NUMERICAL LAST-MILE TSUNAMI EARLY WARNING AND EVACUATION INFORMATION SYSTEM ("LAST-MILE – EVACUATION")

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ABSTRACT: The structure and aims of the joint research project "Numerical Last-Mile Tsunami Early Warning and Evacuation Information System ("Last-Mile – Evacuation)" is introduced in this paper. The prospective goals are highlighted in consideration of the organisational structure consisting of academical and industrial research partners. The joint research project focus on highly resolved geodata and earth observation techniques in order to accurately simulate wave dynamics, run-up and onland flow. Finally in-depth recommendations on evacuation procedures might be available in the future for the city of Padang based on the hydrodynamical studies and evacuation simulations. The presented results in this paper underline the effectiveness of the interdisciplinary work.

1. INTRODUCTION

The joint research project funded by DFG/BMBF (Sponsorship code: 03G0666A-H) develops a numerical last-mile tsunami early warning and evacuation information system on the basis of detailed earth observation data and techniques as well as unsteady, hydraulic numerical modelling of small-scale flooding and inundation dynamics of the tsunami including evacuation simulations in the coastal hinterland for the city of Padang, West Sumatra, Indonesia. The joint research project is composed of five working packages, based on field expertise of each working partner, namely socio-economic vulnerability assessment (WP 1000), inundation scenarios, flow analysis (WP 2000), geodatabase, information system and vulnerability assessment (WP 3000), evacuation analysis and pedestrian traffic optimization (WP 4000) and highly-resolved 3D-model of Padang (WP 5000) . The project has accomplished its first project year. In the following sections, the actual progress of each working package is briefly explained.

2. WP 1000: SOCIO-ECONOMIC VULNERABILITY ASSESSMENT

In order to ensure a people-centred tsunami early warning and evacuation information system, focusing on reducing vulnerability to tsunami risk, a socio-economic vulnerability assessment is conducted. It particularly aims at identifying the vulnerable areas to potential threat to life and livelihoods due to tsunamis where spatial planning measures (such as evacuation shelters, coastal protection zone and structures) are necessary.

2.1 Vulnerability indicator framework

Starting with the definition of vulnerability "….The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards; for positive factors, which increase the ability of people to cope with hazards..." [UN/ISDR, 2004] and based on the concept of vulnerability delineated in the BBC-Metaframework [See Birkmann, 2006], a vulnerability indicator framework should be structured. In close cooperation with the GITEWS WP 4000, an indicator framework following the tsunami early warning chain (exposure – receiving and understanding the warning – evacuation decision and behaviour – evacuation capability – emergency relief and rehabilitation) was developed as an orientation to analyse the functionality between early warning technology, social capacity and information for decision making process in a systematic manner [Gebert, 2007].

In scope of "Last-Mile – Evacuation", the WP 1000 focuses on the following research questions of the indicator framework:

1. What are the socio-economic factors that determine the exposure of the people (and critical facilities) to potential tsunamis?
2. To what extent are the people and various social groups in the position to conduct an evacuation appropriately (determinants for evacuation time, bottlenecks of evacuation) and what are the most influencing parameters?

The results of the analysis should be displayed as a spatial distribution of the socio-economic vulnerability to support the identification of hotspots in the sub-districts of the city of Padang.

2.2 Questionnaire-based household and critical facilities survey

Due to the fact that the existing statistical data are insufficient for a detailed vulnerability assessment, an additional survey was conducted. A set of questionnaires for households and various critical facilities was developed in consultation with the local partners. The questionnaire was structured according to the indicator framework. A sample of 1000 household (of which about 935 households responded) were selected using a combination of stratified and purposive sampling in order to cover representative socio-economic and physical characteristics (in cooperation with WP 3000). In addition, more than 200 critical facilities were also surveyed. In close cooperation with the Social and Politics Faculty, University of Andalas (Padang), the survey was conducted from April 28 until June 25, 2008.

2.3 Interim results of the household survey

In general, the socio-demographic profile (such as gender, age, religion, proportion of migrants, education attainment and job sector) of the sampling households is proven to be representative for the socio-demographic profile of the whole district (city of Padang).

