Overview, Design concepts, and Details (ODD) of the Creative City Model

This document is intended to describe fundamental aspects of the Creative City Model following the ODD protocol developed by Grimm *et al.* (2006). Figure 1 below provides the graphical user interface which captures all primary elements of the model. The user specified input parameters are listed on the left panel, and are arranged in categories of agent attributes including population, education, segregation, and income levels. The right panel contains several graphs, charts and reporters containing output values obtained from the model. Finally, the middle panel includes the model environment and related user controls for experimentation.
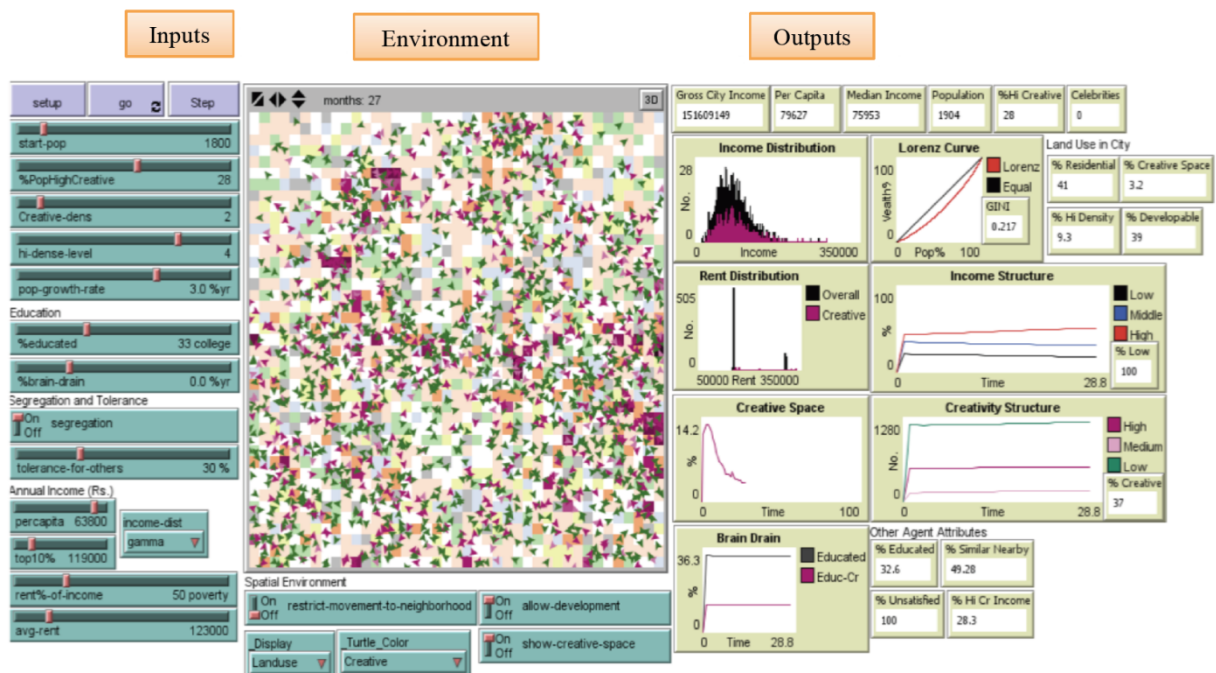

Figure 1: The Creative City Model User Interface

1 Overview

1.1 Model Purpose

The model is designed as a tool for understanding the relationship between human creativity and urban development through transportation, social segregation and land-use regulation perspectives. Obtaining stylized facts from urban studies literature, we create a simplified

theoretical abstraction of real-world cities to better understand specific dynamics of urban development. Moreover, the model allows users to run "what-if" scenarios, generate hypotheses and test policy ideas related to urban development policy.

1.2 State Variables and Scales

Since the main focus of this model is the interaction of individual agents residing within the city, we attempt to create representative agents that capture various elements of modern urban life. The model's environment is theoretical, albeit land-use structure is obtained from real-world zoning information from Karachi, Pakistan.

