

Exploring the Dynamics of Urban Development with Agent-Based Modeling

Ammar A. Malik, PhD

Center on International Development & Governance
Urban Institute, 2100 M St NW, Washington DC, USA
amalik@urban.org

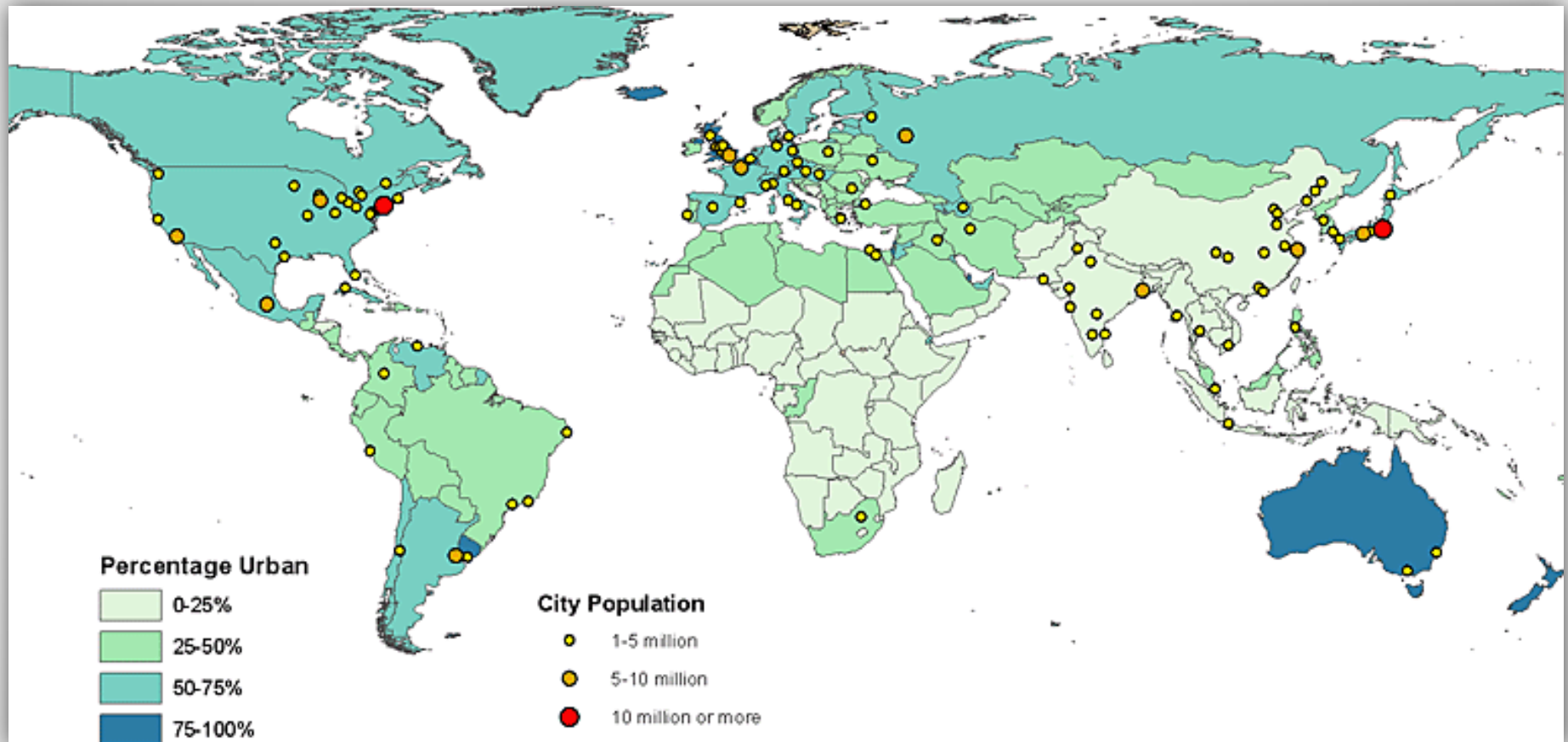
PIDE Nurturing Minds Seminar Series

