Bouncing Back or Bouncing Forward? Simulating Urban Resilience and Policy in the Aftermath of an Earthquake

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Abstract: While the direct physical effects of an urban catastrophe are relatively straightforward to assess, indirect and long-term impact on the urban system are more circumspect. A large scale shock such as an earthquake derails the complex urban system from its equilibrium path onto an unknown trajectory. Consequently, assessing the effect of policy intervention that aims to mitigate this shock and increase urban resilience, is fraught with complexity. This paper presents the implementation of dynamic agent-based simulation to test long run effects of a hypothetical earthquake in Jerusalem, Israel. We focus on investigating the effectiveness of policy choices aimed at restoring the urban equilibrium. Cities are found to have a self-organizing market-based mechanism which strives to attain a new equilibrium. They therefore may not always bounce back- they may also bounce forward. Decision makers, engineers, emergency and urban planners need to be cognizant of this tendency when designing policy interventions. Otherwise, well-intentioned efforts may inhibit urban rejuvenation and delay the onset of city recovery.

Keywords: Urban resilience, earthquake, Jerusalem, agent-based simulation, urban equilibrium, disaster policy.

1. Introduction; understanding resilience

Over the last few decades cities have been subjected to ever-increasing disastrous events resulting in casualties and extensive property damage (Wamsler, 2004). As city populations and densities continue to rise, it is reasonable to assume that the trend of increasing damage from such events will intensify (Quarantelli, 1996; UNISDR 2012). Given the magnitude of the potential catastrophes and also the expanding availability of data, tools and knowledge, increasing multi-disciplinary effort is being focused on mediating the hazards facing cities and bolstering their resilience (Zolli and Healy 2012). Much of this interest tends to focus on restoring urban conditions and rejuvenating city life. For us, the ability of the city to continue to restore critical services and maintain community capital in the aftermath of a catastrophic event, is a cornerstone of resilience. However, the issue of exactly what level of rejuvenation and for what purpose, is often left vague. There is a general acceptance of a direct and linear cause and effect relationship in that a larger shock necessitates a larger effort to achieve restoration and that time to recovery is somewhat proportionate to the magnitude of the disturbance (Chang and Rose 2012).

This paper shows in the context of the long term urban effects of an earthquake, that such direct relationships are hard to justify. Efforts at promoting city resilience do not necessarily produce such causal outcomes. Our reading of ‘resilience’ follows that common in ecology and engineering (Adger 2000, Holling 1996) and denotes the ability of system (natural or constructed) to recover from a shock. While consciously focussed on the notion of equilibrium urban growth, we recognize that the outcome of an unanticipated event is not predetermined, as multiple unstable equilbria may exist. Thus, a small and perhaps inocuous perturbation can tip the system from one equilibrium state to another. While shocks are invariably exogenous there is no knowing a priori which one is going to tilt the city or region onto a new growth path.

We also note that nuanced but important differences exist as to whether this recovery is to a previous state, thereby assuming a single stable equilibrium (bouncing back) or whether the system post-shock has various trajectories for recovery and multiple potential equilibria (bouncing forward). ‘Bouncing back’ denotes the traditional occupation with regaining pre-disaster conditions (Chang 2010). An urban disaster derails city development and it bounces back to a new growth path. In this case the counterfactual or city-growth-without-disaster state, is not known. Furthermore we do not know whether the current bounce back is a permanent long term adjustment or not. ‘Bouncing forward’ observes how much disturbance the urban system can endure before it changes its structure. A key feature of post disaster recovery is ‘time compression’ (Olshansky, Hopkins and Johnson 2012). This expresses the knee-jerk reaction in the aftermath of an unanticipated event. It is characterized by attempts to compress rebuilding activities such as renewal of capital stock, rebuilding of institutions, rejuvenating land use and commercial activity over a short period of time and in a focused area. The replacement of public housing with mixed affordability developments in post-Katrina New Orleans is a case in point (Olshansky et al 2012).

However different urban processes rejuvenate at different speeds: commercial activity can revive quickly while physical and social rebuilding needs a much longer time frame. This implies multiple and unstable urban equilibria and no linear causality between size of the shock and type of rejuvenation. It also suggests no necessary congruence between point of disaster and place of recovery. Additionally it illustrates that disaster can (perversely) offer opportunity for change and renewed growth. For example, the devastation wrought by World War II bombing on cities in Germany and Japan has been shown to have ‘bounced forward’ the economies of the devastated cities (Brakman, Garretsen and Schramm 2004, Davis and Weinstein 2002).

. This equilibrium view of resilience has been challenged in the context of urban recovery (Martin 2012, Davoudi 2012). The first claim is that cities are not as mechanistic and predictable as the equilibrium view purports. Second, recovery to a former state may not be desired goal for those urban areas whose pre-disaster state was unattractive in the first place. Finally, the equilibrium view ignores ‘the intentionality of human actions’ (Davoudi op cit., p305) implying that human intervention through regulation, planning and policy is effectively ignored.

