Method for cascading effect analysis in flooding events

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ABSTRACT
A method is presented aiming at enabling more holistic flood risk management efforts by accounting for cascading effects that arise in critical infrastructure and vital societal functions in flooding events. The method is under development but shows promise in guiding national, regional and local risk management efforts in Sweden towards flooding events.

1 INTRODUCTION

Flooding events in urbanised areas tend to lead to high direct consequences for the population and the environment, but also to high indirect consequences in the society if vital societal functions and critical infrastructures are affected [1-3]. Hence, through the European Commission's Flood Directive, all member states in EU are required to develop Flood Risk Management Strategies. In Sweden, this is currently done through flood hazard mapping and spatial analysis of flood-prone areas in two stages. The first stage includes identification and analysis of flood-prone areas at the national level. The second step consists of identifying, e.g. people, critical infrastructure, buildings and land that would be affected by the flood. These two stages are then followed by a consequence analysis at local and regional levels.

The identification of vital societal functions or critical infrastructures within a flood risk area is of importance, but not sufficient. It is also of necessity to be able to describe the impact on the society. In Sweden, this is currently focused towards analysing only the direct consequences. Several studies have, however, shown that consequences by floods are not restricted to inundated areas (see, e.g. [2-3]) but so-called indirect effects also tend to aggravate the consequences heavily. These indirect effects are due to the existence of functional and logical dependencies between critical infrastructures and societal functions.

To be able to take these indirect consequences of floods into account, it is necessary to perform more detailed studies of the infrastructures and vital societal functions that can be affected, the consequences that arise, and how other infrastructures or societal functions are dependent upon them. The aim here is to present a method under development and some preliminary findings aiming at capturing these direct and indirect consequences. The method is developed in cooperation with the Swedish Civil Contingencies Agency, Swedish county boards and municipalities.

2 BACKGROUND

Past events have shown that flooding impact society beyond the direct water damages, both in Sweden (e.g. [4]) and internationally (e.g. [2]). As a consequence, researchers have been trying to find ways to account for dependencies in various risk management contexts. To account for dependencies is most commonly done through consulting experts on the studied systems (e.g. [5-6]) or by utilising more detailed models and simulation approaches (e.g. [7]). The applications of Geographical Information Systems (GIS) have expanded with the increased computing power during the last decades [8]. Flood risk management is one of the areas where GIS have proven to be useful, in particular for representing the results of flood models, the effects of different mitigation measures and supporting decision making [9].

3 DEVELOPED METHOD

The method aims to be used within existing risk management processes in municipalities and regional county boards, by providing a structured way of gathering relevant data for assessing direct and indirect societal consequences due to flooding events. To enhance decision support, the data is further collected so that it can be analysed and presented in an aggregated form using GIS. The method has been developed in the context of flooding but is also aiming at being applicable for other types of events, such as storms and landslides.

Once an event has been selected, the method consists of three overarching steps: a direct and indirect consequence analysis of affected critical infrastructures and societal functions, structuring this data into a database for aggregation purposes and lastly performing an aggregated geographical analysis. It thus is a mixed-method approach, including expert-based questionnaires, databases and GIS technology.

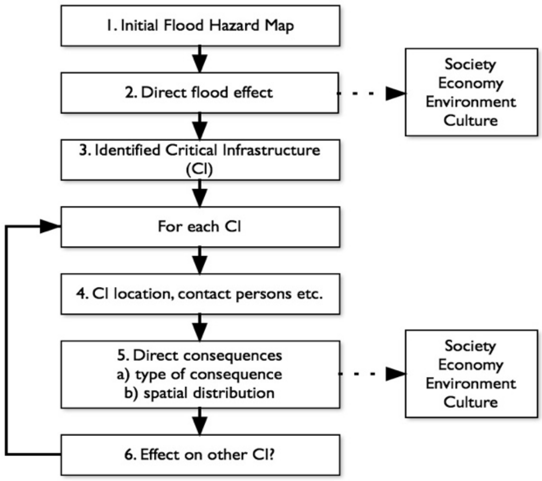

Figure 1. Overview of the workflow.