Individual heterogeneous agents are the most significant component of this model. Their location decisions and rule-based interactions determine the shape and size of creative clusters. Despite the innate creativity of each individual, the extent to which they apply it in professional settings varies. In the absence of any objective metrics for human creativity (Torrance, 1988), we classify agents as having low, medium or high levels of creativity. This classification merely highlights the extent to which agents apply creativity for problem-solving in their workplace. To further minimize pre-supposed subjectivity, we allow users to set the percentage of highly creative individuals in the model. The model then equally divides the remaining agents between the medium and low categories. As the simulation progress through time and thus agents interact, these creativity levels become crucial determinants of residential clustering and associated economic outcomes.

As shown in Table 1, each agent possesses several socio-economic attributes including literacy and annual income levels. The user-specified education level randomly assigns each agent as either educated or illiterate, without differentiating them by level or type of education. Upon model setup, an income distribution (user-defined, either bimodal or gamma) is created around the user-specified average and top ten percent income levels, thus allowing users to control both absolute and relative prosperity. Every agent is therefore allocated a starting income level at the onset, which is subject to change during the course of model runs. Besides individual attributes however, agent behavior is impacted by several user-defined inputs such as agent population growth rate, societal tolerance level, rate of brain drain, restrictions on agent mobility and new construction, as discussed in Section 2.

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

Table 1: Summary of Agent Attributes

Given the model's theoretical focus, we design an urban landscape that broadly replicates real-world urban land-use patterns. Since urban land-use is regulated by local government primary through zoning laws, we classify constituent urban land cells as follows: residential (60 percent), commercial (10 percent), green area (10 percent), water way (10 percent) and infrastructure (10 percent). Notwithstanding the unique land-use mix of each city, we estimate these values from Karachi, Pakistan. In the absence of government issued land-use maps, we undertook visual inspection using Google Earth imagery to determine the approximate land-use structure through a 40 x 40 grid representing roughly 1,600 square kilometers of the Karachi region. At the time of model initialization, these land-use categories are randomly applied onto constituent cells. The presence of high or medium creative agents on any residential parcel boosts the creative value of land cells and the user-specified creative density level serves as the threshold to classify land parcels as being creative or otherwise. Being creative often becomes the starting points for the emergence of creative clusters. However, while agents are free to move across the environment, they can only settle in residential areas. As clusters grow, neighboring commercial zones and public spaces get absorbed into them as well.

In line with standard ABM practice, land units essentially act as interactive agents albeit without spatial mobility capability. Their basic attributes however, including rental price and creativity level, dictate the behavior of agents operating within them. Average annual rents are user-specified, but vary across cells on the environment and depend on their population density and creative value (defined as number of high or medium creative) population density. As the model progresses through time, the spillovers from highly dense land units diffuse into the surrounding von Neumann neighborhood of 4 adjoining cells, boosting their creativity and

population density (von Neumann, 1966). As these surrounding cells are frequented by agents with medium and high creativity, they gain creative value, thus resulting in the emergence of clusters of creativity.

As shown in Figure 2, the color intensity of land patches indicates the density of creative population, with darker shades representing greater creativity and consequently, higher rents. Similarly, the triangular-looking agents are color coded accordingly to creativity endowments with green, pink and magenta representing low, medium and high levels respectively. The model initializes with allowing agents to start out on patches that are residential but can then move around from these patches or move to find more affordable living. Some of the patches may be visited but cannot be inhabited as they represent land-use types that are typically off limits to residential settlements such as waterways, industrial zones and green areas. The user however has the option of allowing development into some of these areas. In order to capture spatial segregation of real-world cities, the environment constitutes seven randomly assigned neighborhoods (inspired by the number of Karachi's constituent zones) with some overlap. Users can view the environment by toggling between color-coded land-use types (shown below), the neighborhood boundary configurations, rents, and creative value.