We acknoweldge the existence of human intervention and test its effects in the realm of policy. In this context, policies have the potential to influence resilience. Specific policies may strive to re-establish damaged infrastructure and services, to control and direct flows, or initiate a change in the environment. A shock can therefore be used as an opportunity to improve the state of the city. Yet, cities are complex systems, which are not easy to predict and understand, especially when thrown out of balance by a disturbance. It is not surprising therefore that so much policy implementation fails to achieve expected outcomes and sometime even has the potential to exacerbate a disaster situation (Chamlee-Wright & Rothschild, 2007; Williams, 2008). This paper directly addresses this issue. We present the results of a dynamic agent-based simulation that simulates an earthquake in an urban area and the possible policy responses to this shock. We highlight the direct and indirect effect of these human interventions and assess their role in making cities more resilient.

We proceed as follows. The next section presents a non-technical overview of the agent based simulation framework that we employ and its implementation in the real world context of an earthquake centered on downtown Jerusalem. We then present the basic indicators used to assess city resilience: time to recovery, land use rejuvenation and CBD shift. We simulate the baseline conditions both with and without the joint effect of three policy options relating to human actions aimed at mediating the effect of the earthquake. These are, tight land use regulation, public provision of shelter for displaced citizens and the restoration of damaged public services. We highlight the outcomes of the policy interventions and discuss their implications for city resilience.

2. Methodology

Agent-based simulation 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. In our context the key agents are households, workers, firms and local policy makers. Each of these 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 its' morphology which has accrued 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 complexity of unanticipated events in urban areas.

Agent based simulation is one way of demystifying this process. Figure 1 graphically outlines the components of the agent based system serving this paper. This figure describes the different interdependencies between citizen agents and the urban environment. Exogenous and endogenous inputs (such as income level, migration probabilities) are used to characterize the decision process of the agents. This is also based on the conditions prevailing in the external environment and in turn affects this environment. The direct effects of both the shock and policy decisions are highlighted and point to the possible feedback responses as the direct effect of the shock begins to ripple through the system. A key characteristic of agent-based simulations is their reliance on simple behavioral rules. These dictates the simplified specification of agent-environment interactions outlined in Figure 1.

<Figure 1>

3.a. Simulating the Urban Environment

The basic agent is the individual citizen, who under the constraints of the environment and individual attributes, strives for a ‘normal’existence, i.e. an existence that satisfies certain pre-defined, behavioral objectives. These include maximizing utility in terms of residence and participating in activities such as work, leisure, commercial and other social activities. Land-use which is represented by individual buildings, acts as a quasi-agent. While not mobile or able to act autonomously, it still reacts to actions of other agents thereby changing the urban system. A shock to the system (such as an earthquake) and policy decisions to deal with this shock are exogenous (See figure 1). While the spatial scale of the simulation can vary according to the needs of the task at hand, the temporal scale of the simulation is set to one iteration (i.e. the equivalent of one day). The simulation tool runs on the Repast Simphony platform, which is a popular Java-based development environment for agent-based simulations (Crooks & Castle, 2012).

3.b. Citizen Agents

Figure 1 illustrates that agent behavior consists of two kinds of decision making – residential decisions and activity participation decisions. We attempt to make these as realistic as possible. Residence decisions are the first process undertaken each iteration (day). The citizen can decide to leave current place of residence in favor of a location outside the city or choose a different location within the city. These decisions are probabilistic and are based on the existing intra-urban movements and relocation probabilities at the neighborhood scale. Out migration rates are derived from the citywide out-migration/total population ratio. The choice of new building of residence is dependent on the availability of housing space and utility maximizing behavior – the willingness to allocate one third of household income (derived from the average income in a spatial unit) on housing. Price of residential buildings is generated using a dynamic pricing system, in which the monthly cost of an apartment is derived from the value of the individual building in which it is located, which in turn is dependent on building floor-space and average housing price in its neighborhood. The latter changes with change in demand, supply and level of services. If an agent is unsuccessful in relocating within the city, due to lack of space or high price/income ratio, it relocates outside the city.

Once all residential decisions are made, agents that out-migrate are removed from the simulation database, and the others continue to the second phase of the decision making. This relates to participation in activities. At each iteration, an agent may participate in up to three different activities, all of them located in one of the buildings in the study area with at least one being non-residential. Activities are associated with types of land-use (residential or non-residential) and the choice of activity location is also probabilistic in nature. Each building has an attractiveness index based on its distance from the agent, the nature of its environment (the percent of non-occupied buildings in its surrounding area), and its floor space size (for non-residential uses only). If the attractiveness index exceeds a random value assigned to the agent (representing agent preference), then the building is visited. Agents sequence their activities and move between them on the road network, using a non-optimizing, aerial distance based route selection criteria. This results in satisficing behavior (Simon 1952) and reduces computing loads with respect to the alternative (ie optimization). Agent behavior also represents two further behavioral assumptions. The first is risk-aversion which is expressed in the tendency to avoid non-occupied buildings and shock affected areas. The second relates to a preference for agglomeration, which is represented by a higher propensity to visit land-uses that have greater sizes of floor space.

3.c. Urban Dynamics

Changes in land use are effected as follows: as commercial land-use is dependent on consumer flows and residential use on the presence of citizens, a deficit or surplus of agents may lead buildings to change their land-use or to become unoccupied. The only use which is considered to be stable and insensitive to changes is public use. The freedom of a building to switch land-uses can be controlled by the user.