April 8th 2015

Presentation Outline

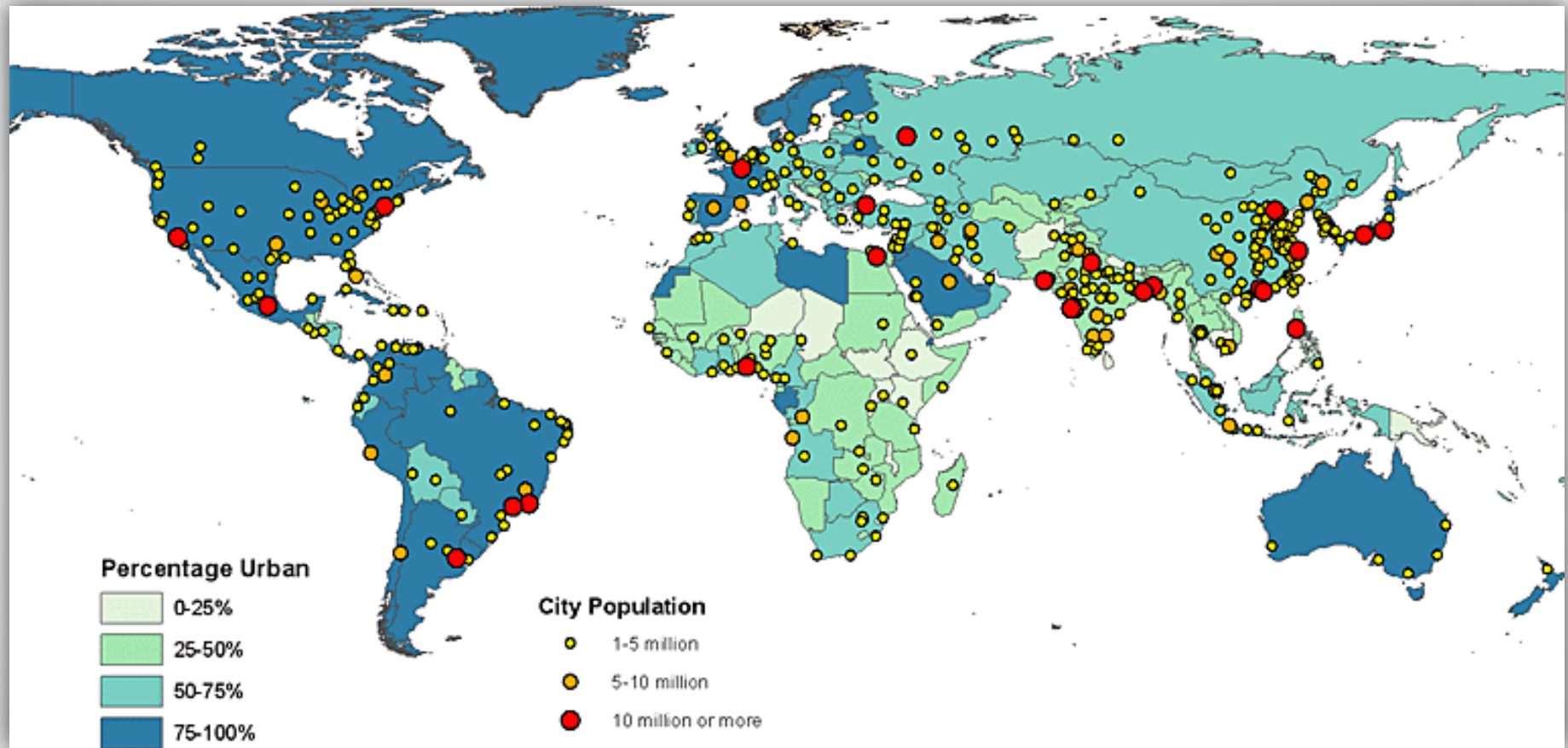
- Research Context, for background
- Key Insights from Literature
- Research Framework, including methodology
- The Creative City Model
- Summary of Policy Implications
- Questions and Discussion