2.3.1 Exposure to tsunami risk

The main activities of the female population with the highest proportion are household work (28%) and working (28%), while for the male population is working permanently (39%) in various job sectors, which shows already that the mobility pattern of the female population is more static. The predominant job sector for the whole population is accommodation/transportation and trading (total percentage of 66%), the sector that many households also perform at their houses (mixed uses). From the survey, it was found that about 1/3 of the households use their dwelled houses for own businesses. For the daytime-specific evacuation modelling, such characteristics should be considered for determining dynamic population distribution. More detailed information on the activity pattern of the respondents are also obtained will be used as inputs for the evacuation modelling in WP 4000.

2.3.2 Evacuation experience

From the experience of past strong earthquakes (particularly in September 2007) and warning for a potential tsunami in Padang, it was found out that 65% of the respondents who received a warning of potential tsunami did not evacuate (Figure 1), mostly due to doubt on the warning or thought that it was only an alert warning. From about 35% respondents who evacuated, merely 13% performed immediate evacuation while more than 40% answered that they either gathered the household members, collected important items at home and/or securing the house before evacuated. This finding also confirms the finding of a small-scale study conducted by GTZ in Padang that the warning provided was not perceived as information about an imminent threat which requires immediate reaction (GTZ 2007). Delay in evacuation should be taken into consideration, since most of the households would take some time before starting to evacuate. With regards to the evacuation conduction, most of the respondents (75%) evacuated with the family members and the predominant evacuation places are places or friends/relatives´ house located on the higher ground (73%), while buildings for vertical evacuation were not yet favourable option (20%).

2.3.3 Evacuation intention

In addition to the patterns derived from evacuation experience, the respondents were also asked about their intended behaviour in future potential earthquake and tsunami warning. Regardless of their behaviour in the past experience, 37% of the respondents intend to gather their family members and evacuate directly after a strong earthquake and 64% intend to do so after receiving a tsunami warning. It is to emphasize that most of the respondents intend to evacuate together with the family members no matter how long it takes. Moreover, as found previously from experience, higher ground was also rated the highest as a place perceived safe for evacuation destination (72%), and to some extent also the closest high buildings (32%).

2.3.4 Evacuation capability

The demographic profile plays definitely a significant role in determining the evacuation speed and it highly depends on the population distribution on the specific daytime / weekday, which composition of population would exist. Taking into consideration that most of the people intend to evacuate only together with their family members, it is important to examine the household profile. Although most of the households thought that they would need time less than 30 minutes before starting to evacuate (as well-known estimated arrival time of tsunami after a strong earthquake), Figure 2 shows that the estimated time needed of longer than 30 minutes could be more likely the problem for the household with children and elderly. For the estimated time of reaching any evacuation place, some other variables were taken into consideration:

1. knowledge on evacuation places and routes
2. participation in tsunami simulation
3. availability of vehicles

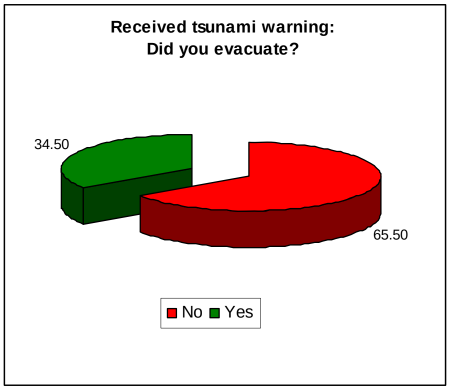

Figure 1: Proportion of respondents who evacuated after receiving a tsunami warning

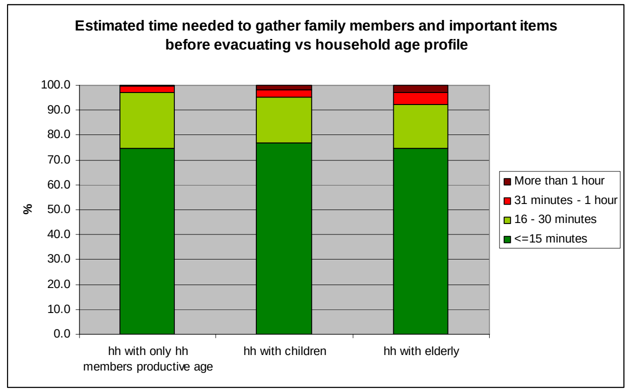

Figure 2: Estimated time to gather family members and collect important items by household age profile