Four land-use change dynamics are considered: residential to commercial, commercial to unoccupied, residential to unoccupied, unoccupied to residential. The first two are dependent on consumer flows, represented by the volume of traffic (citizen agents per day) on the road nearest in the location. This implies that revenue is proportionate to number of visits, which is proportionate to nearby traffic volume. The traffic volume needed to sustain a commercial use is commensurate with floor-space, so that larger buildings need to be near higher traffic loads. If the traffic volume does not satisfy this condition the building sheds its original use and is eligible for new uses. High traffic volumes may induce a change towards commercial use, again in proportion to floor-space and nearby traffic volume. Citizens of buildings that become commercial make the choice between relocating and migrating. The third and fourth dynamics (residential to unoccupied, and vice-versa) are dependent on the number of residents within a building – citizen agents may decide to move into an unoccupied building thereby changing its land-use, or may leave a residential building, to the extent that it becomes abandoned.

Agents can also affect urban dynamics is through the creation of available housing which induces in-migration. The city starts initially as fully occupied and the volume of in-migration is dependent on changes in residential stock, as housing space becomes available. The volume of in-migration is proportional to the amount of available housing spaces, through the in-migration/total population ratio but some variance is allowed in order to facilitate changes in migration trends. Each potential citizen is added to the database only if they succeed in locating suitable available housing (where the monthly price is lower than a third of the agents' randomly generated, city average income).

3.d. Exogenous Inputs to Urban Dynamics

Two key exogenous factors influence urban dynamics (Fig 1). The first is the single urban shock (i.e. the earthquake) which occurs on the fifth iteration of the simulation and is located randomly in space. The effect of the shock spreads outwards from the epicenter, and decays exponentially. A resilience index is calculated for each building, in relation to its distance from the epicenter and its height. If a random number that is assigned to the building exceeds its resilience index, the building collapses. Its land use is annulled, residents lose their home and the nearest road becomes blocked for as long as the building remains in ruins. The duration of re-establishment is dependent on floor-space size. Thus although the earthquake is a one-time, static event, it has directly impacts the land-use system and citizen behavior.

We also consider three exogenous policy options. These are all of a binary yes/no nature and relate to land-use regulation, sheltering policy, and service replacement.

- Land-use regulation policy: defines the freedom with which land-use may change. In the absence of regulation, land-use changes freely driven by the market. With regulation, no land-use change is allowed (with the exception of abandonment) and all rejuvenating land use simply replaces previous land use.
- Sheltering policy: in the absence of policy citizens who lose their homes have an equal chance of migrating or relocating. In the presence of policy, they are concentrated in public buildings whey they remain until their home is rebuilt. They can decide to relocate/migrate before this happens or may be displaced from their homes and will thus relocate/migrate.
- Service replacement policy: this is aimed at maintaining public services in the aftermath of the earthquake. When exercised, a similar sized commercial building replaces each public building that becomes damaged and remains as such until the

original building is restored. In the absence of policy the level of services in the city decreases considerably.

The policies serve as an heuristic tool for testing the extent of urban resilience in the baseline (no policy) case. They span the gamut of possible public intervention ranging from status quo to heavy-handed regulation. On this basis, we can discern whether resilience is expressed as bouncing back or bouncing forward. In principle, other more subtle policies, could be articulated. However, the aim of this simulation exercise is demonstrative not exhaustive.

3.e. Case study - earthquake in Jerusalem

This simulation tool described above is demonstrated with in respect to an earthquake in downtown Jerusalem (Figure 2). The city of Jerusalem, located 30 km southeast of the active Dead Sea Fault line , has witnessed several major earthquakes, the last of which occurred on 1927. Although the center of the city lies in a relatively stable area, thereby reducing natural hazard, the fact that many of the buildings within it were constructed before antiseismic codes were established makes it prone to earthquake-related damages (Salamon, Katz & Crouvi, 2010). This is a unique mixed land use area covering 1.45 sq km and characterized by low-rise buildings a punctuated by high rise structures. The area encompasses two major commercial spaces; the Mahaneh Yehuda enclosed street market and the city CBD. Three major transportation arteries roads traverse the area with Agripas and Jaffa Streets (light railway route) running north-west to the south-east, and King George Street running north -south. The area exhibits a heterogeneous mix of residential, commercial governmental and public land use and high traffic volumes.

<Insert Figure 2>

GIS shapefiles are the basic input for the simulation and include disaggregate data for each building (i.e. floor space, land-use, height). In order to assign agents and their socio-economic attributes to buildings and obtain a spatially accurate representation of their distribution, we disaggregate statistical area (SA)[1] data for population, income and household size to a per m^2

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[1] A statistical area is the finest level of spatial resolution for which Census data is made available by the Israel Central Bureau of Statistics (CBS). It is a small homogenous unit containing roughly 3000 inhabitants.

base. The case study area comprises 19 SA's. We then reassign socio economic characteristics to the buildings based on their proportional floor sizes within the SA (see Lichter and Felsenstein 2012 for a detailed description of the method). The variables reassigned using this method are listed in Figure 3.