Percentage of Urban Population by Size, 1960



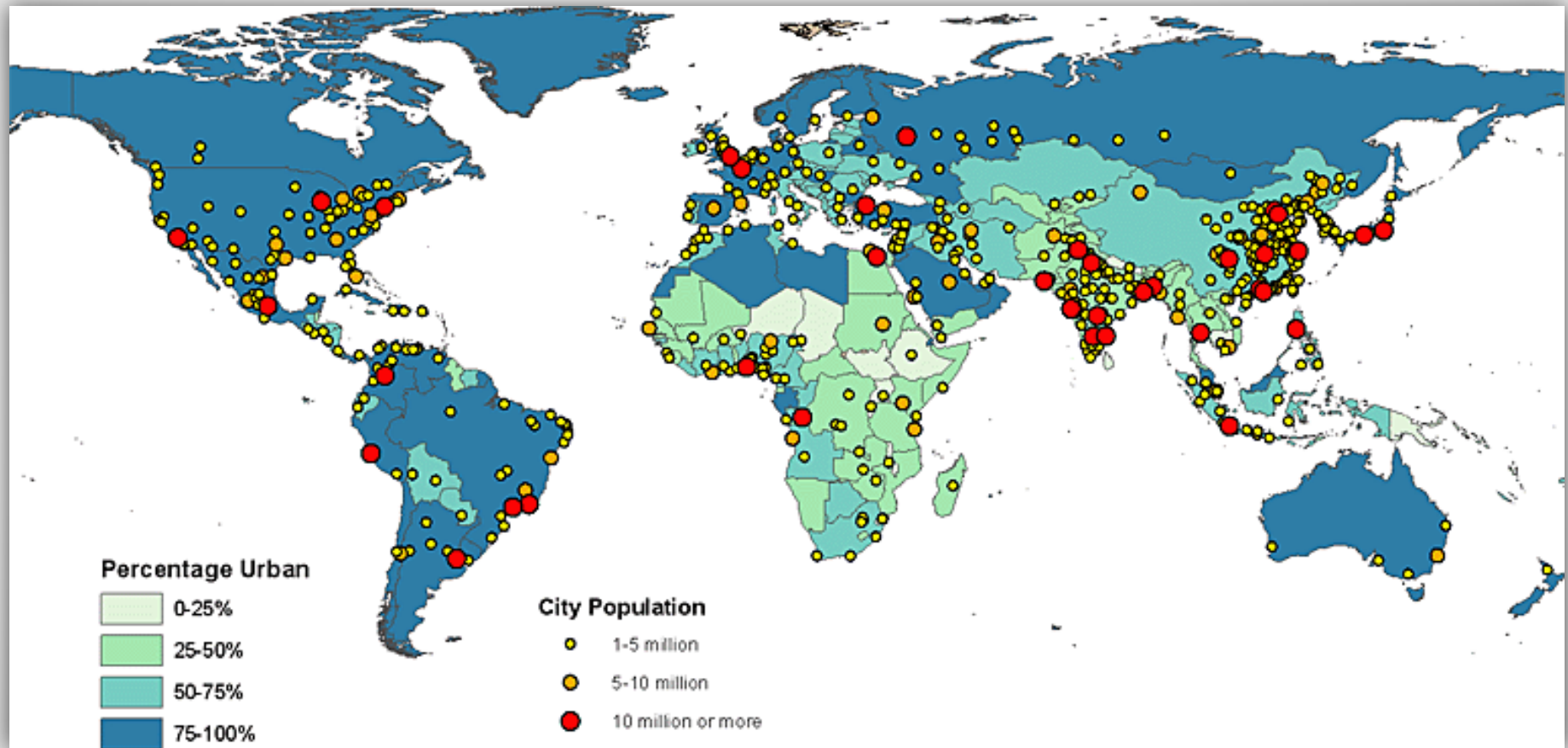
Source: UN Stats

Percentage of Urban Population by Size, 2011



Source: UN Stats

Percentage of Urban Population by Size, 2025



Source: UN Stats

The Century of Cities

- Worldwide urbanization was 33 percent in 1960; grew to 50 percent in 2006, expected to rise up to **75 percent by 2050**.
- Every week, more than **1 million people** are being added to cities, likely to continue till 2050.
- The rise of **poor megacities** with low governance capacity.
- **Problems:** congestion, energy shortages, pollution, crime etc.
- **Opportunities:** hubs of talent, avenues for entrepreneurship and drivers of economic growth.
- **Challenge:** maximizing benefits while minimizing costs!

Insights from Literature

Literature I – Key Insights

- Cities are “*human systems*” and “*..happen to be problems in organized complexity, like the life sciences.*” (Jacobs 1961)
 - “*...the whole is more than the sum of the parts.*” (Simon 1962)
 - Exhibit emergence, interdependence, tipping points etc.
- Florida’s (2002) “Theory of the Creative Class” –
 - Presence of creative workers, who “*draw on complex bodies of knowledge to solve specific problems*” associated with prosperity.
 - The 3Ts: Technology, Tolerance & Talent and the Creativity Index.
 - One explanation of the drivers of urban economic performance.
- Urbanization has both positive and negative externalities
 - Productivity increases achieved from density of jobs and creative interactions, public transit improvements, and greater tolerance.
 - But traffic congestion, unaffordable land rents and intolerance limit these positive externalities in real world cities.

Literature II – Main Stylized Facts

- **Density** of all types fosters human interactions, which are “*the loci for development*” (Glaeser 2011)
 - Doubling employment density associated with 2-6 percent rise in productivity (Combes *et al.* 2010; Baldwin *et al.* 2010).
 - “Creative Density” associated with productivity improvements, using panel data of 240 U.S. metropolitan regions (Knudsen *et al.* 2008).
- Accessible Urban **Mobility** allows interactions, Alonso’s (1964) bid-rent framework remains relevant
 - Per unit rents much higher in CBDs, established by panel data from 120 U.S. metros (Drennan and Kelly 2011).
 - “Tyranny of Distance” (Atkinson 1998) overcome by public transit.
- Societal **Tolerance** and the non-existence of segregation are prerequisites for improved economic performance.
 - Vibrant and unique urban cultures, along with ample public spaces needed to attract, retain and produce top talent (Landry 2000).
 - Segregation along ethnic or economic destroys the urban fabric, which has been the hallmark of great cities (Mumford 1964).

Literature III – Modeling Cities

- Models are cognitive aids (Bailor-Jones 2009) for overcoming the bounded rationality of human minds (Simon 1962)
 - Simplified abstractions of complex realities, *“All models are wrong, some are useful”* (Box and Draper 1986)
- Predictive ability is contested, depends on the tradeoff between openness and explanatory power (Rosenberg 1995)
 - Simulations are models that change over time, thus create artificial social laboratories for experimentation (Axtell and Epstein 1999)
- Urban modeling’s journey from macroscopic to individual-level (Batty 2007) and from static to dynamic (Torrens 2002)
 - ABMs allow “theory building” and “hypothesis generation” along with the ability to simultaneously handle several parameters (Barros 2012)
 - ???

Research Framework

The Framework

- **Research Questions**
 - What factors are inhibiting the emergence of creative clusters in cities of the developing world?
 - What kinds of spatial urban forms and socioeconomic conditions could facilitate their emergence?
- **Theory Building** from “stylized facts” (Kaldor 1957)
 - Population Density
 - Urban Mobility
 - Societal Tolerance
- **Modeling Approach / Research Methodology**
 - Artificial environment from empirically grounded facts.
 - Simulate from the bottom-up at the micro-level with heterogeneous agents and the ability to test scenarios.

Why use Agent-Based Modeling?