Most of the respondents knew the location of higher buildings or higher ground and how to reach there based on their own knowledge (more than 70%), but about 50% did not know the evacuation areas and routes designated by the government or did not understand evacuation signs placed along the main streets. It needs to be examined, whether the routes and places that the people know are appropriate for evacuation. Moreover, only 10% of the respondents have participated in evacuation simulation. With regard to potential vehicle use, the majority of the households possess motorcycle (67%), while only 22% have cars. Motorcycle would most likely be vehicle that would be used in case of evacuation.

2.4 Conclusions and next steps

In order to develop realistic evacuation scenarios, dynamic population distribution has to be included (WP3000). At the next stage, multivariate analysis will be done for various sub-sets of variables related with specific research questions. The correlation of specific vulnerability indicators with general socio-demographic indicators will be assessed, as well as to examine how to generalize the results for the whole district. Based on the further analysis, indicators related with evacuation analysis such as evacuation participation rate, evacuation mobility, intended evacuation behaviour as well as possible evacuation scenarios will be derived together with WP 4000. Moreover, linkage between various physical and socio-economic characteristics of the house (households) will be explored in cooperation with WP 3000.

3. WP 2000: TSUNAMI INUNDATION SCENARIOS

The vastly exposed urban coastal agglomeration of Padang, West Sumatra, Indonesia, has recently been taken into consideration for further evaluation and risk assessment to the potential threat of tsunamis due to the amplified risk of future earthquakes in this region (McCaffrey 2007), aiming at improved recommendations on evacuation routes. The present work comprises hydrodynamic simulations of the inundation dynamics of a Tsunami in the urban coastal hinterland of Padang, Western Sumatra for the computational domain sketched below.

We considered two digital elevation models (DEM) for the conducted simulations differing basically from the spatial accuracy and resolution of the underlying geodatabase. The first DEM consists of coarsely resolved and adjusted SRTM topography and digitised nautical chart bathymetry. The second one is build from highly resolved HRSC topography and newly surveyed multibeam bathymetry. Looking at cross sections of both DEM, relative differences of up 25% are obvious between the two geometries. The primary advantage of the higher resolution is that infrastructure and buildings are captured adequately. We found notably differences in height of both topography and bathymetry that influence the results of our numerical models significantly.

3.1 Model setup

We have chosen a hybrid approach where we coupled two numerical models in subsequent steps. At the first step, the ocean-wide Tsunami propagation was modelled using TsunAwi (Harig et al. 2007). Based on that results delivered from AWI, Bremerhaven, we secondly interpolated the results to our boundary. The hydrodynamic inundation modelling tool used for the detailed near-shore simulation is constantly developed by the Australian National University and Geoscience Australia (ANUGA). Some features are:

- Nonlinear shallow water wave equations (Nielsen et. al. 2005), solved by finite-volume method
- Flexible mesh capabilities
- Robust wetting and drying algorithm allow modeling run-up, overtopping and inundation

The two compared model domains comprise between 400000 to 550000 cells with areas ranging between 3 - 2000m².

3.2 Results

Initially the comparison of both results originating from the different geometries shows diverse inundation pattern. Inundation at similar time-steps for different DEM varies in time and space. It is obvious, that by considering finer geometry, inundation is delayed and retarded. Differences in run-up for a particular time-step of e.g. 2040s vary from 50m to 200m.

The two figures below illustrate maximum inundation for both geometries. Here differences in run-up are even more significant, ranging from 100m to 670m. The higher resolved geometry leads to a more uniform flow pattern whereas the coarser geometry affects areas to be inundated more easily. We found a noticeable time shift for the wave arriving at a distinct point of a few hundred seconds as well. This time shift is essential for further steps in evacuation planning process. Thus an improvement in terms of accuracy leads to a deeper insight into inundation dynamics. Streets which are already flooded and therefore inoperative as evacuation route to a distinct time-step arise to be longer effective when we modelled the same process with higher accurate spatial database.

