Modelling the impact of flooding on transport systems with MATSim

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Introduction

The literature shows that flood risk is a complex combination of several factors: flood hazard which relates to the probability and features of events such as water depth, velocity, frequency, duration; flood exposure (population, assets), and vulnerability/resilience (the capacity of the system to respond to and recover from a disruption) (Pregnolato et al., 2017; Saadi et al., 2018). The complex interplay between flood hazard scenarios and the evolution of future urban and transport systems can lead to various levels of flood risk, which need to be quantified.

A resilient transport system must not only adapt to the immediate impacts of flooding but also be designed to recover quickly, ensuring continued connectivity and functionality during and after such events. Here we develop an integrated agent-based modelling framework to go from climate variables (i.e. extreme rainfall) through hazard models (i.e. hydrodynamic flood modelling), to impact assessment on the transport system (including network and travel demand/behaviours) and ultimately quantifiable metrics to identify key infrastructure assets at risk from climate-related hazards and exposed segments of the population, and underlying behavioural changes. This is demonstrated for an extreme rainfall impacts on road infrastructure at an urban scale (Figure 1), and tested through MATSIM agent-based transport model implementation in Greater Manchester and Newcastle upon Tyne. The findings can better inform policymakers on how and to what extent the transport system should be upgraded to handle extreme rainfall and resulting flooding. This includes considering potential adaptation options to improve the resilience of future transport systems and prioritizing key urban and transport planning policies.

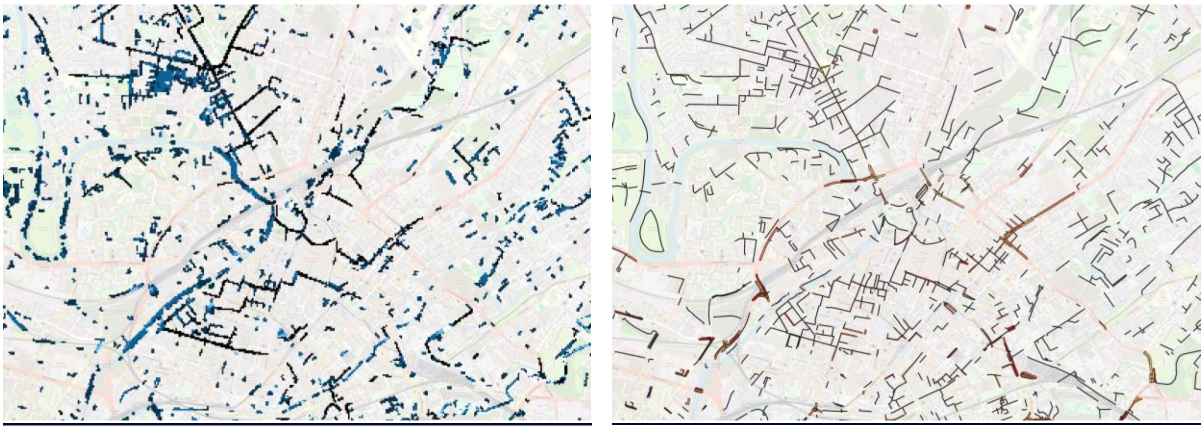

Figure 1 - Flooded areas (left) and disrupted road segments (right)

Preliminary findings

Findings can be summarized as follows:

a) ABM are particularly suited to capturing complex interactions between the road network and people's micro-scale behaviours. We can assess the transport system's ability to recover as flooding progresses.

b) Low-intensity flooding, in conjunction with normal traffic congestion, may result in significant effects such as increased travel time and reduced accessibility. The preliminary results for Greater Manchester demonstrate the average travel times for three scenarios: the base case, the scenario with the early warning system, and the scenario without the early warning system. The base case shows an average travel time of 22 mins. The average travel time with the early warning system increases slightly to 27 mins, reflecting a relative increase of 22.2%. In contrast, the average travel time for the scenario without early warning is much higher at 49 mins, resulting in a relative increase of 123% compared to the base case.

c) Early warning system provides a significant reduction in travel time, translating to time savings in the order of 45.4% (average delay of 22 mins avoided) when compared to the scenario without the system, offering clear benefits in terms of efficiency and reducing delays. People take detours and reach their destinations with only minimal increases in travel time.

Discussion

The agent-based modelling framework developed here is particularly useful for testing various adaptation strategies to transition towards more resilient future transport systems under different extreme event scenarios driven by climate change. The model integrates both the demand side (passenger and freight demand) and the supply side (multimodal transport network) of the transport system. In this early study, we tested a behaviour-based adaptation strategy that consists of implementing policies that take population early warnings into account, allowing them to anticipate incoming flooding and make appropriate decisions to mitigate the impact. The high spatiotemporal resolution of the model — with individuals/vehicles moving around the network — allows for the testing of fine-grained adaptation options, such as changes to specific road links or the reallocation of geographically at-risk population groups. The model can also identify vulnerable population groups and evaluate accessibility to urgent services during disruptive events, such as floods.

Next steps

We aim to make further extensions to the model to address resilience and adaptation. These extensions will help us better understand how the system can withstand and adapt to future challenges, particularly those posed by climate change and extreme events.

In the short run, the next steps of the research focus on testing the resilience of the public transport systems. This will help us evaluate its role in maintaining a sufficient level of service, especially when people rely on these modes of transport.

In the medium/long run, we aim to develop a set of accessibility models to understand if population groups continue to have access to critical destinations, such as healthcare. Additionally, we plan to test other types of policies, such as reallocating households from areas at risk in order to mitigate flood exposure. Finally, we intend to investigate the effects of increased urbanization and its role in amplifying future flood risk.

References

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