Traditional Models	Agent-Based Simulations
Deterministic (one future)	Stochastic (multiple futures)
Allocative (top-down)	Aggregative (bottom-up)
Equation-based formulas	Adaptive agents
Do not give explanations	Explanatory power
Few parameters	Many parameters
Environment Given	Environment Created
You can React to them	You can Learn from them

Source: Bernard (1999)

The Creative City Model

Model Purpose

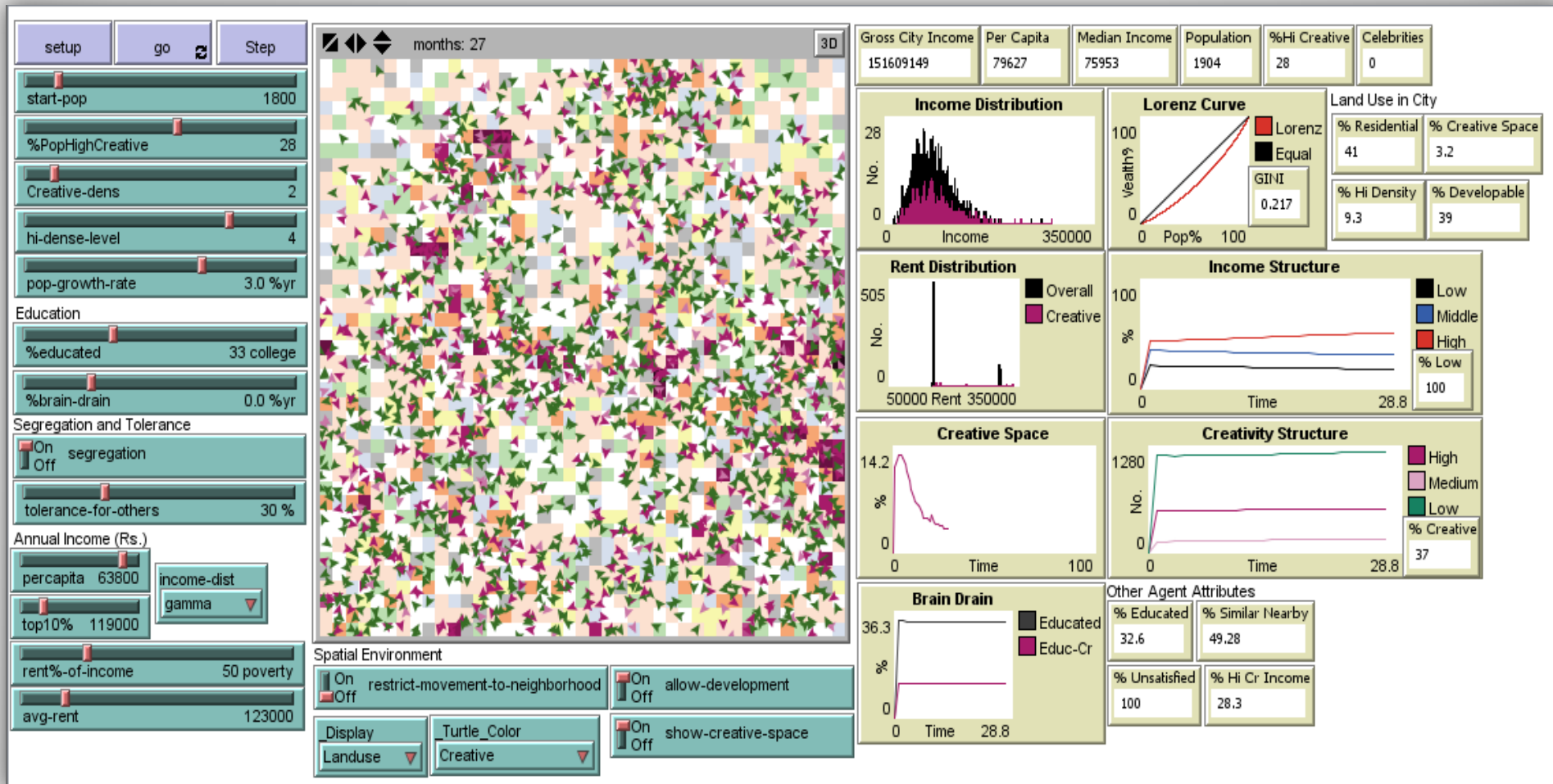
- An **Urban Laboratory** for asking **what-if** questions and **testing policy ideas**.
- **To Explain:**
 - The relationship between land-use regulation and creative economy.
 - When, where and how creative clusters emerge in cities?
- **To Test Policy Scenarios:**
 - What if land-use zones are altered in favor of mixed land-use?
 - What if urban mobility or transportation costs change?
- **“Level 1”** model, only in qualitative agreement with emergent macro-structures of cities(Axtell and Epstein 1994).

Basic Model Interface

Inputs

Environment

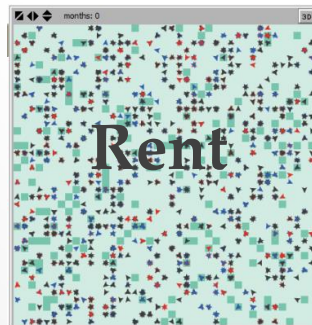
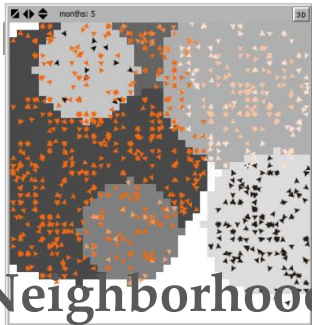
Outputs