<Insert Figure 3>

We simulate two scenarios, a no-intervention scenario (policy variables set to "False") and a full intervention scenario (variables set to "True"). The no-policy scenario generates the baseline conditions against which policy interventions are assessed. Since the simulation requires intense computing resources, each scenario is simulated only 35 times[2] with each run consisting of 1000 iterations (1000 days). For each run, the earthquake occurs randomly in space at day 5 in order to characterize effects that are not location-dependent[3]. The results below relate to the averages for each scenario.

Results

As noted above, citizens are the main force driving urban dynamics in the model by moving, populating and affecting land-uses. Accordingly, the sole purpose of sheltering policy is to maintain original population levels in order to mitigate the loss of economic activity and to help residential stock to recover quickly. The first measure tested relates to change in total population size (figure 4). Implementing policy intervention allows the city to return to close to pre-shock levels within a year but the no-policy simulation presents very similar outcomes and a return to a slightly higher equilibrium level. Over the long run, the two scenarios converge towards a trend of population decline, probably driven by the slow recovery rate of the residential stock and the concomitant rise in house prices that this generates.

<Insert Figure 4>

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[2] This rather arbitrary number of simulations was selected in order to balance computing requirements with the convergence of the results.

[3] The 5-day period was chosen in order to let non-earthquake-related urban mechanisms to reach full activity when the earthquake occurs

Gross patterns of population change in the city do not however offer many insights on spatial change at the micro level and the way incremental actions by agents can lead to structural urban change. The effects of such change can be seen in Figures 5-7. Except for a few vulnerable large non-residential units, policy implementation stabilizes the land-use system by regulating change and aiding the population. In contrast, the no-policy scenario presents a picture of a much more vulnerable commercial stock and an unstable residential stock more prone to high turnover rates, as reflected in the high frequencies for building use change (Figure 5).

<Insert Figure 5 – Frequency of land-use change>

The difference between the scenarios is more profound than a mere destabilization, as seen in changes to stock sizes and total values (figure 6). While the policy scenario presents high levels of total non-residential stock value and low levels of residential stock value due to the lack of demand and to lower levels of services, the no-policy scenario presents an opposite picture, with a slow increase in stock size accompanying the decrease in non-residential values. Translated to average values, these results point to a decrease in average non-residential values and an increase in residential values in the no-policy scenario. Since floor space is one of the dominant elements in the calculation of building value, this finding is tantamount to stating that average floor space size of non-residential buildings decreases and while the opposite occurs in residential stock. This can be interpreted as evidence of the city bouncing forward to a new equilibrium where commercial uses with abundant floor-space cannot sustain themselves and become residential while smaller residential uses identify the opportunity and switch to commercial use.

These changes reflect the change in the behavior of individual agents. Change in commercial and housing stock is driven by the changing nature of traffic volumes. Agents who react to the shock change their travel patterns thereby changing traffic volumes around the city and consequently affect the ability of large commercial uses to sustain themselves. This leads to a new pattern of land use in the process of economic rejuvenation: in the aftermath of an earthquake small scale convenience stores replace large commercial structures (malls) and apartment buildings replace family homes in the residential sector[4].

<Insert Figure 6 >

A further issue relates not just to the form and pattern of land use rejuvenation but whether an earthquake can affect urban function. A key indicator here is whether the magnitude of a shock causes shifts in the function and location of the CBD, thereby altering the urban center of gravity. The magnitude of this shift is also an indicator of urban resilience. CBD vitality is measured as the CBD share of floor space out of total city floor space. The epicenter of the CBD is identified as a single building housing the maximum average of non-residential floor space (per building) in a specified radius (250 meters). The sum of the non-residential floor space in a radius of 250m around the epicenter (FS(b)) is taken to denote CBD floor space[5]. A change in the identity of the building representing the CBD epicenter is indicative of dispersal of commercial activity and a shift in the urban center of gravity. Figure 7 shows that while the urban system may reach a new state, such a change is rare and the basic functionality of the CBD is not easily shifted (maximum shifting of 20m on average). CBD movement may be induced by an overall loss of commercial activity through migration of economic functions. The average floor-space size measure shows that in the absence of policy we get rising average size around the CBD while in the policy case we witness decrease in average size around the CBD. Therefore, only in the no-policy scenario is there evidence of a significant shift in the urban center of gravity.

<Insert Figure 7>

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[4] Anecdotal empirical evidence of this tendency can be found in newspaper and internet media reports describing the aftermath of missile attacks on cities in Southern Israel in 2012. See for example: "Empty Malls as Consumers Shop Close to Home", www.ynet.co.il, 18.11.2012

[5] $FS(b) = \frac{\sum_{i=1}^{n} FS(i)}{n}$ where FS(b) is the average amount of non-residential floor space in a distance of 250 meters from building *b*, FS(i) is the non-residential floor space of building *i*, *n* is the number of buildings in a distance of 250 meters from building *b*.

