A proposal for an integrated model of disaster management and socio-economic analysis

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1. Introduction

To contribute to urban resilience analysis, we pool the combined expertise of two research groups in Japan and Israel in order to develop a Dynamic Integrated Model for Disaster Management and Socio-Economic Analysis (DIM2SEA). Here we introduce the objectives, plan and expected outcomes of this project related to simulation, agent-based modeling and socio economic analysis for earthquake and tsunami disasters. The project has started on December 2015 (running until March 2019) under the Strategic International Collaborative Research Program (SICORP) sponsored by the Japan Science and Technology Agency (JST) and the Israeli Ministry of Science, Technology and Space (MOST). The vision of this research program is to increase urban resilience to large-scale disasters such as earthquake and tsunamis. This is achieved by harnessing state of the art developments in spatial analysis and Geographic Information Systems (GIS). In this project, we will combine dynamic agent-based simulations with the generation of synthetic big data such that every individual agent in the model has a socio-economic profile and an accurate spatial distribution. The generation of this detailed micro data from aggregate statistical information allows for the socio-economic analysis of populations at risk, social vulnerability and distributional effects of disasters at various spatial and temporal scales. The model can identify whether short run shocks have long term impacts and whether the urban system over time 'settles down' to a new equilibrium in the aftermath of a disaster and whether or not this equilibrium is stable. These features are critical in post-disaster recovery scenarios in order to *Build Back Better* and, therefore, increase urban resilience.

2. Objective

At the project we aim to develop a prototype of a Dynamic Integrated Model for Disaster Management and Socio-Economic Analysis (DIM2SEA) that will give disaster officials, stakeholders, urban engineers and planners an analytic tool for mitigating catastrophic events. In this paper, we aim to introduce the framework of our project and its components.

3. Methodology

The framework of the project is shown in Fig. 1. Four stages are schematically explained in the framework. The detail of each stage is explained in the next section. In addition, an overview of the expected workflow of the DIM2SEA model is shown in Fig. 2. As shown, the spatial database

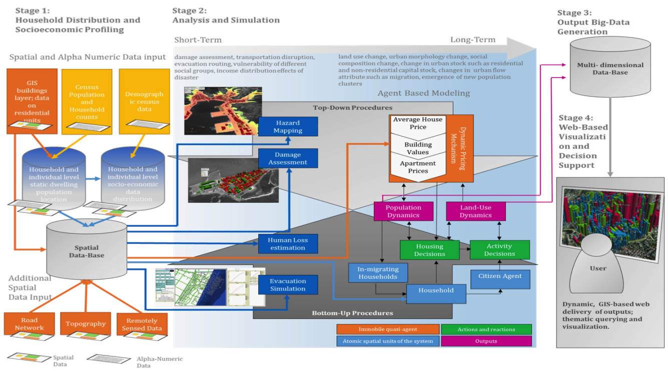

Figure 1: Framework of the project and its four stages from profiling to simulation and output analysis and visualization

corresponds to the urban and population pre-disaster situation. After an earthquake and tsunami hazard scenario is selected, strong ground motion and tsunami inundation estimations are loaded. The magnitude of the event determines a response in the population estimated through evacuation simulation. The modeled evacuation behavior together with the outcome of building and road disruption estimation will show human loss estimation and an urban post-disaster situation. This situation of hazard impact is used as initial condition for post-disaster relief simulation and land-use and population dynamic estimation. For disaster relief simulation, after the evacuation is completed, survivors whereabouts are known and shelter needs are assumed corresponding to the number of evacuees obtained in simulation. Optimum alternatives for disaster relief response under such conditions are estimated together with a time frame of evacuee attendance and evacuee migration. The dynamics of evacuees and population in general is decided based on socioeconomic factors and damage extent in the area. Thus, urban condition and socio-economic profiles of households are put together into an agent-based model that produces synthetic big data and an overall view of the dynamics in the simulated area. The time taken for the model to reach equilibrium on its dynamics is the unit scale used to measure urban resilience. The faster an urban space reaches adaptation, the higher the resilience is evaluated.