An overview of the workflow of the suggested method can be found in Figure 1 and is described shortly here. 1. The initial consequence analysis can take input from for example national flood risk maps or existing risk and vulnerability analyses. 2. In general, these tend to focus only on the direct flood consequences. 3. Critical infrastructure and vital societal functions within the flooded area then need to be identified and be the subject of further study. 4-5. Through a questionnaire, risk managers can summarise local expert knowledge concerning direct and indirect consequences, the spatial extent of these consequences, estimated downtime and suggested mitigation measures along with other useful information such as responsible organisation and contact persons. 6. Newly detected dependencies should be analysed in at least one additional round of consequence analysis and be added to the database.

With a finalised database, the aggregated data is used for more holistic GIS-oriented consequence analyses. A layered geographical analysis of all the direct and indirect consequences reveal the spatial extent and areas with high concentration of consequences. Additionally, this also helps in identifying potentially other indirectly affected critical infrastructures or societal functions. The geographical visualisation of the consequences aids decision-making processes, in particular when communicating risk between different stakeholders [5].

4 INITIAL CONCLUSIONS

From document reviews and the workshops we have conducted in the study, we conclude that current risk and vulnerability analyses in Sweden very rarely identify or account for indirect consequences concerning flood risk.

While the suggested method is under development, initial responses from respondents reveal that it would offer meaningful and much needed support for municipalities and counties when performing consequence analyses, by in a structured way taking into account both direct and indirect consequences. It does require public-private cooperation, not always straightforwardly established, as a significant share of critical infrastructures is owned and operated by private entities. However, having structured and guided questions to ask critical infrastructure owners and better arguments of the necessity of the data are argued to be helpful in this aspect. The next step is to deploy the method in a case study for a specific municipality to validate the method further, evaluate the results, and suggest an approach for the aggregated GIS-analysis. At the conference, further concrete details and results will be presented.

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REFERENCES

[1] Espada, R. J., Apan, A., & McDougall, K. (2015). Vulnerability assessment and interdependency analysis of critical infrastructures for climate adaptation and flood mitigation. International Journal of Disaster Resilience in the Built Environment, 6(3), 313–346.

[2] Haraguchi, M., Haraguchi, M., Kim, S., & Kim, S. (2016). Critical infrastructure interdependence in New York City during Hurricane Sandy. International Journal of Disaster Resilience in the Built Environment, 7(2), 133-143.

[3] Simpson, D. M., Lasley, C. B., Rockaway, T. D., & Weigel, T. A. (2010). Understanding critical infrastructure failure: Examining the experience of Biloxi and Gulfport, Mississippi after Hurricane Katrina. International Journal of Critical Infrastructures, 6(3), 246–276.

[4] Arvidsson, B., Johansson, J., Hassel, H., & Cedergren, A. (2015). Investigation method for cascading effects between critical infrastructures. European Safety and Reliability Conference (ESREL2015), Zürich, Schweiz.

[5] Chang, S. E., Mcdaniels, T., Fox, J., Dhariwal, R., & Longstaff, H. (2014). Toward disaster-resilient cities: Characterizing resilience of infrastructure systems with expert judgments. Risk Analysis, 34(3), 4164(3),

[6] Toubin, M., Serre, D., Diab, Y., & Laganier, R. (2012). Brief communication 'an auto-diagnosis tool to highlight interdependencies between urban technical networks'. Natural Hazards and Earth System Science, 12(7), 2219–2224.

[7] Johansson, J., Hassel, H., Svegrup, L. (2016) 'Capturing Societal Interdependencies from a Flow perspective – Part I: Method and Model, in Proceedings of the 26th European Safety and Reliability Conference (ESREL2016), Glasgow, Scotland.

[8] Longley, P. (Ed.). (2011). Geographic information systems & science (3. ed., fully updated). Hoboken, NJ: Wiley.

[9] Pender, G., & Néelz, S. (2007). Use of computer models of flood inundation to facilitate communication in flood risk management. Environmental Hazards, 7(2), 106–114.