Finally, we attempt to test the nature of urban resilience. Does the city bounce back to a previous single state equilibrium or does it bounce forward to one of multiple potential equilibria? Evidence presented so far shows ambiguous trends but these results only present a snapshot of a final state and do not tell the story in relation to stability and permanency of change. To investigate this issue we present various indicators of equilibrium (Figure 8). These estimate the ability to bounce back, by returning to pre-shock values and to bounce forward by attaining a new equilibrium. This is defined as preserving the same level of value for at least the last 50 simulated days.

<Insert Figure 8>

These measures are presented in Figure 8. They show the greatest divergence across the two scenarios and may represent the most significant findings. The role of policy as conceived here is to "force" the city back to its pre-shock state. In other words, policies are designed to induce bouncing-back. Success in this instance is indicated by the speed and frequency with which pre-shock values are restored. However the equilibrium measures in Figure 8 suggest that this recovery is not stable at all. With the exception of r population size, equilibrium is rarely reached with the highest frequency being 9 of 35 times (25.7%) in the case of the effect of policy on average residential values. Even when it is attained, it appears much later than the return to previous values with the minimum time lag being 670 days. The no-policy scenario presents an opposite picture. While bouncing back is rarely achieved with three measures reaching equilibrium one time or less, stabilization via bouncing-forward, is much more frequently attained and requires a shorter span of time with minimal frequency of 20 times (57.1%).

These findings suggest that the city has an inherent market-based tendency to bounce-forward to a new state. Well intentioned policies aimed at changing this trajectory and restoring pre-shock conditions may ironically serve to inhibit urban resilience. The policy message from these results is that the one-size-fits-all policy prescription many not be suitable. Trying to force the city into some preferred recovery pattern may just retard the rejuvenation process. Policy implementation should try and avoid ready-made handbook solutions and should rather focus on the specifics of the city, the nature of the shock and the likely growth trajectories derived from these.

Conclusions

Targeting policy is difficult to achieve at the best of times (Hansen 1989). The situation is all the more complex when policy is harnessed to redirect an urban development trajectory in the aftermath of a disaster. Complex spatial dependencies between agents and markets mean that the effects of focused intervention may not end up where intended and may even unintentionally generate a second round of 'recovery disaster' (Tierney 2009). However this does not mean that policy intervention should be eschewed. This paper, presents a subtle message to the effect that cities are not helpless entities in the wake of a catastrophe. The results of the simulations, relating to impacts on the CBD, land-use and stock value changes, and the stability of different equilibria, suggest that cities harbor an inherent self-organizing mechanism that presupposes an ability for self-recovery and promoting resilience. This mechanism does not necessarily direct the city back to its pre-shock state. As demonstrated above, a shock can result in bouncing-forward to a new, commercially dispersed equilibrium.

In terms of urban planning and management praxis the implications are clear. Just as 'bouncing back' may not be the best recovery path for the city, 'bouncing forward' may also not offer an optimal strategy. Policy makers and planners need to be able to assess potential bounce-forward trajectories and to harness the self-organizing mechanism that facilitates recovery. Policy decisions, therefore should not be purely reactive to immediate needs. Intervention needs to be carefully and idiosyncratically crafted. In this respect, making cities more resilient is the thoughtful process of understanding urban dynamics and designing a tailor-made recovery process.

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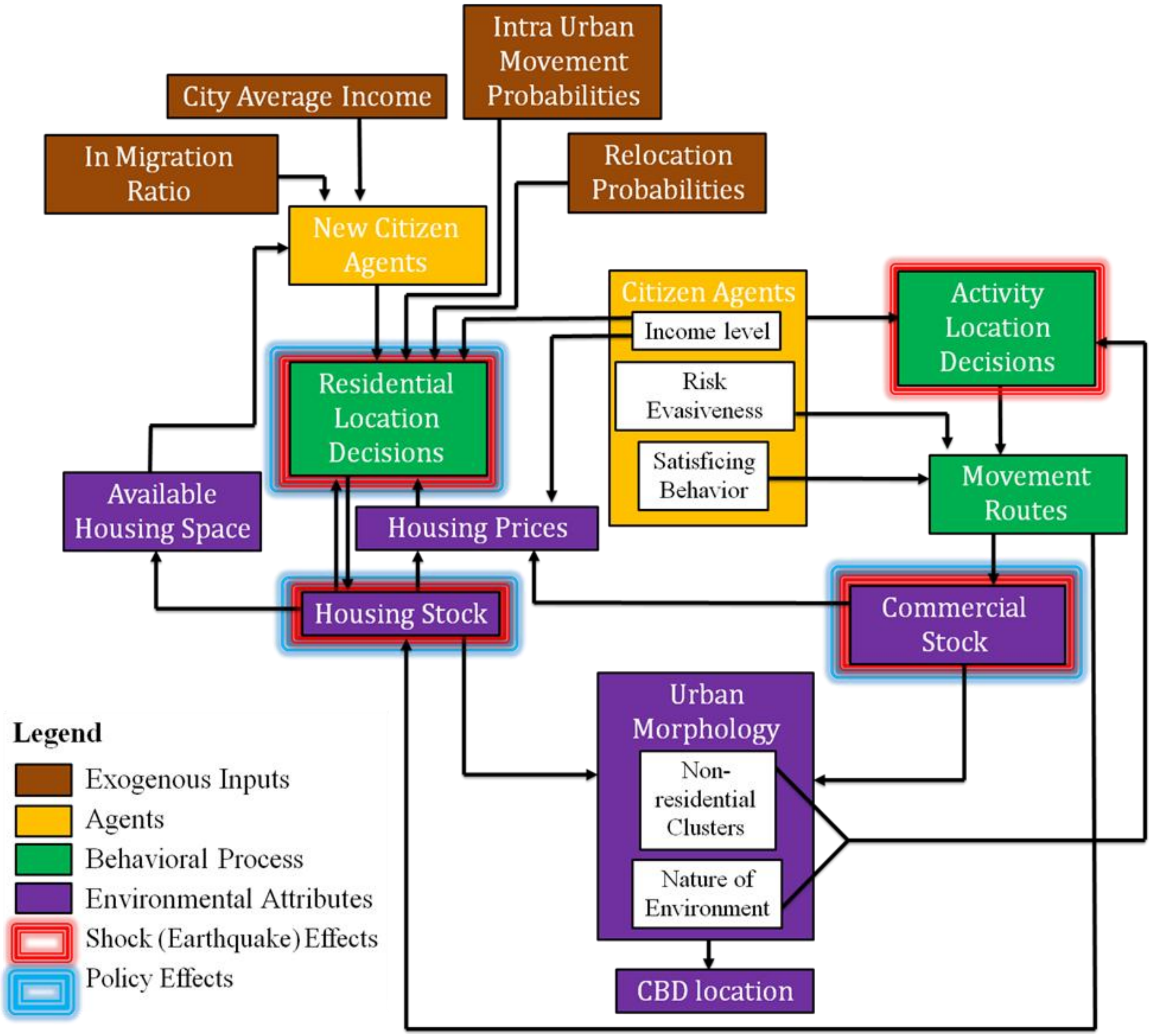