Additionally we compared time series at two different locations in the computational domain shown above. For the A. Yani street gauge we detected higher values for velocity as well as flow depth, when running the simulation with higher resolution and accuracy.

This effect is mainly caused by friction and energy dissipation induced by infrastructure represented in the highly resolved DEM. Furthermore, this implies higher water stages near the coast and significantly higher velocities in the streets. By contrast this effect is absent at the flood relief channel where the quantities of velocity and flow depth are almost similar.

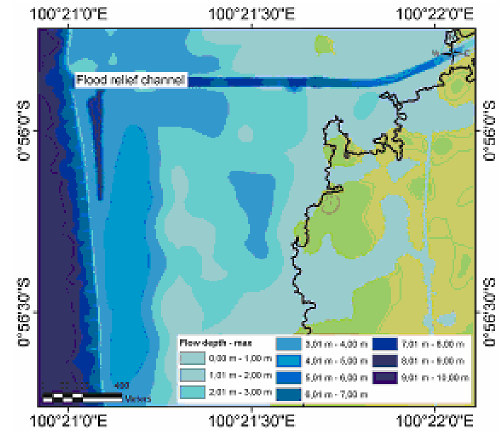

Figure 3: Maximum inundation for the coarse DEM at t=2520 sec., black line indicates inundation limit of high resolved DEM

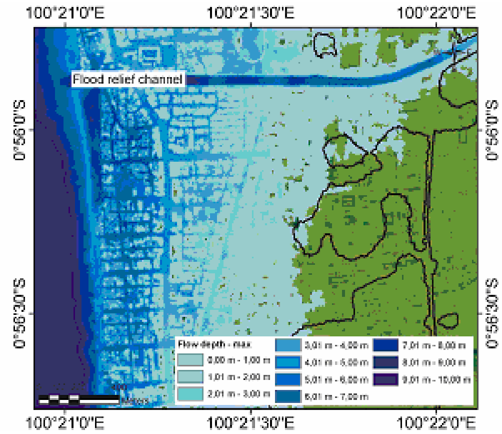

Figure 4: Maximum inundation for high resolved DEM at t=3030 sec., black line indicates inundation limit of coarse DEM

3.3 Conclusions

Accuracy and resolution of digital elevation models used for small-scale hydrodynamics is a crucial component when detailed information about inundation dynamics and evacuation routes are needed. Hence, there is an urgent demand for highly resolved data when detailed information about evacuation routes is requested. Modelling efforts for coastal areas around the world would highly benefit from improvements in spatial database.

4. WP 3000: CONTRIBUTION OF REMOTE SENSING TO A COMPREHENSIVE EARLY WARNING CHAIN

Remote sensing is one scientific field contributing to a comprehensive early warning chain for a potential tsunami event in Padang, West Sumatra, Indonesia. Efficient risk and vulnerability management and an accordingly substantial urban planning need precise, up-to-date and area-wide spatial knowledge on the urban situation. We used multi-sensoral remotely sensed data to provide a highly detailed city model as information basis for planning of field surveys, physical vulnerability analysis, socio-economic analysis (WP 1000), the analysis of interactions of simulated tsunami impact (WP 2000) and evacuation planning (WP 4000). To ensure substantial collaboration within the project partners a data exchange platform has been setup.

