ABSTRACT

The objective of this research program is to increase urban resilience to large scale disasters, both natural and anthropogenic. This is achieved by harnessing state of the art developments in spatial analysis and GIS. We aim to develop a prototype 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 some of the worst excesses of catastrophic events. These events can be natural disasters such as hurricanes, storm surges, typhoons, tsunamis and forest fires, man-made shocks such as industrial accidents, warfare and terror events or any combination of the two, as witnessed in the 2011 Tohoku earthquake, tsunami and nuclear power accident in Japan. While much effort has been expended in the development of engineering tools for increasing resilience, our focus is on enhancing disaster response and socio-economic resilience. Less attention has been focussed on the differential socio-economic impacts of disasters on sub-sectors of the population and on the long term system-wide effects on the urban environment. In this respect, we fill an important gap in both technology development and disaster management practice. The proposed model is able to combine both short term damage assessment, evacuation routing and transportation disruption along with longer term assessment of urban dynmaics post-disaster. While the former focuses on damage and casualty estimation, the latter includes land use change, shifts in urban morphology and changes in urban social and demographic composition.

The method to be employed combines the latest ICT developments for spatial analysis: agent based simulation, GIS-based socio-economic profiling and the web-based delivery of results using dynamic mapping. At the heart of our approach is a dynamic agent based model coupled with post-disaster damage assessment and a socio-economic profiling algorithm. The former simulates the effects of the disaster. The latter allows for assigning detailed socio-economc attributes to the population at risk when spatially accurate data is not available. The large amounts of simulated spatial and temporal data generated by the agent based model are fused with the socio economic profiles of the target population to generate a multi-dimensional data base of inherently 'synthetic' big data. Results are made accessible to the engineer and planner through web-based delivery in an intuitive and non-threatening manner. The model itself can be used for real-time analysis as well as for ex ante training and simulation exercises.

This proposal pools the combined expertise of two research groups:

- The Japanese team from IRIDeS Tohoku University has strong competencies in geomatics and remote sensing. They have international experience in tsunami hazard simulation and in estimating localized short run results such as casualty esimation, evacuation management, building damage and fragility assessment.
- The Israeli research group from the Center for Computational Geography at the Hebrew University of Jerusalem has complementary expertise in agent based modeling, land use modeling and GIS. They have worked in the areas of sea level rise, coastal flooding and earthquakes looking at both short run and long term effects of disasters on the urban system.

The proposed DIM2SEA model will result an integrative disaster management tool with a level of spatial and temporal detail that hitherto has not existed. Fusing the competencies of the two groups will result in a whole greater than the sum of its parts.

The envisaged mode of co-operation between the two teams will comprise of stand-alone work packages to be undertaken by each group in parallel. Co-ordination will be achieved through two annual product development meetings where individual model components will be presented and then integrated into the model. In addition, in the first and second years of the project, scientific exchange will be accomplished through short stays at counterpart countries from researchers on both teams. Moreover, a scientific workshop will be held in each of the host countries to share research progress and outcomes with the scientific community and local stakeholders. In the final year an international conference and training workshop will be held in order to launch the model and generate exposure across the community of disaster management official and practitioners (engineers, urban and evacuation planners, emergency response teams, policy makers).

RESEARCH TOPIC AND PLAN OF WORK

1. Background and State of the Art

Urban resilience is a timely issue. The ravages of Hurricane Katrina in New Orleans (2005), the Haiti and Christchurch earthquakes in 2010 and 2011, the Tokohu earthquake and tsunami (2011) and Superstorm Sandy (2012) have brought home the urban impacts of natural disasters and the differential abilities of cities to mitigate them. The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) adopted at the recent Third World Conference on Disaster Risk Reduction on March 2015, has noted that "it is urgent and critical to anticipate, plan for and reduce disaster risk to effectively protect people and socioeconomic assets, amongst others, to strengthen community resilience". The notion of resilience has been invoked as a priority within the SFDRR.. However like many metaphors, its precise meaning is ambigious and not seamlessly transferable to the urban context. The roots of the concept lie in the biological and ecological sciences (Holling 1973, Adger 2003) and for that reason it is often discused in the context of particular physical shocks such as ecological degradation, climatic change and natural disasters. While the role of shocks on ecosytems may be conceptually analagous to those on cities, such comparisons are inevitably limited. The urban system responds to a very different set of forces to those fashioning the natural environment.

Coping with natural shocks to the urban system is becoming ever more demanding as perturbations increase in magnitude and complexity. As cities increase in size and complexity they also become increasingly vulnerable to unanticipated events, both natural and anthropogenic (Godschalk, 2003). Urban engineers and planners often lack the tools for dealing with the complexity of these situations.

This proposal aims at contributing to urban resilience through harnessing recent advances in geo-simulation modeling and web-based dynamic visualization for communicating results. 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). The proposed model goes beyond the standard evacuation and damage/hazard loss models commonly used for dealing with emergency disaster situations (Burics et al 2004, Hittle 2011). It combines dynamic simulation 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 or remote sensing units allows for the socio-economic analysis of populations at risk, social vulnerability and distributional effects of natural disasters at varying spatial and temporal scales.