4. Stages

1. **Household Distribution and Socioeconomic Profiling**
   A data disaggregation algorithm is developed to build individual socio-economic profiles from census tract data. The allocation of the census data into households and discrete individuals allow for deep analysis of the urban and socio-economic dynamic. The Israeli group has developed a dedicated algorithm for data disaggregation and the generation of synthetic spatial microdata (Lichter and Felsenstein, 2012). The approach calls on combining census tract level data with GIS buildings layers in order to generate synthetic spatial microdata. The resultant

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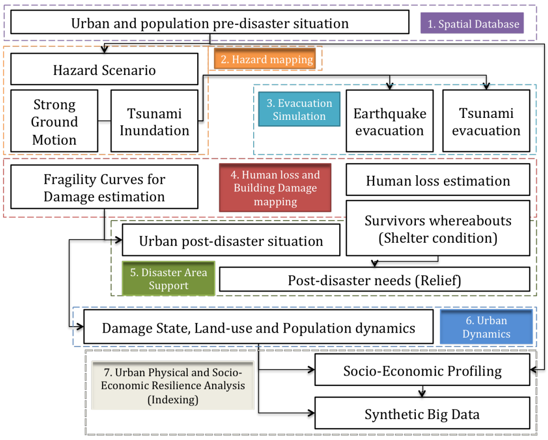

Figure 2: DIM2SEA Model framework

synthetic database is both detailed and accurately and represents the spatial distribution of buildings, dwelling units, households and inhabitants within the urban area.

2. **Analysis and Simulation**
Hazards are simulated on their generation, propagation and impact to the urban environment using physical and geospatial models to estimate the damage to buildings. For instance, the QuiQuake system provides strong ground motion maps of peak ground velocities soon after an event. Such information consists on a valuable database of earthquake scenarios that can be combined with seismic fragility curves developed elsewhere (Murao and Yamazaki, 2000) to assess an estimation of the level of damage of buildings in the area. Similarly, tsunami numerical simulation combined with tsunami fragility curves (Koshimura et al., 2009) are also used to estimate the level of damage due to tsunami. Progress on this topic has been published elsewhere (Adriano et al., 2014). In addition, agent based models are used to estimate human losses. A model to estimate casualty during tsunami (Mas et al., 2012) is used to test the human behavior in evacuation and combine the tsunami inundation output to observe the process of evacuation on a realistic and dynamic approach. The next component deals with the issue of relief allocation strategy under limited information environments. As known, after a disaster, there is limited information on the areas affected but possible high necessity of relief. A best strategy aims to respond fast, use relief items with minimum amount of wastage and shortage time. An agent-based model is developed (Das and Hanaoka, 2014) to deal with this issue and to integrate it into the scenario of the DIM2SEA model. Finally, land-use and population dynamics is modeled following socioeconomic traits. For instance, households with large income and small damage to property or workplace may recover faster than lower incomers or highly disaster affected agents. The processes of decisions for migration and adaptation will be discuss in the future within the project and reported lately.

3. **Synthetic Big-Data output generation**
The outcome of simulation scenarios will provide a large amount of data at multidimensional levels in the urban environment. This information is considered as synthetic big data needed to be process for scenario analysis. The kind of information expected at this stage is individual agents position track and disaster response schedule, household composition, individual economical recovery and overall dynamic equilibrium. The methods to process this information are still under study and will be reported in the future.

4. **Web-based visualization platform**
The geospatial information and the analysis of the synthetic big data produced during the scenario modeling are presented through a web-based environment that facilitates accessibility, managing and understandability. A limited interactive environment is constructed to share the scenarios and the outcomes of impact, recovery and adaptation of the target areas.

5. Conclusions

We have introduced an ongoing collaboration project between Japan and Israel researchers engaged on the development of an integrated model for disaster impact and socioeconomic analysis. The objective, framework, methodologies discussed and stages of the project were presented to share with the scientific community the ideas and ongoing activities of our collaboration. The DIM2SEA model is under development and will continue improving within the following three years to produce an integrated platform of scenario analysis that combines short-term hazard and damage assessment modeling outputs with long-term socio-economic impact of urban areas. The outcome of the DIM2SEA projected is expected to contribute to disaster managers and planners as an analytic tool to mitigate the impact to disasters.

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