Figure 1 – Agent-Based Conceptualization of Urban Life

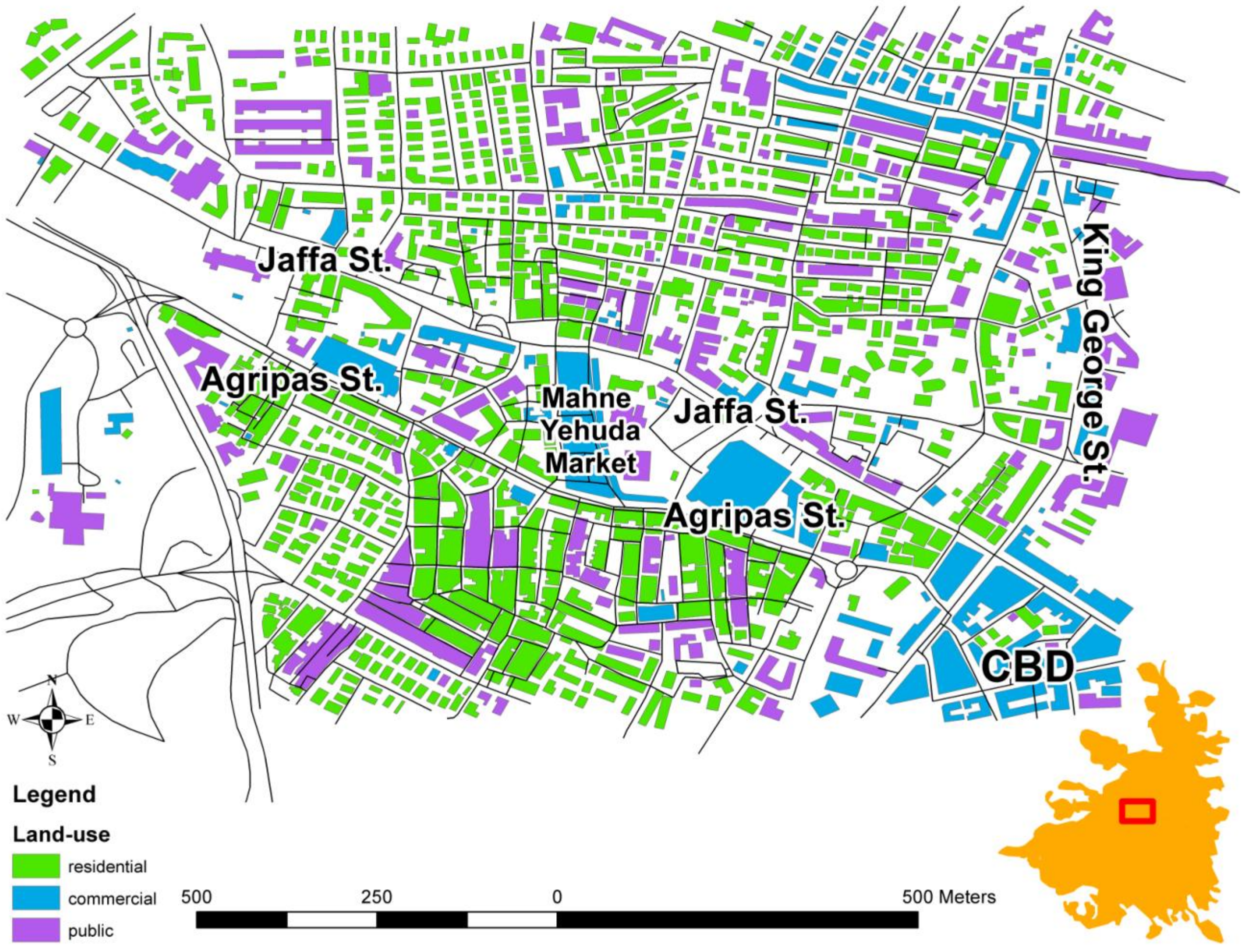

Figure 2 – Study Area.

