Large-scale Multi-Modal Evacuation Analysis with an Application to Hamburg

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Evacuation is one possible option when facing natural or man-made risks. The evacuation of a building block, part of a city, or even a whole city or reagion is a far-reaching measure, though. Therefore, it is usually also the last measure and only taken when a social catastrophe is impending. The city of Hamburg was hit by flooding in 1961. The homes of 50,000 people were destroyed and a total of 315 persons died. The situation today is not comparable to the situation in the early 1960s. Back then, many buildings were still barracks and built or repaired just after world war II. These few considerations show the complex context, in which decisions about evacuations are made. In order to reduce the complexity for the decision makers simulations for the prediction of evacuation times and potential congestion or delays are one option. They can provide objective criteria and make the consequences of certain alternatives more intuitive by visualizing them based on well-known representations of the city like street maps.

In this paper we will present results on a microscopic evacuation simulation combined with different calculations for the evacuation time. Four different modes of transport are taken into account: walking, busses, railway, and cars. In detail: walking to shelters, walking to bus and train stations, bus shuttle and local trains, and finally motorized individual transport by car. The major result is a range for the evacuation time. It is in the order of three to four hours which fits into the overall time-frame of nine hours for the total time availale (i.e., the available safe evacuation time ASET). ASET consists of three hours for preparation and warning, four hours for evacuation, and two hours as buffer. ASET must be larger than the required safe evacuation time (RSET), which is in our case determined by the simulations and calculations.

The Available Safe Egress Time (ASET) is limited first of all by the external risk. In our case, the external risk is flooding. To be more specific: we assumed a leakage of one of the dams. Hydrological and hydrodynamic simulations are routinely performed by the civil defense authorities in Hamburg. On that basis, a detailed plan exists, providing warning times and a time schedule for a large-scale evacuation. The overall schedule is 9 hours, for observation and warning there are 4 hours and 1 hour, respectively. Therefore, the current time frame for individual preparation and movement is four hours.

Pre-movement or pre-evacuation time
When assessing evacuation processes, many different phases of information gathering, decision making, communication, and feedback collection have to be taken into account. These phases are to some extent overlapping. In general, the overall time can be divided into the following parts:
Evacuation Time = Detection + Decision + Alarm + Individual Preparation + Movement

One major uncertainty is the individual preparation time. It might be influenced by the warning mechanisms and messages. For a different case study, the Indonesian city of Padang, up to 50% of the population stated they would stay in place in case of a Tsunami warning (Taubenboeck2009).

Warning mechanisms
There is a plethora of warning mechanisms planned for this evacuation scenario, ranging from radio messages and SMS to canon-shots, sirens, individual phone calls, etc. Details are given in (HPA2011, in German) and BSI2011 (in German).

Places of refuge
The safe places are within the evacuation area as well as outside. In Hamburg-Wilhelmsburg, places of refuge are either higher floors of private buildings or public buildings prepared as evacuation shelters. The places of such shelters are shown in the warning brochure distributed to all inhabitants (see figure).
Further places of refuge are outside the evacuation are requiring transportation. Several modes of transport are employed: motorized inidividual, bus shuttle, and local trains (S-Bahn).

Simulation Modell
This paper presents results on the simulation of the evacuation of Hamburg Wilhelmsburg. In the simulation, 25,000 agents were distributed in the area of the Elbe island, where Wilhelmsburg is located. The model used is MATSim (www.matsim.org). The simulation was part of a comprehensive assessment taking into account public transport (by local trains and busses), foot traffic to shelters, and motorized individual traffic on the one hand. On the other hand, capacities of shelters and infrastructure, first responders, and information dissemination were taken into account. The traffic simulation module was used to determine the overall evacuation time for motorized individual traffic. Since the movement to shelters and the transportation by public transport (local trains and busses) is independent thereof, the maximum of the times for the different evacuation modes can be considered the overall evacuation time.

First Results
In the scenario analyzed an advance warning of 3 hours was assumed. This time is also used for the preparation of the emergency and rescue service. For motorized individual traffic the overall evacuation time is less than 90 minutes. However, the transportation by public transport takes about four hours, which uses up the available safe evacuation time given local authorities. The service times for the public transport evacuation was based on an evacuation exercise performed in Cologne. In order to improve the situations an increase of the available transport infrastructure (i.e. number of busses/ trains) or a more effective usage of the existing transport infrastructure is needed. This would mean to increase the number of persons per bus or train. It has to be noted that the number of persons per bus was less than 20% as under normal conditions. This is due to the extensive amount of luggage carried by the evacuees.

Further Steps

The results presented here are embedded into a larger context, which is the GRIPS research project. More details about GRIPS are given by Walencial et. al. (in these proceedings).

References

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