In the temporal dimension, the model can simulate both the short run effects of a catastrophic event, such as disruption of city life, infrastructure collapse, evacuation and rehousing along with the longer term changes to land use, and urban morphology. 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. This feature is critical in post-disaster recovery scenarios in order to “Build Back Better” and, therefore, increase urban resilience.

A key component in the modeling system is an agent based simulation model that decomposes the complexities of the urban system into the operation of ‘agents’. These can be both individual entities such as citizens or aggregate institutions such as markets. Central agents are households, workers, firms and local policy makers. Each operates according to certain (programmable) behavioral rules and in so doing, affects the behavior of other individual agents and in the aggregate, the operation of urban institutions such as land and housing markets and the planning system. The urban system is particularly inflexible. This is because urban morphology which accrues cumulatively over time, does not respond rapidly to change and because planned physical change is essentially a highly time-dependent process with a long gestation lag. Furthermore, given the inter-connectedness of agents, a shock to this system transferred through the aggregate behavior of agents may have random spatial impacts. Given these temporal and spatial complexities, decision makers have difficulty in fully comprehending the outcomes of unanticipated events in urban areas.

Agent-based simulations have been applied in a variety of disaster contexts such as flooding, fires and earthquakes (Chen and Zhan, 2008; Crooks and Wise, 2013; Dawson et al., 2011). This simulation framework lends itself to these situations. A high level of agent heterogeneity can be programmed and applied differentially to the various stages of an urban disaster from mitigation and preparation through response and on to recovery. This yields a rich array of human behaviors. For example, agent- based models have been coupled with network models for simulating evacuation (Chen, et al., 2012). GIS tools and crowdsourced data has been combined with agent based modeling to assist with post disaster recovery analysis (Crooks and Wise, 2013). Kwan and Lee (2005) merged network analysis, GIS and 3D visualization tools to provide a realtime micro-scale simulation tools for emergency response at the the individual building or city block level. In the field of traffic modeling, Chen and Zhan (2008) have used the agent based approach to evaluate different evacuation strategies under different road network and population density regimes. However, in most instances the models are solely driven by demand with scant attention to supply side issues, largely inaccessible to practitioners, only tangentially touch on issues of resilience and vulnerability and are generally too bespoke to serve multiple disaster contexts and spatial scales of analysis.

2. Goals and Objectives:

The goal of this project is to utilize state of the art ICT to generate an analytic framework for evaluating, planning and mitigating the possible impacts of large-scale disasters. This will increase urban resilience and will provide decision makers, urban engineers and planners with a set of competencies to reduce human vulnerability to unanticipated events.

The proposed model will be used for both training-for-disaster and in real time. The system will be made fully accessible and delivered as a dynamic web-based platform. Using a simple internet browser users will be able to generate multiple scenarios of hazard, damage estimation, evacuation and post-disaster socio-economic recovery with time lapse visualizations in the form of maps and charts without any previous knowledge in handling spatial data or using GIS.

3. Method:

The DIM2SEA modeling approach is outlined schematically in Figure 1. Here we expand on the four stages that comprise the proposed analytic framework:

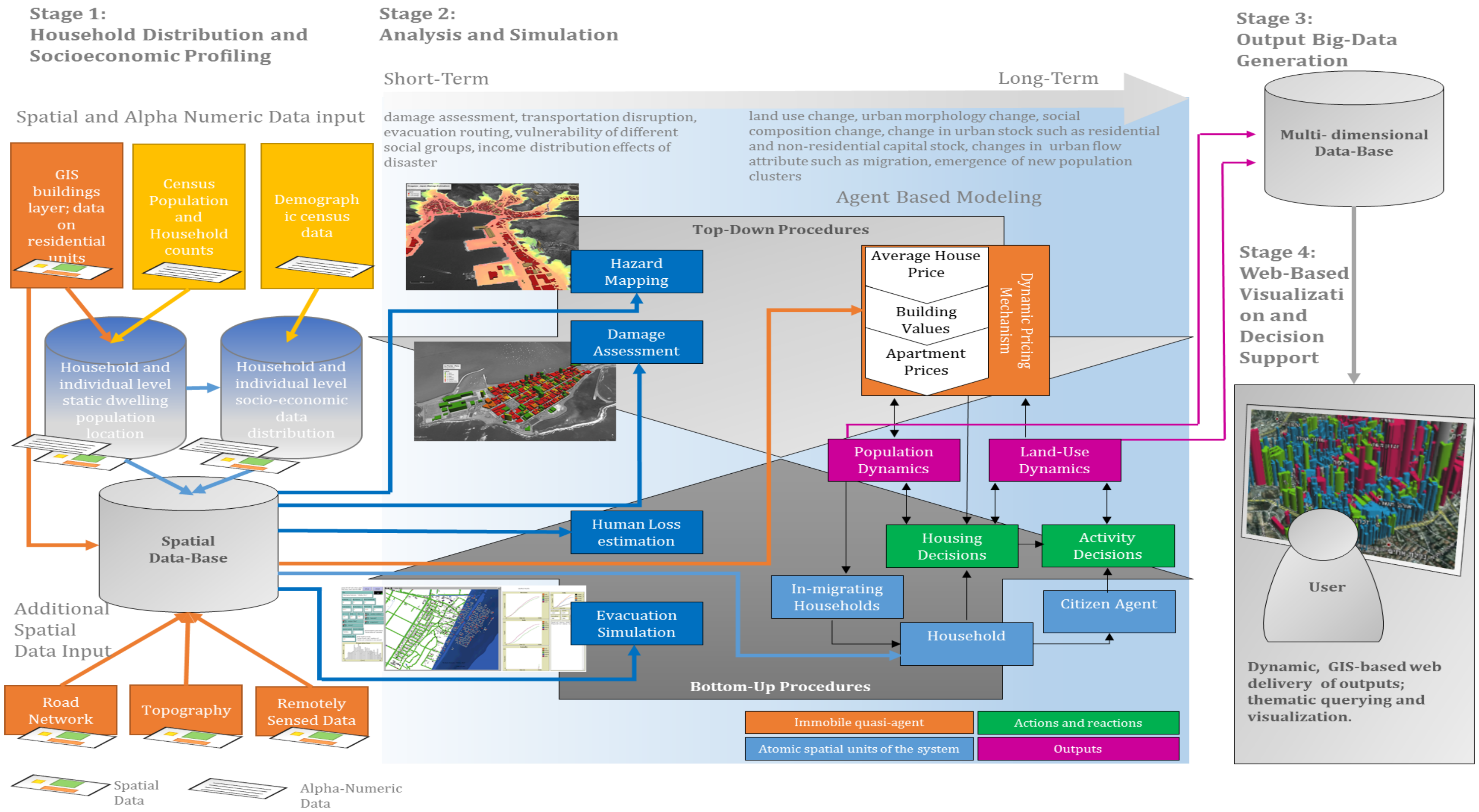
***<u>Stage 1</u>*; Data disaggregation and socio-economic profiling**. We develop a disaggregation algorithm that allocates aggregate census area data on households, household size and population counts to discrete individuals. Each household and individual in a household in a given census tract unit is represented in this database. The original census tract data is dis-aggregated into households and individuals in a way that represents the distribution of their attributes in the census data. This stage is comprised of three steps:

i. *Household Level Non-Spatial Dataset* The total number of households of each size (number of residents) is calculated using the total household count per census tract and the (percentage) distribution of household sizes in each census tract. The result is a dataset containing a unique representation of each household. Each household is of a different size and all the households in each census tract represent the distribution of household sizes in the original data.

ii. *Individual Level Non-spatial Dataset* The data is further broken down to represent the number of residents in each household as distinct entities in the dataset. The dataset now contains a total of millions of entities representing individuals tied to households.

iii. *Allocating Households to buildings to obtain an accurate spatial distribution of agents*: each household in the dis-aggregated households dataset (broken down into individuals) is allocated to a residential building in its corresponding census tract. The number of households in a census tract is calculated using a spatial building layer, from which the total floorspace of buildings is calculated using building landuse and height. We also use ancillary data relating to the number of residential units per building, their floorspace (area in m^2), and their respective floor in that building. Households are allocated to buildings and residential units according to a ranking of household size residential unit floorspace in each respective census tract. Appendix A-Figure A.1 is a 3D representation of the distribution of individuals into floors inside residential buildings. The rest of the socio-economic variables used in the profiling are summarized in Appendix B-Table B.1.

Figure 1: The DIM2SEA Model Framework



iv. *Validation:* in order to verify the accuracy of the baseline allocation model, we propose constructing similarity indices that compare our synthetic distributions with those from representative large scale surveys in urban areas in Japan and Israel where data exist on individuals by home location and socio-economic attributes. To validate and calibrate the simulation model we will engage in back-casting using data from previous disasters in Japan and Israel that relate to both evacuation and reconstruction.

Stage 2: ***Agent based simulation modeling***. The synthetically generated data provides a detailed account of the urban environment and the population at risk. When dynamics are introduced by way of simulation, a multi-dimensional database is created. The microscopic nature of the data calls for the use of a micro-simulation, such as agent-based simulation. The simulated agents interact among themselves and with the environment. These interactions aggregate into system-wide behavior trends. Each agent is assigned specific characteristics resulting in rich spatio-temporal data.

The atomic units of an urban system may be conceptualized as individuals and households. Choices made by these agents affect traffic loads, success of commercial activity and the supply of housing. Accordingly, the direct physical effects of a disaster are translated into social and economic crisis through the behavior of individuals. This behavior could be simulated at a number of temporal and spatial scales. The Israeli team has experience in simulating macro social, economic and morphological changes, while the IRIDeS-Tohoku team has expertise in micro-behavior models of evacuation and damage assessments.