4.1 Urban city model

A substantial information basis on the urban landscape of Padang is the foundation for any subsequent analysis. Therefore a highly detailed urban city model was derived based on multi-sensoral data sets. First of all, high resolution optical satellite data (Ikonos) with a geometric quality of 1 m for the panchromatic band served as basis to extract urban land-cover. The combination of an automatic object-oriented, hierarchical classification methodology (Taubenböck & Roth, 2007; Kass et al. 2007) and subsequent manual enhancement resulted in a classification accuracy of about 97 %. This product displays essential basic information to know 'what' is 'where' in the city of Padang. The results are eight classes mapping the urban structure—houses, streets, sealed areas, grassland, trees, wetland, bare soil, and water. For the generation of a city model parameters defining the urban objects have been added. In particular building sizes were calculated as well as building height, which was inferred from the correlation of the house and the corresponding shadow length. Utilizing the field work experience land use was assessed as an additional feature of every building, basically differentiating between residential, mixed and commercial usage. The orographic condition of the urban region of

Padang utilizing the digital elevation model (DEM) from the Shuttle Radar Topography Missions completes the urban environment of the coastal city of Padang. Thus, a three-dimensional city model displays the complex, heterogeneous and fine-scale urban morphology and urban land use in a very detailed manner. Figure 5 shows a perspective view on urban city model of Padang.

4.2 Surveys

WP 1000 developed a standardized questionnaire to derive information on physical features of the buildings, the function of the building as well as demographic information and socioeconomic parameters of the people living there. Based on the results of the physical city model the surveyed buildings were selected by reason of different attributes to cover the spatial and thematic spectrum of urban morphology. With respect to the geographic location and the physical building types remote sensing results supported the selection of 1000 individual buildings for the survey, which was conducted in spring 2008.

4.3 Continuative Results

The city model is basis for a detailed vulnerability assessment with respect to a possible tsunami threat. In a first step correlation of urban morphology with population distribution has been calculated. On the basis of the punctual population data collected through the survey, the mathematical concept relies on the correlation with urban morphologic parameters. Utilizing the building size and its particular height living spaces are calculated. Thus, calculation of average number of inhabitants per m² is derived based on 1000 surveyed sample buildings distributed around Padang. The mathematical concept of bottom-up extrapolation has been presented in detail by Taubenböck et al. 2007. A linear extrapolation algorithm projects the people proportionally to the living spaces of the particular house. In addition the detailed knowledge on the usage of the buildings is at hand. Thus, the bottom-up extrapolation algorithm is calibrated on the different utilization of the buildings –residentially or commercially used – with respect to the time of day. The result is a highly detailed knowledge on the dynamic spatial behaviour and whereabouts of people within the complex urban landscape. Figure 6a provides an overview on population distribution on building level. Figure 6b and 6c display the dynamic spatial shift of population per building for a small detail of central Padang.

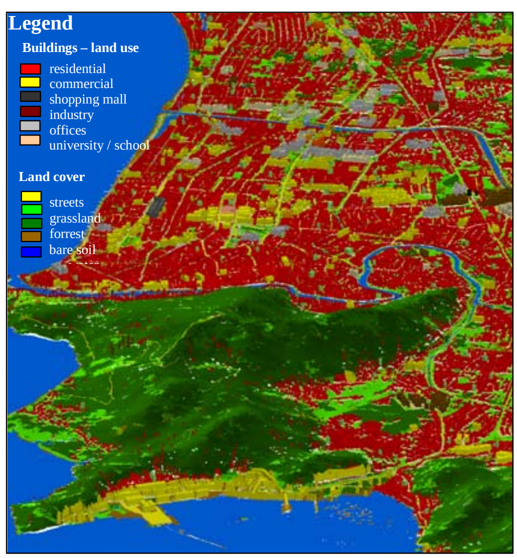

Figure 5: City model of Padang derived from high resolution satellite data and digital elevation model utilizing Shuttle Radar Topography Mission (SRTM) data

A second step was the analysis of safe areas for evacuation in case of a tsunami impact. Conditions for classification of safe areas were various parameters. The distance to the shoreline in combination with the DEM as well as appropriate land-cover enables to infer from multi-sensoral remote sensing results a spatial pattern of safe areas as well as risk zones, crucial for evacuation. A third step is the analysis of vulnerability (stability) of structures. A correlation method of surveyed building stability with urban morphologic parameters, like height, size, roof type or orientation is on the works. The objective is extrapolation on the complete building stock of Padang to identify safe structures for vertical evacuation. In addition the correlation of socioeconomic analysis (WP1000) with spatial pattern of urban morphology is promising for localisation of differently vulnerable groups of people. The knowledge of population distribution in combination with the street network and location and size of safe areas serves as information input to model evacuation scenarios with respect to the time of day (WP4000). Furthermore the city model supports to simulate the impact of different tsunami scenarios (WP2000).