Aggregate Measure	Scale	Value (simulation total)	Disaggregate Measure
Population Size	SA	2,681 resident agents	Residents in building
Average Income	SA	6,002.54 NIS/month	Income per citizen
Average Household Size	Citywide	3.4 people/household	
Capital Stock Value	Citywide	40,588,658 NIS	Non residential building value
Average Housing Price per Meter	SA	13,840.44 NIS/meter	Residential building value
Residential Stock Size	SA	717 buildings	
Non-Residential Stock Size	SA	298 buildings	
Number of Agents	SA	2,681 resident agents	

Figure 3 – Aggregate and disaggregate variables.

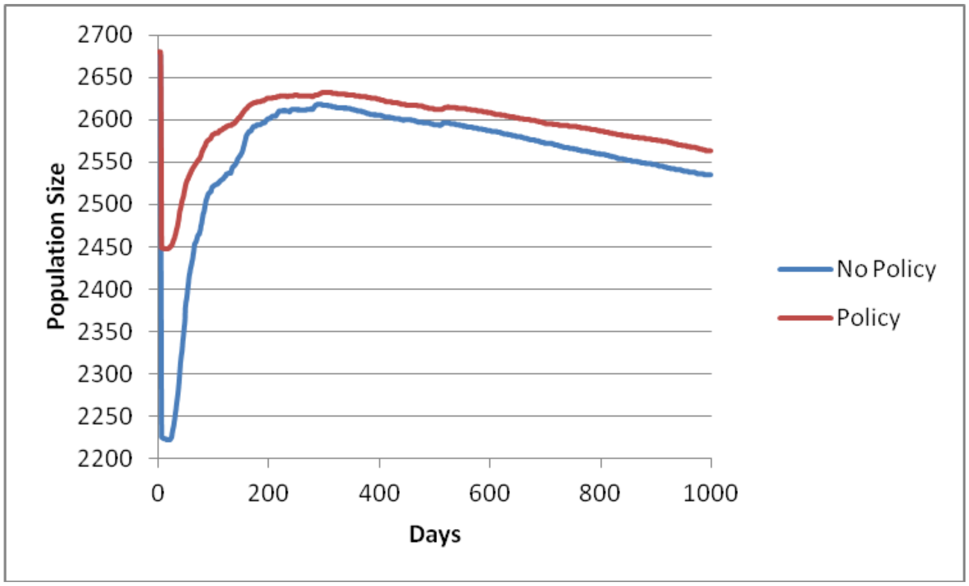

Figure 4 – Change in Population Size, by Time and Scenario.

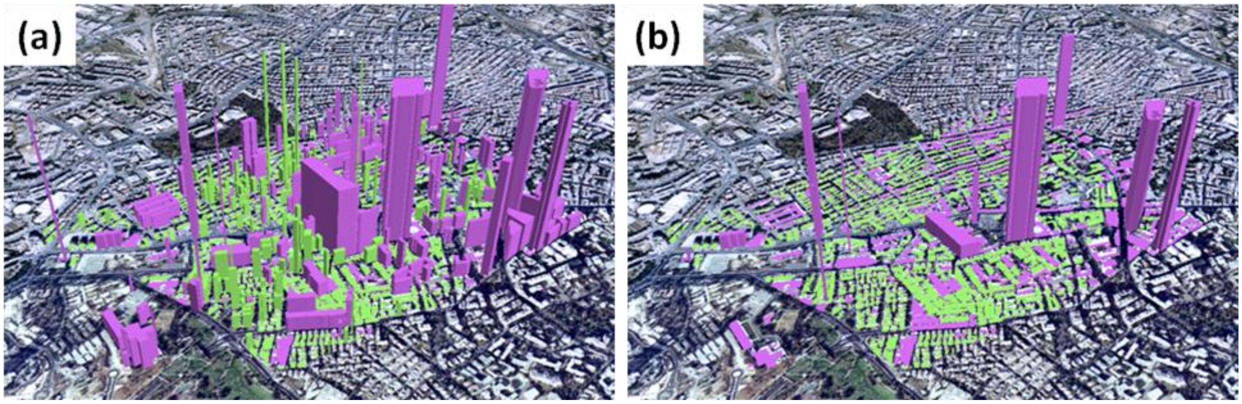

Figure 5 – Frequency of change in land-use for no policy scenario (a) and policy scenario (b). Height represents the number of simulation runs for each building in which the final land-use was different than the initial one. Color represents initial use – residential (green) and non-residential (purple).