The proposed model will combine both capabilities in order to enhance urban resilience. For the short-term analysis, hazard mapping combined with spatial sub-models of damage assessment will be coupled with evacuation modeling to provide scenarios of disaster impact estimation and inputs for disaster recovery analysis. For the long-term analysis, we intend to formulate two types of bottom-up behavior at different scales (activity and housing decisions made by individuals and households respectively, see Fig. 1). We also formulate a third, top-down (supply side) environmental influence by conceptualizing buildings as quasi-agents (see Fig. 1). They are not mobile or active, but are still sensitive to changes in their immediate environment. The components of the long-term sub-model are therefore:

i. Activity decisions – based on location, attractiveness of available destinations and the mobility profile of individuals (e.g. disability, age, workplace location) a sequence of activity locations are identified along with the paths connecting them. These behaviors aggregate into consumption flows affecting commercial activity, traffic flows and infrastructure overloads.

ii. Residence decisions – given a disaster, households choose between staying put, relocating or moving out of the region according to their income levels, migration ratios and the characteristics of potential residence locations. In-migration is also considered and varies in accordance to housing supply. This set of decisions translates into housing market related changes.

iii. Environmental top-down procedure; this defines processes of land-use and value change for different spatial units such as census tracts, buildings and dwelling units. The supply of commercial uses changes via the sensitivity of individual commercial uses to aggregate flows of individuals. Commercial activity locates itself in locations attracting enough traffic to achieve profitability. Changes to housing costs trickle down from the census tract level to the individual dwelling unit.

We intend to vary the severity, physical extent and dynamics across a series of disasters in order to assess varying scales of resilience across different urban environments. Different simulated events, tsunamis, industrial accidents, or warfare may engage different forms of resilience. This will call for very different evacuation contingencies, highly varied costs in terms of human life and physical damage and very different short-term responses and long-term changes in terms of social composition, land use rejuvenation and morphological shifting.

Stage 3; Generating a multi-dimensional data base. During the simulation model changes to the spatial and contextual attributes of each synthetic entity are registered at frequent intervals. The content of the entire database changes as some entities (damaged buildings or roads, casualties, out-migrating households) are removed while new ones are added. This results in a multi-dimensional big database that accurately describes the spatio-temporal dynamics of multiple urban sub-systems.

The model outputs represent various dimensions of the notion of resilience and inform different levels of decision and policy making. For example immediate response and evacuation procedures can be evaluated in relation to mobility and land-use data. Residential mobility, along with capital stock value can inform planning for long-term social and financial urban resilience. However, as in many 'big' databases, communicating the content of this output is complex and traditional static platforms are ill-equipped for the job. We therefore propose an innovative method for make these results universally accessible.

***Stage 4**: Visualization and Communication of results: Using ICT for the delivery of outputs.*

As noted above, the dynamic simulation of disasters yields vast amounts of temporal and spatial information. With the increase in sophistication, volume and complexity of modeling urban dynamics and as computing power and big data grow exponentially, this challenge is compounded. Web-based cartographic spatial and temporal visualization technologies can function as a bridge between the research environment, in which outputs are generated, and the user. We develop a web-based application that serves as a means to communicate outputs generated using an agent-based simulation model to potential end-users, such as disaster related stakeholders, urban engineers and evacuation planners. Communicating spatial information in this way helps to increase transparency and opens the door for public awareness and participation in planning processes both pre and post disaster. Increasing accessibility to data is an important step towards building urban resilience.

We communicate the results using a dedicated web application. This is done by harnessed the latest developments in spatial ICT applications. These allow the user to browse through four types of spatial and non-spatial visualization techniques. In order to transform the volume of simulated data into meaningful information, we will design a visualization platform that will enable a comprehensible display of multi-dimensional results. This dedicated web-based application will allows interactive visualization and querying of the outputs in a user-friendly fashion. A prototype illustrating the data disaggregation component of the proposed system already exists (See Appendix A-Figure A.2 and http://ccg.huji.ac.il/AgentBasedUrbanDisaster/index.html).

The current proposal significantly extends this initial TRL (technological readiness level) archetype. We propose using a web browser that allows the user to generate time animation visualizations in the form of maps and graphs without previous knowledge in GIS or spatial data handling. By using action buttons on the screen, the planner or engineer user can initiate automatic time-lapse visualization or use a slider to manually manipulate time series of spatial and non-spatial results. They can also query the maps and graphs by simply clicking with the mouse on features on the screen (for example see Fig 3). When initiating such "events", a click of the mouse can trigger complex querying of the database in the background. This requires a dedicated database design and construction of selected outputs to allow efficient and rapid application response and data extraction.

ICT and Visualization Platforms

The proposed web visualization roadmap is outlined in Appendix A-Figure A.3. We intend to use three main spatial ICT platforms:

(i) Google Maps API as a 2D web-mapping platform
(ii) Google Earth API as a 3D display platform
(iii) Google Charts API as a non-spatial graphic visualization platform for aggregate results.