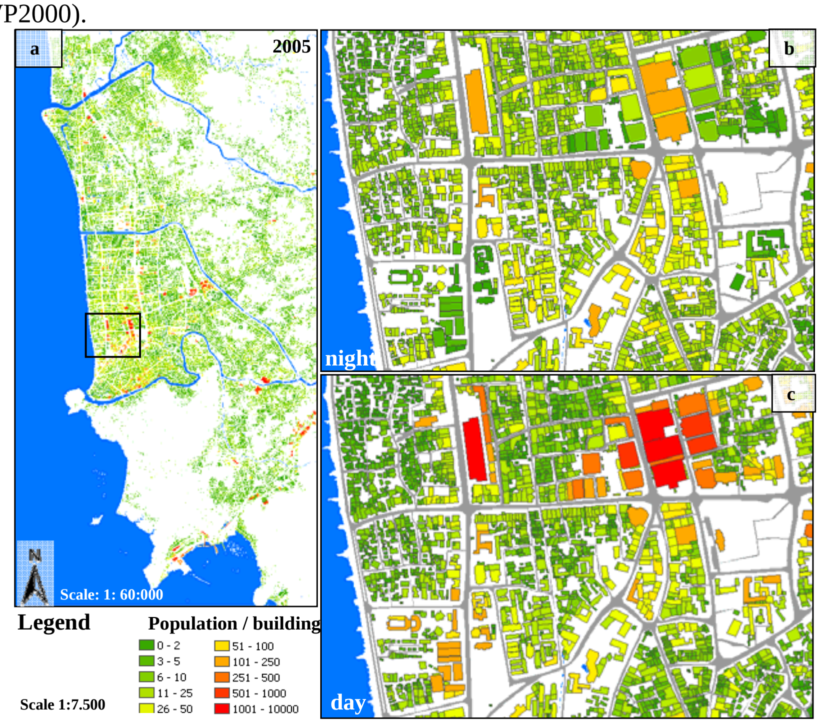

Figure 6: Population distribution on building level

5. WP 4000: EVACUATION SIMULATION

Disaster and evacuation planning has become an important topic in science and politics. In general, especially in the case of a tsunami, the advance warning time is only 20-40 minutes. This makes the evacuation duration an important aspect of disaster management. Even if not all of the estimated 1,000,000 inhabitants of the city of Padang need to be evacuated, the number of evacuees could be hundreds of thousands. Therefore, a detailed analysis of aspects that could influence the evacuation process is necessary. With this analysis it should be possible to:

- Give an estimate of the evacuation time.
- Detect bottlenecks that could for example emerge at bridges.
- Identify highly endangered areas, where a vertical evacuation seems the only way.

From these results, it is planned to derive evacuation recommendations. This could include evacuation maps telling the people where to flee to, or recommendations where to build tsunami proof shelters. Because of the complexity of the system, an analytic solution to the evacuation problem is not possible. Therefore a microscopic multi-agent simulation for the city with all its inhabitants has been developed. With this simulation, it should be possible to get an estimate of the evacuation process.

5.1 Input Data

There are several requirements that have to be met to get a realistic simulation. The simulation needs to reflect the socio-economic profile. This means that information about the distribution of the population as a function of time is needed. Since there is no detailed behavioural information for the complete population, the time dependent distribution will be estimated based on activity chains of a sample of about 1,000 persons that took part in a household survey in April/Mai 2008 conducted by WP 1000. From this data, a synthetic population with complete day plans will be generated. Currently, the generation of the synthetic population is work in progress. In the mean time, we stick with a simple base case. It is assumed that all people are at home. This scenario is also called "evacuation at 3 a.m.". The needed information has been derived from existing census data.Another important aspect for the evacuation is information about potential flooding scenarios. The development of those flooding scenarios is part of the "Last-Mile" research project (WP 2000). There is a mechanism to integrate these results directly in the evacuation simulation. For the physical simulation of the evacuation procedure a detailed picture of geographic structure of the city is used. This information has mainly been extracted from satellite imagery by detecting all the workable area in a first step and generating a network from this afterwards (WP 3000). The network not only includes streets but also sidewalks and squares. However, not all the needed information could be extracted automatically. For example it is almost impossible to detect obstacles like fences and the like from satellite images. Therefore, we conducted a field-trip to take geo-encoded pictures from different places where bottlenecks during evacuation could emerge. With these pictures, we can estimate the accessibility of potential areas of refugee.