<http://css.gmu.edu/CreativeCity>

Model Features and Attributes

Environment



Individual Agents

Income
Tolerance
Education
Neighborhood

City Level Factors

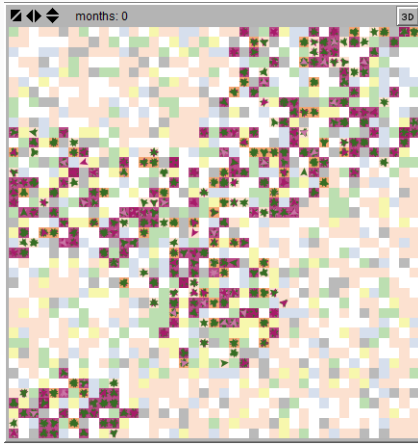
Population growth rates
Brain Drain

Observer Controls

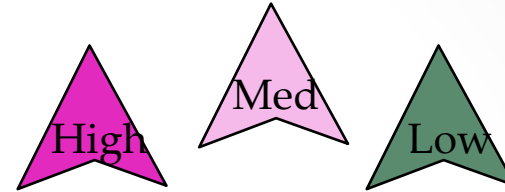
Development Restriction
Mobility Control
Segregation/Tolerance

Model Features and Attributes

Environment



Individual Agents



Creativity Level

Creative Space and Value

- Based on frequency of visits by medium and high creative agents.
- Or, based on creative-density.

- Assigned at model setup.
- Can increase when an agent is “inspired” by partnering with a high creative agent in a creative space.

Summary of Agent Attributes

Attributes	Range
Creativity	Low, Medium or High
Education	Educated or Uneducated
Monthly Income	Rs. 1,000 – 350,000
Tolerance	1 – 99 percent

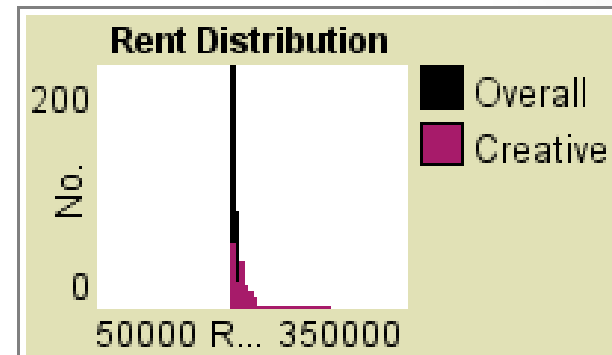
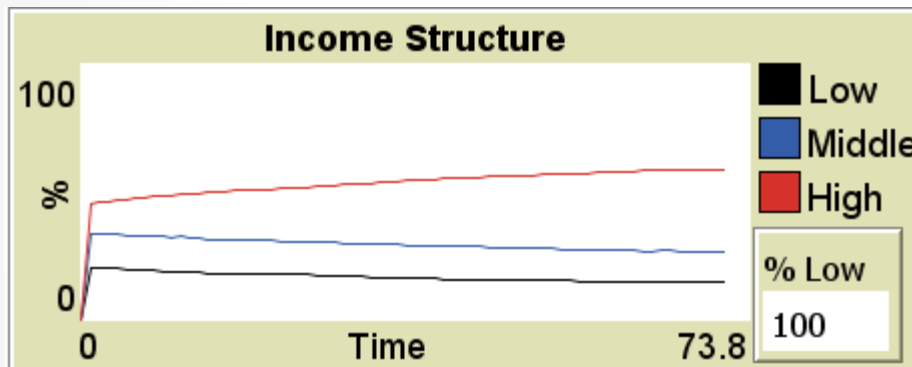
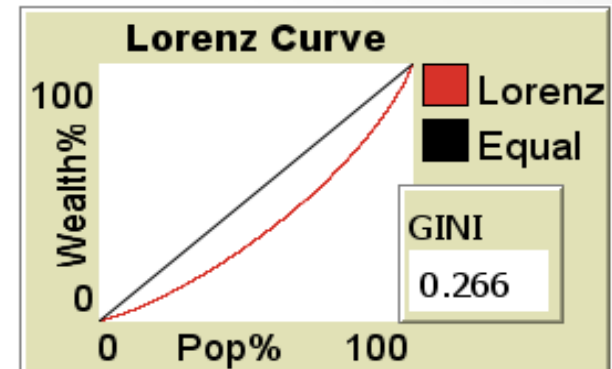
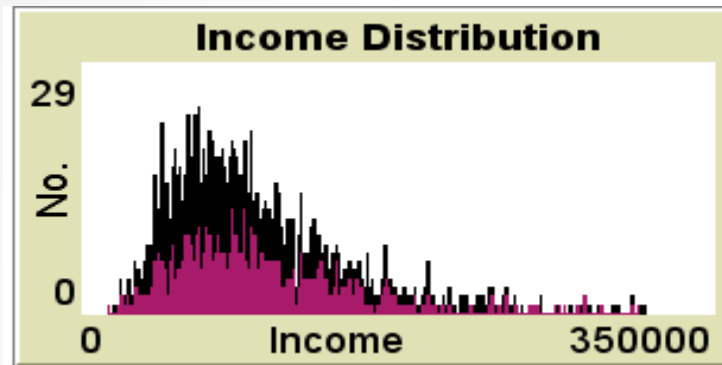
Summary of Cell Attributes

Attributes	Range	Details
Creative Value	$1 - \infty$	Determined by Creative Values.
Land Use Type	$1 - 7$	Commercial, Residential, Mixed land-use, Public Space etc.
Population	$1 - 2,100$	Number of agents residing.
Rental Rate	$1 - 150,000$	Monthly rent, units.