Data Formats

Each of the above platforms requires different formats of input data, and sometimes accepts more than one input format interchangeably. The input data has to be designed so that it can be animated over both the temporal and the spatial dimensions (Appendix A-Figure A.3).

(i) Google Fusion Tables API - We will use Google Fusion Tables API to feed spatial vector 2D layers into Google maps. Each feature in the layers will contain time series of values for each variable. These will be displayed and queried using SQL queries generated in the background when an action button is clicked or when a slider button is dragged.

(ii) .Json data files – will be used to create heat-map visualizations using the 2D Google Maps API. Each time an action button is turned on or the slider is evoked, the time increment is changed, variable values are changed and the heat map draped over the study site will change accordingly.

(iii) Graphs displayed using Google Charts API will be based on a specific data format that feeds into this specific API. A JavaScript loop will be written in order to generate the time lapse visualization with the click of an action button.

(iv) 3D .kml files will be generated in ArcScene to create the color and height simbology. Each file contains features representing the values of on variable over a different time interval. An action button click or a drag of a slider will change the time interval of choice and calls for the appropriate .kml layer to be displayed and the previous layer to be turned off.

4. Potential scientific contribution of the proposed research:

This proposal makes a significant contribution to the mitigation of disaster events. In terms of scientific merit we note the following innovative aspects of the proposal:

- delimiting hazard zones and estimating monetary losses at a high level of spatial resolution via GIS for multiple scenarios
- modeling human loss, infrastructure damage and disaster recovery for multiple levels of vulnerability and social resilience.
- modeling supply side change in an agent based framework
- developing an algorithm for accurate spatial and social profiling
- generating synthetic big data through coupling agent based model outputs with socio-economic profiling
- communicating complex outputs through the novel use of ICT and web-based technology In terms of socio-economic contribution, this proposal yields new insights into the factors promoting urban resilience. Amongst them we note:
- disaggregating impacts of disaster by income classes and social groups to understand the differential vulnerability levels of sub-populations
- estimating a composite index of vulnerability to short and long term shocks in order to formulate potential coping and rejuvenation strategies
- calculating optimal accessibility and evacuation routing for populations with different levels of mobility
- understanding short-term and long-term impacts of disasters in community resilience

5. Workplan

The proposal is to be executed via discrete work packages (see Table 1). Three milestones are articulated. These correspond to key junctures in the work program and each is accompanied by a tangible deliverable. The progression of work is roughly linear and each work package builds on progress achieved in earlier stages. While the research challenge is common to both teams, progress will be achieved through inter-dependent sub-projects. These will be undertaken by each of the partners in parallel. Operationalization and empirical testing of the various work tasks will be done using data from both countries.

The proposal exploits the combined expertise of the two research teams.

- The Japanese group from IRIDeS-Tohoku university has strong competencies in geomatics and remote sensing. They have international experience in tsunami hazard simulation and in estimating localized short run results such as casualty esimation, evacuation managment, building damage and fragility assessment. They will incorporate these abilities within the DIM2SEA resilience framework within Stage 2 of analysis and simulation for short-term damage assessment. (Figure 1).

- The Israeli research team from the Center for Computational Geography at the Hebrew University of Jerusalem has complementary experience in agent based modeling, land use modeling and GIS. These competencies have ben used in the areas of sea level rise, coastal flooding and earthquakes. They will develop the long-term simulation component of the DIM2SEA framework (Figure 1, Stage 2) incorporating inputs from the IRIDeS group.

The DIM2SEA model will result in an integrative disaster management tool with a level of spatial and temporal detail that hitherto has not existed. Fusing the competencies of the two groups will result in a whole greater than the sum of its parts.The project workpackages (WPs) and milestones (MS) are as follows:

<u>WP1</u>: Literature review, data collection (IRIDeS and HUJI)

<u>WP2</u> : Socio Economic Profiling; Generating Accurate Spatial Distribution of Residential Units, Households and Individuals; Spatial data base Construction (IRIDeS and HUJI). This represents Stage 1 in the DIM2SEA modeling framework (Fig 1)

<u>WP3</u>: Estimating Short term resilience: hazard maps, building damage assessment and fragility measures, infrastructure stress and transportation and evacuation routing, social vulnerability indices (IRIDeS).This represents Stage 2 in the DIM2SEA modeling framework (Fig 1)