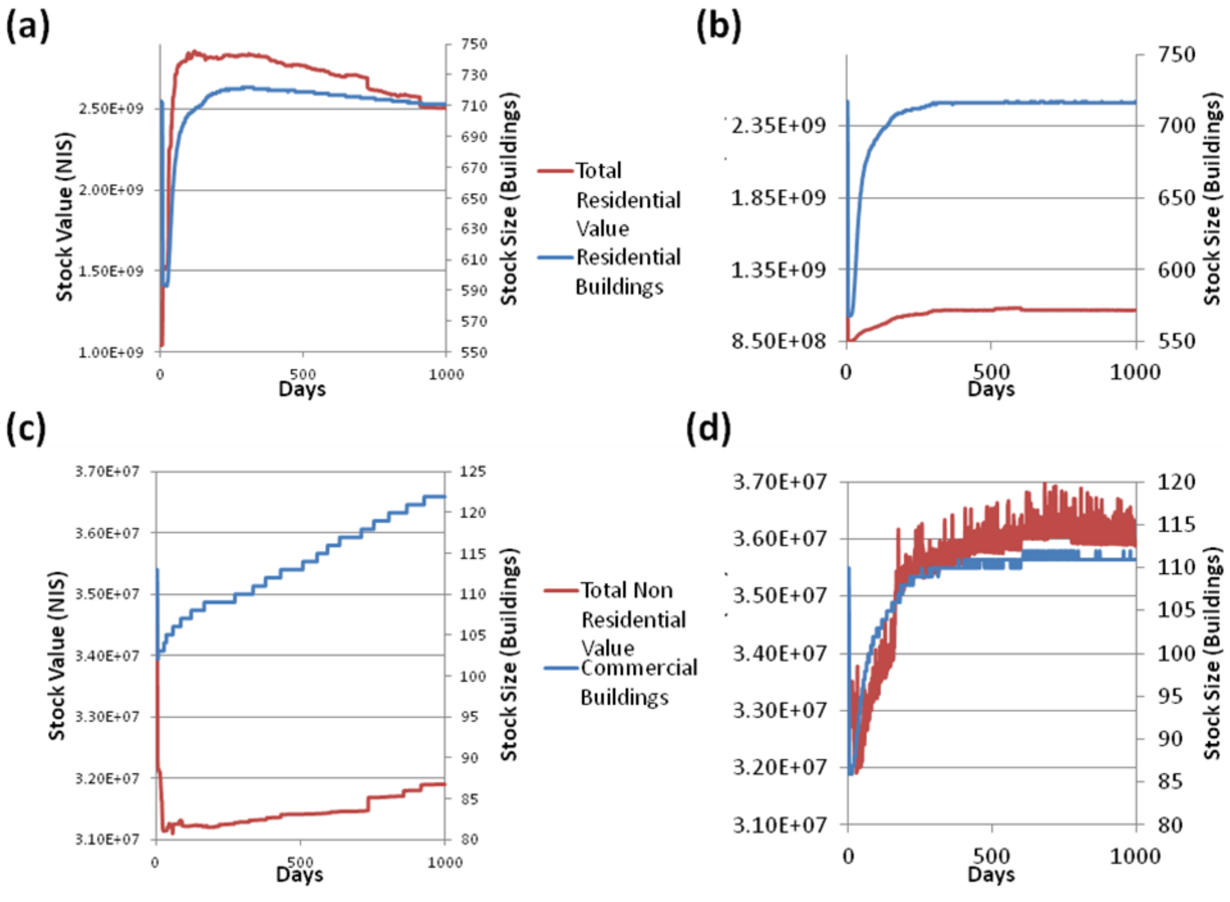

Figure 6 – Changes in stock size and value, for residential (a) and non-residential (b) capital stock in the no policy scenario, and residential (c) and non-residential (d) stocks in the policy scenario

Scenario	State	N	Average Non Residential Floor Space around CBD	Total Non Residential Floor Space	CBD movement (Meters)
	Initial State	35	4,575.97	924,279.59	0.00
No Policy	**Average Final State – all**	35	3,217.63	722,116.30	20.38
	Average Final State – CBD movement	4	3,421.54	726,528.41	178.33
	Average Final State – no CBD movement	31	3,191.32	721,547.00	0.00
Policy	**Average Final State – all**	35	3,940.65	804,589.79	5.10
	Average Final State – CBD movement	1	3,301.20	779,024.24	178.33
	Average Final State – no CBD movement	34	3,959.45	805,341.72	0.00

Figure 7 – Effects on CBD, by scenario.

Scenario	**No Policy**				**Policy**			
Measure	**No. of times previous values restored**	**Average duration to restore values**	**No. of times new equilibrium reached**	**Average duration to new equilibrium**	**No. of times previous values restored**	**Average duration to restore values**	**No. of times new equilibrium reached**	**Average duration to new equilibrium**
Population	0/35	--	35/35	858	0/35	--	35/35	860
Total residential value	0/35	--	20/35	835	33/35	246	8/35	916
Average residential value	0/35	--	22/35	843	33/35	54	9/35	918
Total non residential value	1/35	12	35/35	324	31/35	122	2/35	937
Average non residential value	22/35	145	32/35	819	24/35	40	1/35	940

Figure 8 – Equilibrium measures, by scenario