Behavioral Rules Summary

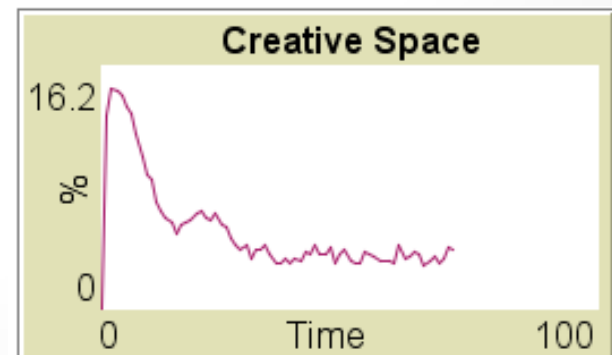
Role	Behavioral Rule
Agent Movement	Stop when satisfied (based on environment) and content (based on nearby agents)
Agent Interaction	Partnering may lead to increased creativity level
Environment Values (Density, Rent, Occupancy, Creative Value)	Based on density/frequency of agent visit
User controls	Impact range of movement of agents
User interaction	Modify values, change display of environment and agents based on attributes, query agents

Model Outputs



Land Use in City

% Residential	% Creative Space
42	4
% Hi Density	% Developable
15.6	53



Typical Model Run



<http://css.gmu.edu/CreativeCity>

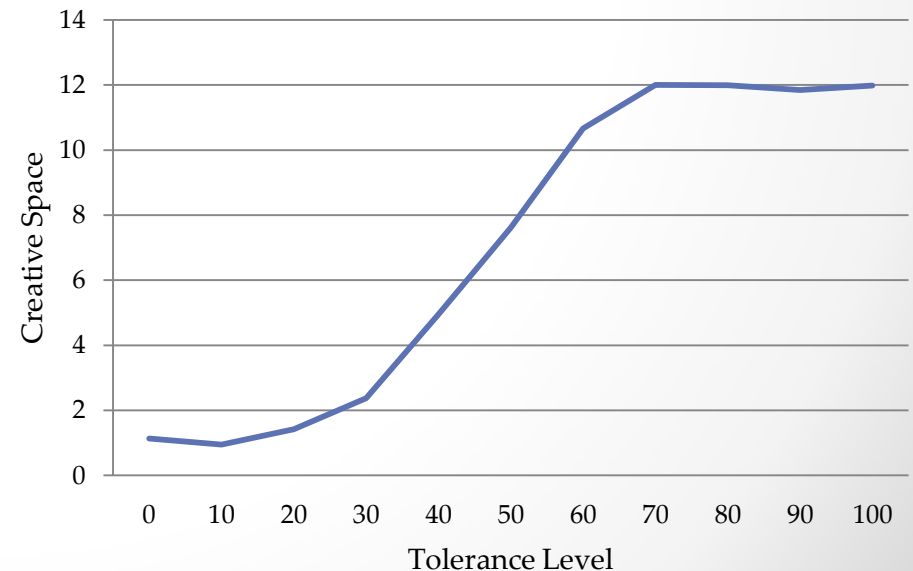
Model Verification

- Allowing development typically increases amount of creative space.
- Restricting movement does not have as big an impact as anticipated.
- Ability to afford rent in a desired neighborhood and tolerance of the neighbors also have a large impact.

Rent Percentage of Income



Tolerance Level



Karachi Experiment

Input Parameters	Karachi Values*
Starting Population	2,100
Population Growth Rate	8
Education	50
Brain Drain	3
Percent Highly Creative	15
Tolerance	30
Income (average) / Top10	30,000 / 100,000
Average Rent	12,000
Rent Percentage of Income	30

Karachi values interpolated based on Karachi youth survey 2011.

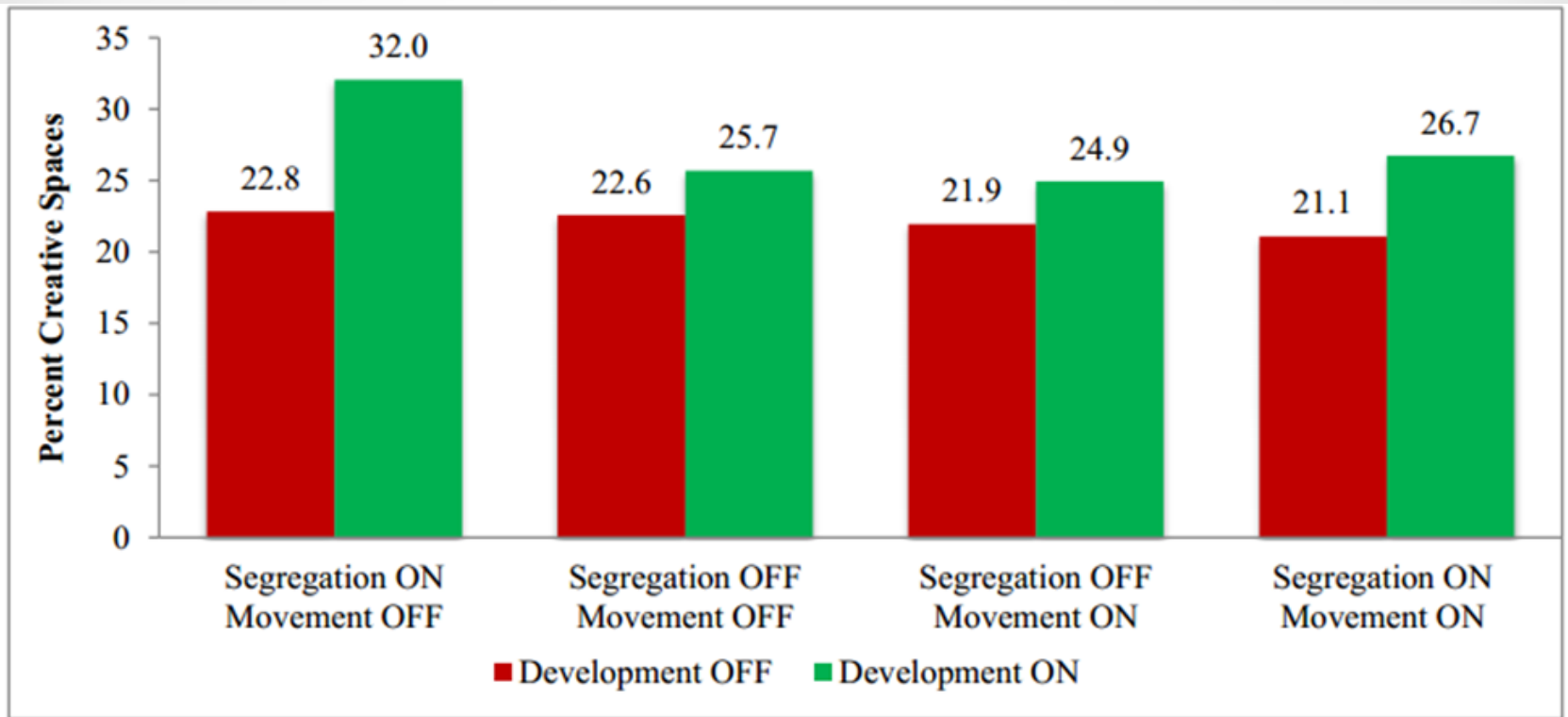
Experiments*
Movement ON/OFF
Development ON/OFF
Segregation ON/OFF