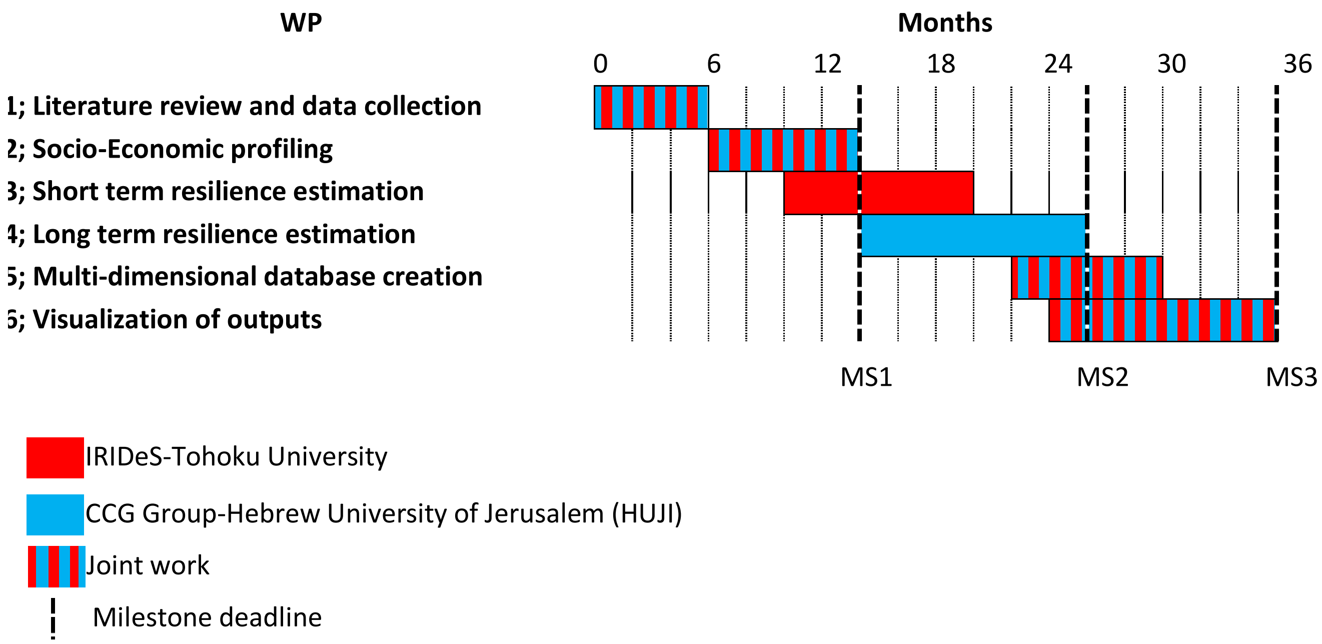
<u>WP4</u>: Estimating long term resilience to change; development of dynamic agent based simulation model for assessing change in land use, social composition, urban morphology, value of capital stock, population migration, social segregation patterns (HUJI) . This represents Stage 2 in the DIM2SEA modeling framework (Fig 1)

<u>WP5</u>: Creation of multi-dimensional (big data) data base (IRIDeS and HUJI). This represents Stage 3 in the DIM2SEA modeling framework (Fig 1)

<u>WP6</u> : Visualization and Web Base delivery of outputs (IRIDeS and HUJI). This represents Stage 4 in the DIM2SEA modeling framework (Fig 1)

<u>Milestone 1:</u> (MS1): Delivery of Spatial data Base
<u>Milestone 2</u> :(MS2): Delivery of Short run and long run resilience assessment
<u>Milestone 3</u> (:MS3): Delivery of web based model for urban decision support

Table 1: GANTT Chart of Proposed Work Schedule: Work packages and Milestones



6. Integration between teams:

The envisaged mode of co-operation between the two teams will comprise of stand-alone work packages to be undertaken by each group in parallel. Co-ordination and scientific exchange will be achieved through short stays at counterpart countries from researchers on both teams and two annual product development meetings where individual model components will be presented and then integrated into the model (see Table 2). Additionally, in the first and second years of the project, a scientific workshop will be held in each of the host countries. Research progress will be exposed to a group of international experts at each meeting. Thus we envisage that the research groups will meet twice each year: once in a limited research capacity and one in a wider forum with invited participants.

This project places great emphasis on the incorporation of younger scientists and in leveraging their interaction through joint work. It is expected that they will be intimately invoved in developing various components of the DIM2SEA model and that the product development meeting will serve as a forum for exposure of their work.

At the start of Year 3 we will convene an practitioner/stakeholder roundtable to ensure that the model meets public expectations. At the end of the final year an international conference and training workshop will be conducted. Ths will showcase the model to a wide international audience and will generate exposure across the community of disaster management officials and practitioners (engineers, urban and evacuation planners, emergency response teams, policy makers). We also intend that this launch be accompanied by a training workshop for practitioners in which instruction will be conducted jointly by the younger scientists responsible for the development of the various DIM2SEA components.

We plan on maximum scientific and public visibility for our work. This will be achieved via public meetings, scientific workshops, a training workshop, active stakeholder involvement, joint academic publications and a joint scientific volume to coincide with the culmination of the project on the topic of "Increasing Urban Resilience to Large Scale Disasters".