Figure 2: Creative City Model Environment

1.3 Process Overview and Scheduling

The key output from the model is the emergence of creative clusters depending on various input configurations from the interactions of individual agents. Therefore, the percentage of land parcels classified as creative (termed creative spaces) and their clustering offer the most useful insights. As consequences of these agglomerations, problems of income inequality and thus socio-economic disparity emerge (Peck, 2005). These problems are captured by the model's constantly updating output side displays including the Lorenz curve, income distribution and per capita income. As will be discussed in Section 3, housing affordability is central to the evolution of simulated social interactions in our model, hence the distribution of rents indicator offers insights on the interplay of rent levels with the overall spatial structure of the city.
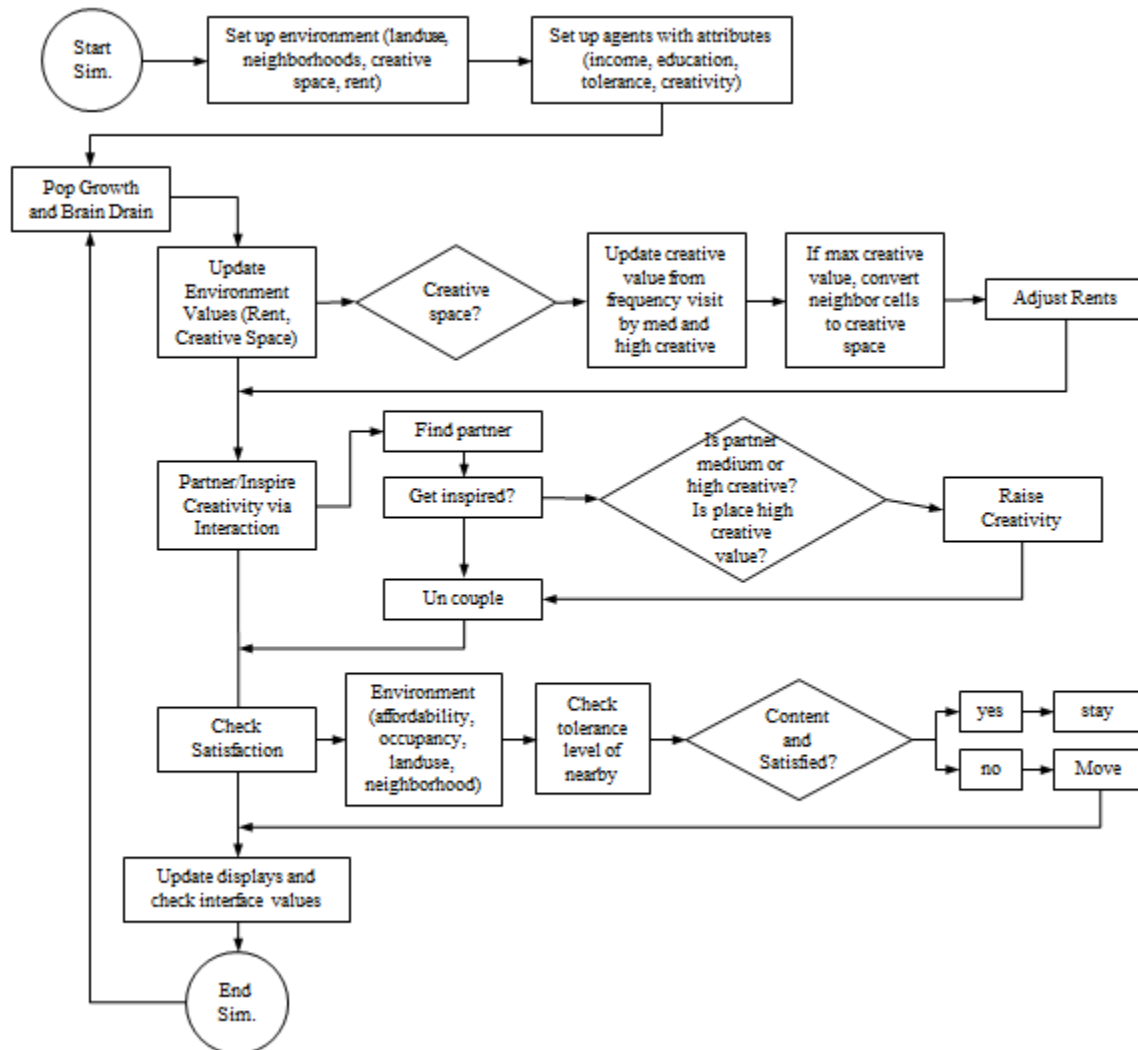

