsby C. (2024), CityCAT urban flood model. Factsheet http://www.urbanfloodresilience.ac.uk/documents/factsheet-citycat.pdf (last visit 17/01/2025)

Pregnolato, M., Ford, A., Wilkinson, S. M., and Dawson, R. J., (2017) The impact of flooding on road transport: A depth-disruption function, Transportation Research Part D: Transport and Environment, Volume 55, Pages 67-81, ISSN 1361-9209, https://doi.org/10.1016/j.trd.2017.06.020.