Table 2: Proposed meetings and visits

Year	**1**		**2**		**3**	
Time	Mid-year	End of year	Mid-year	End of year	Mid-year	End of year
Purpose	Product development meeting	Scientific workshop	Product development meeting	Scientific workshop	Product development meeting	International conference and training workshop
Venue	IRIDeS	HUJI	HUJI	IRIDeS	HUJI	IRIDeS
Number of participants	5-10	15-20	5-10	15-20	10-20	40-60
Duration	1 week	3 days	1 week	3 days	1 week	3 days
Additional Features	Site Study: Tohoku tsunami affected areas		Site Study: Jerusalem Urban Security and Disaster Management Systems		Practitioners and Stakeholders roundtable	

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Appendix A: Figures

Figure A.1: Distribution of individuals (red lines) inside residential buildings (in blue) by floors

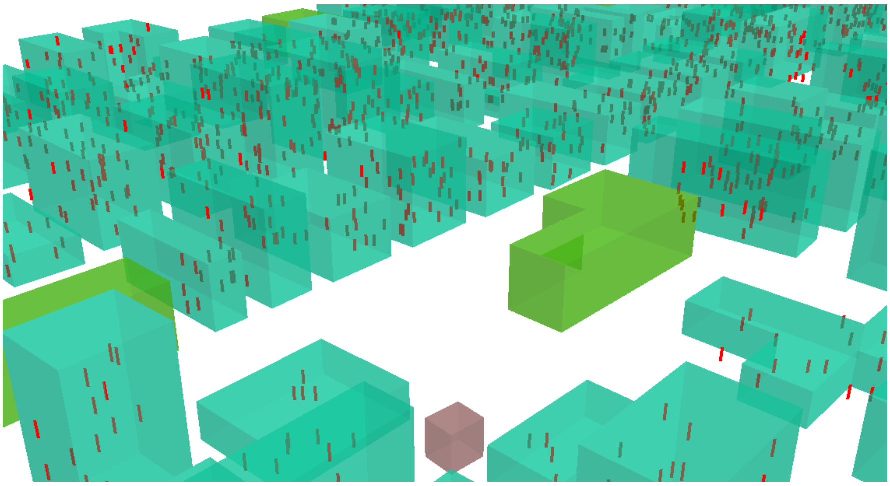


Figure A.2: Visualization of Results in 3D

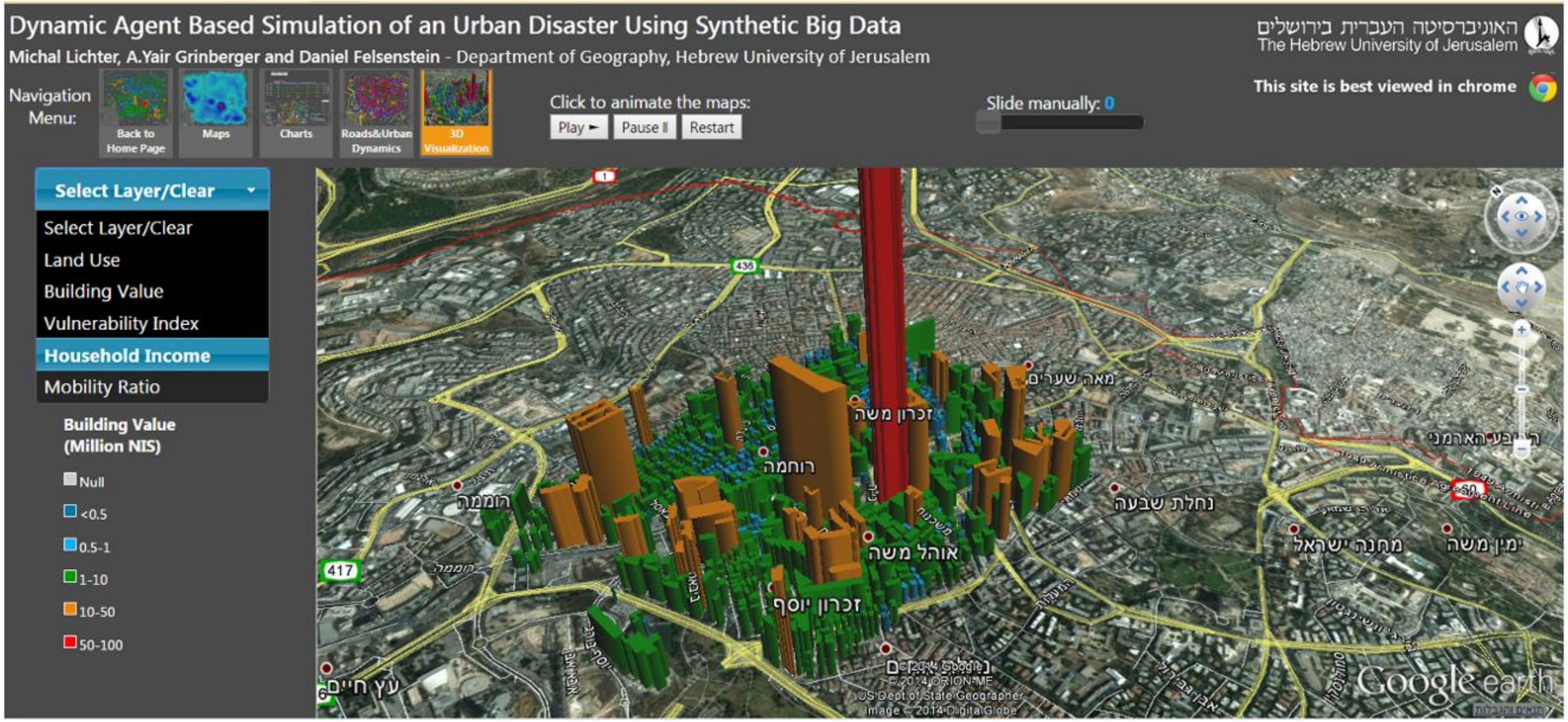
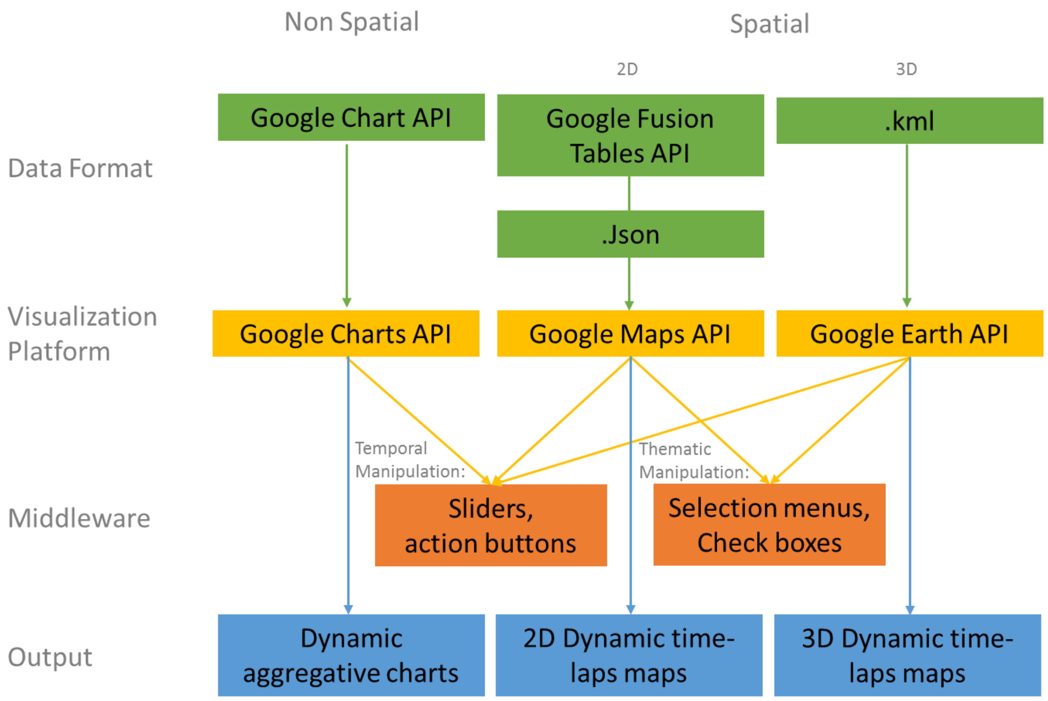