5.2 Multi-Agent Simulation

The evacuation simulation is based on the MATSim (multi-agent traffic simulation www.matsim.org) framework, where each evacuee is modeled as an individual agent. The underlying flow model simulates the traffic based on a simple queue model where only free speed, storage restrictions, and bottleneck flow capacities are taken into account. The queue simulation, albeit simple, captures the most important aspects of evacuations such as the congestion effects of bottlenecks and the time needed to evacuate the endangered area. During a simulation the agents make independent decisions about escape routes or when to evacuate (i.e. their individual response times). Consequently, the evacuation for every single agent is modeled separately and will be stored in a so-called plan containing the starting time and the evacuation route. All agents' plans are simultaneously executed in the simulation of the physical system. After a simulation run is finished the agents can revise their plans (i.e. they can generate new plans or select other plans out of their memory). After replaning, a new simulation run with the new plans will be started. Based on iterated learning, the agents' behavior will move towards a Nash equilibrium.

5.3 Simulation Results and Recommendations

The results of the simulation are an estimation for the occurrence of bottlenecks and the overall evacuation time. A major determinant for the overall evacuation time is the number and place of shelters and places of refugee. In the simulation, these as sinks. Different to the natural places of refugee like hills, the number and place of shelters (including buildings used as shelters like concrete multi-storey buildings) can be influenced by the administration (and potentially the city's inhabitants and especially owners of buildings). Therefore, a second strategy within "Last-mile" (next to providing information and guidance on evacuation strategies) is to provide recommendations on the number and place of shelters and to identify buildings and recommend their use as shelters.

5.4 Identification of Shelter Location

If the overall evacuation time for the situation as it is, exceeds an agreed maximum time (i.e., acceptance criterion), one possible strategy is to place shelters at locations identified on the basis of simulation results. Next to bottlenecks, the walking distance to a place of refuge is the second major determinant for the overall evacuation time. Additional shelters will, by reducing this walking distance for persons living or working close to those shelter, also reduce the overall evacuation time, if provided for all evacuees having an individual evacuation time beeing "too large" (i.e., higher than the accepted time). Therefore, this seems to be a very promising strategy. The success of this strategy can be quantified by performing a simulation with taking the shelters into account.

6. WP 5000: VERY HIGH RESOLUTION TOPOGRAPHIC MAPPING OF DENSELY POPULATED COASTS IN SUPPORT OF RISK ASSESSMENT OF TSUNAMI HAZARDS IN INDONESIA

The evaluation of satellite imagery after the tsunami hazard of 2004 clearly showed that not all coasts were similarly affected. Along SE-Asian coasts were complex patterns of damage and the topography of the coastal flats was identified as one of the most important parameters influencing the degree of damage. High resolution topographic information derived from digital aerial imagery and digital surface models (DSM) represent a fundamental part of risk assessment and evacuation planning. The city of Padang on the Southern Shore of Sumatra, Indonesia, with approximately 1 million inhabitants, serves as a pilot test site. Padang is at imminent risk of potential tsunami disasters due to its geographic location at the Sumatra-Andaman-bend. A detailed evacuation plan is of utmost importance because a tsunami wave will hit the city within 15 minutes. In cooperation with the German Aerospace Centre (DLR), Remote Sensing Solutions GmbH (RSS) organized an aerial image flight campaign over Padang, covering about 120km2 in autumn 2007. The aerial survey was conducted with an advanced digital line scanner system "Multifunctional Camera" (MFC). The MFC is a follow on development to the High Resolution Stereoscopic Camera (HRSC) by the DLR. The MFC scans the surface in three different viewing angles that allow for the creation of high resolution color images (resolution of about 20 cm), and highly precise digital terrain models (DTM) by applying automatic photogrammetric processing techniques. The image data is then enhanced to a so-called "True-Ortho"-image with minimal geometric distortion.