Run model for period of 10 years for each combination

Business as usual...

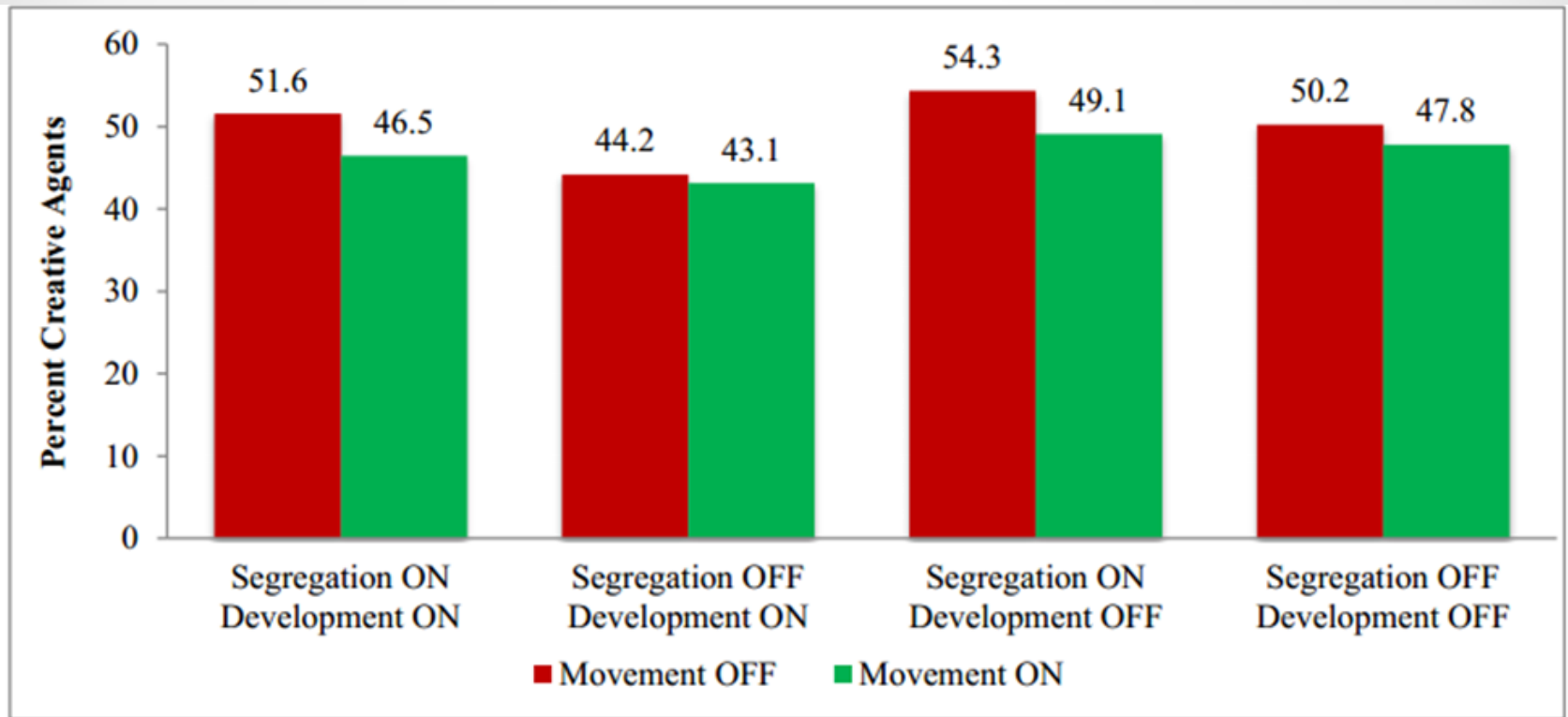
Key Outputs	Today	3 Years	5 Years	10 Years	20 Years
Percent Highly Creative	10	7	6	3	1
Gini Coefficient	0.67	0.66	0.69	0.72	0.75
Percent Creative Space	1.8	3.7	6	4.5	4.8
Percent University Edu.	50	38	32	21	15
Average Income (Rs.)	37,000	41,165	45,200	55,013	60,394