Figure A.3: Proposed web visualization design roadmap



Appendix B: Tables

Table B.1: Allocation of Socio-Economic Attributes to households and individuals

Variable	Definition	Method of allocation	Allocation to
Age	Individuals in each household are assigned an age attribute using three variables that represent the age distribution of households in each census tract.	*Number of children* per household in each census unit is used in order to allocate an age attribute of 0-17 to residents in each household in a way that represents the original distribution of the number of children in a household in each census unit. An automated code is written to ensure no households are composed entirely of children, and that in each household there remains at least one adult. In this way, for example, children are not allocated to households with only one resident. *Elderly population living alone* in each census tract is used in order to allocate the age attribute of 65+ to residents of households until the quota in each census tract is filled. *Non allocated* remaining age distribution of the population in each census tract is assigned randomly to individuals with no age attribute in the database	Individuals
Gender	Individuals are assigned a gender attribute (male/female)	Gender distribution in each census tract is allocated to individuals on the basis of the distribution in the age group to which each individual belongs	Individuals
Education	The number of formal education years	Level of education is attributed to individuals in each census tract according to the distribution of education level by gender	Individuals
Work force participation gender	This boolean variable, indicating the distribution of adult individuals participating in the work force by gender	Work force participation is allocated to adult individuals in each census tract until the quota of working individuals of each gender is filled. A ranking preference is applied to first allocate participation to adults in age groups under 65 years old. If the quota is not filled, participation is allocated to individuals in the 65+ age group until the quota is filled	Individuals
Occupation and Industry	Occupation and industry of employment categories	Workers are allocated occupation and industry according to the gender distribution of the adult population. A ranking preference is given to individuals participating in the work force.	Individuals
Disabilities	Formal disabilities recognized by the state: difficulties dressing, hearing. seeing, walking	This attribute is allocated to individuals randomly, based on the distribution in each census tract	Individuals
Car ownership	None, one or two+ cars per household	Randomly allocated to households until the census tract quota is filled	Households
Income		The average income per household in a census tract.	Households