The combination of the true color orthophotos and DSM allow for the creation of useful risk assessment and urban planning tools. RSS GmbH developed an advanced semiautomatic process chain in order to extract 3D buildings from DSM data and create three dimensional city models. The Franzius Institute (WP 2000) will use the topographic data and the 3D city model to perform hydrodynamic simulations in order to estimate the potential threat to different parts of the city and each of its buildings with different tsunami scenarios. These results are then used for evacuation planning. A web application will be developed in cooperation with the University of Bonn, which allows an interactive visualisation of the 3D city and the potential threats by tsunami waves. This application targets the use of spatial geodata within the Internet and visualizes interactively a high resolution city model including dynamic water levels, damage patterns, and evacuation scenarios. The information is scaleable and includes all relevant results of the project "Last-Mile". The application will be developed in close cooperation with the Indonesian Partner BPPT and will be bilingual, English and Bahasa Indonesian.

The results obtained so far demonstrate that the MFC System distinguishes itself by high flexibility due to its size, robustness and lightness. It can be applied within 24 hours globally; therefore, it forms a feasible tool for rapid mapping of hazard areas, as well an economic solution to derive previously unrepresented and accurate surface and digital elevation models, prior to disasters. The results may be viewable in 3D, interpreted by an interactive viewer, and accessible via the internet worldwide.

Figure 7: Aerial image mosaic of the city Padang with 20 cm resolution, acquired in November 2007

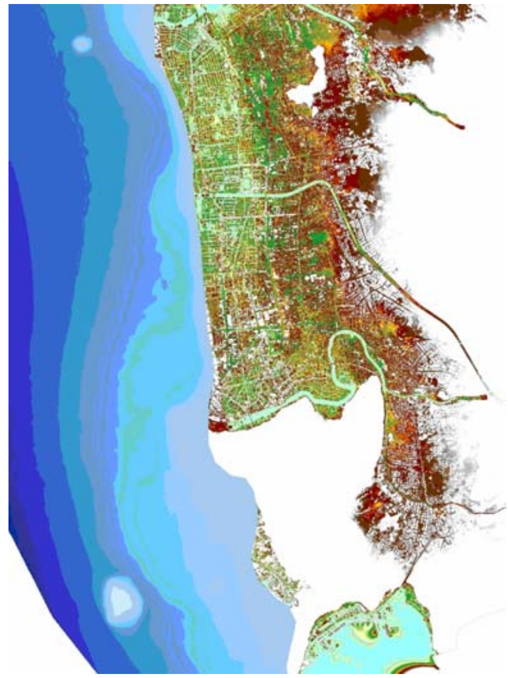

Figure 8: Surface model of the city Padang. Colors: areas below 5 m asl.

7. CONCLUSION

The project status of the interdisciplinary research project "Last-mile - Evacuation" is introduced according to the five major project partners. The presented results reflect the progress which was achieved during the first project year, but it should be emphasized that these results are still work-in-progress. Advanced information about the particular activities in the work packages could be found in the conference proceedings ("Socio-Economic Vulnerability Assessment at the local level in context of tsunami early warning and evacuation planning in the city of Padang, West Sumatra" by J. Birkmann, " Relevant factors on the extent of inundation due to Tsunami scenarios for the city of Padang, West Sumatra" by N. Goseberg and T. Schlurmann, "Multi-Scale Assessment of Population Distribution Utilizing Remotely Sensed Data The Case Study Padang, West Sumatra, Indonesia" by H. Taubenböck et al, " Preliminary Result of a Large Scale Microscopic Evacuation Simulation for the City of Padang in the Case of Tsunami" by G. Lämmel et al). A main finding is that interdisciplinary research teams could upgrade the quality of research in the complex field of risk assessment and disaster mitigation essentially.

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