Development



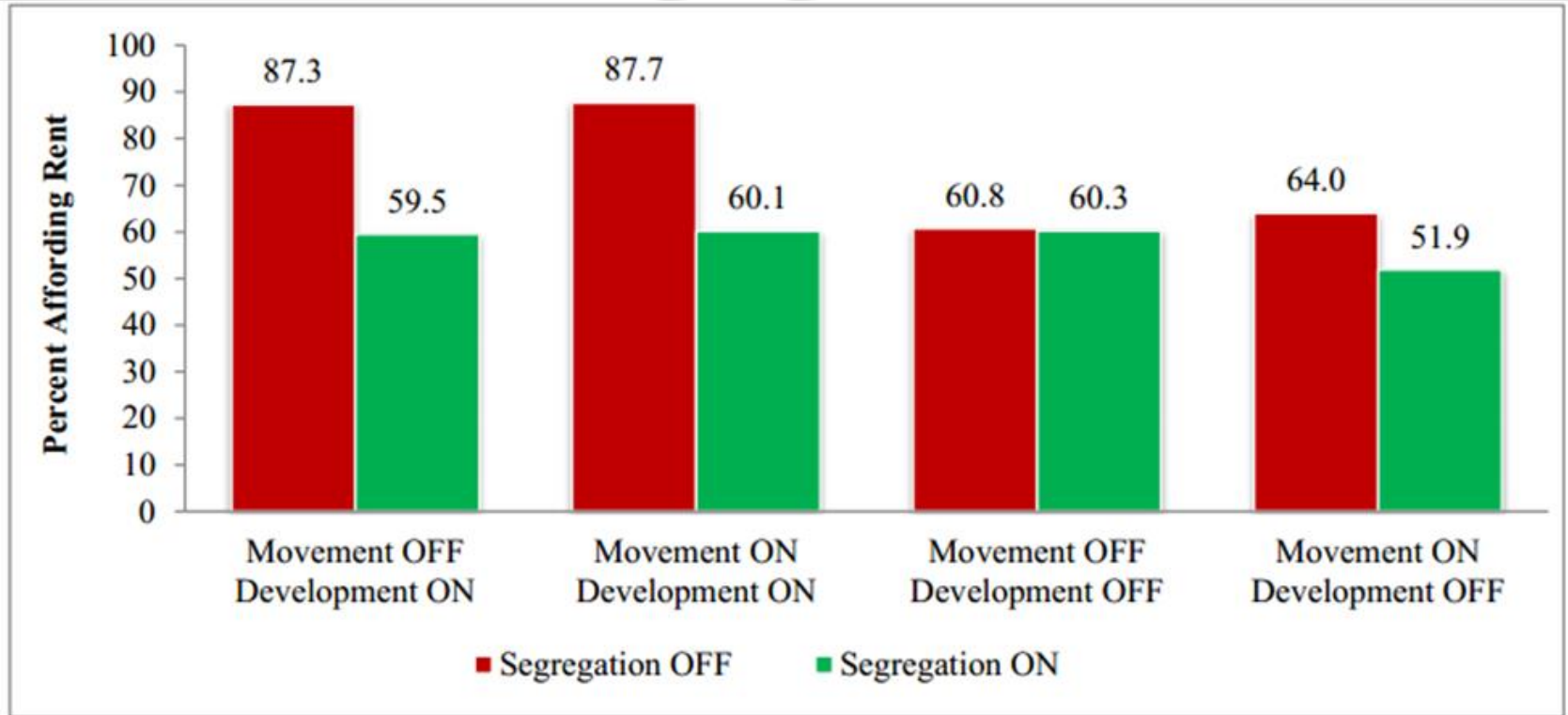
- Development, proxy for density, is sensitive to creative spaces.
- Allowing development fosters creative spaces, and packing people together results in greatest clustering.
- Highest level achieved with Dev On, Seg On, Mov Off.

Movement



- Allowing movement always reduces creative agent population!
- Relatively low sensitivity of creative agents to movement, but highest levels achieved when movement was restricted with segregation.
- Highest creative agent population when Mov Off, Seg On, Dev Off. •

Segregation



- Absence of segregation improves rent affordability, especially when development is allowed.
- Development improves rent affordability, movement not as sensitive.
- Highest affordability with Seg Off, Mov On, Dev On.

Summary of Key Findings

- Tested for two policies, Development and Movement, and one societal change, i.e. Segregation/Tolerance.
- The intensity of interactions, and clusters of creativity are crucial.
- Mixed land-use, greater mobility or tolerance won't work alone.
- Policy trade-off between widespread rent affordability and the rapid diffusion of creativity.
- Challenge of applying theory based on datasets from the developed world, to the developing world.
- More experimentation, calibration & interpretation required!



Exploring the Dynamics of Urban Development with Agent-Based Modeling

Ammar A. Malik, PhD

Center on International Development & Governance
Urban Institute, 2100 M St NW, Washington DC, USA
amalik@urban.org

PIDE Nurturing Minds Seminar Series

April 8th 2015