Figure 3: Creative City Model Logic Flow

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2 Design Concepts

2.1 Observation

The model's environmental visualization is demonstrated in Figure 1, allowing users to follow the diffusion of creativity and emergence of creative clusters in the city. While color coded patches indicate land-use type, the emergence of multi-cell dark purple patches indicates the density of creative agents residing in these areas. At the global level, we monitor the following statistics as indicated on the user interface: percent creative spaces, income distribution, GINI coefficient, per capita GDP, percent highly creative agents, brain drain level and percent educated. In addition, users have the option of viewing the environment based on land-use structure, neighborhood configuration or by levels of creativity.

2.2 Interactions

The interactions amongst agents and between the environment and agents dictate the dynamics and development of the model through time. Agent movements trigger serendipitous encounters that potentially lead to entrepreneurial ventures creating economic value. The frequency and success of these encounters depends largely on the environmental attributes such as the creativity level and rental rates. Agents settle in patches where they can achieve complete rent affordability.

2.3 Sensing

At all times, agents are aware of the environmental attributes related to their residential patches. Moreover, they actively compute the average creativity level of agents in a 4-cell neighborhood to determine whether they are currently in a preferred area or otherwise. In interacting with other agents, they gauge their partner's creativity level along with environmental endowments before deciding to sprout a partnership.

2.4 Emergence

The spread of creativity in the model demonstrates emergence, with the partnering of two or more agents creates additional economic value. In other words, the whole turns out to be the sum of the constituent parts. The key takeaway from the model therefore is the emergence of economic value from the interaction of creative agents in well-endowed patches with the city.

2.5 Stochasticity

At the time of setup, the agents acquire income levels based on random distribution which adds an element of stochasticity into all subsequent model runs. In other words, the starting income levels profoundly impacts outcomes at the individual level, which in turn adds up to the macro level. Several user defined model inputs add stochastic characters to the model, including the creativity distribution, educational attainment, rates of brain drain and population growth etc.

3 Details

3.1 Initialization

The model is initialized based on a series of inputs form users, as well as pre-defined values obtained from Karachi, Pakistan which serves as the sample city. Users can therefore run experiments by varying input parameters and observing their impact on the environment and output panels as described earlier. For example, what impact will the relaxing land-use regulations and zoning laws have on the distribution of agents throughout the city? Using data from Karachi, the default input values are summarized in Table 2 below.

Input Parameters	Experiment Values[1]
Starting Population	2,100
Annual Population Growth Rate	8 percent
Literacy Rate	50 percent
Annual Rate of Brain Drain	3 percent
Proportion of Highly Creative Agents	15 percent
Average Societal Tolerance Level – Segregation	30 percent
Monthly Income: per capita / top 10 percent	Rupees 30,000 / 100,000
Average Monthly Rent	Rupees 12,000
Rent Percentage of Income Affordability Threshold	30 percent

Table 2: Input Parameters for Experiments

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[1] The following variables estimated from Karachi youth survey: literacy rate, rate of brain drain, proportion of highly creative agents, societal tolerance level; population growth rate and starting population from Kotkin and Cox (2003); income distribution from Pakistan census data; rental rates using real-estate website Zameen.com; and rent affordability threshold from U.S. government standards.

3.2 Inputs

The set of input values detailed in Table 2 were obtained from multiple sources, with the Karachi Youth Survey of 2011 (Malik and Karim, 2012). The survey provided estimates for levels of educational attainment, brain drain, high levels of creativity, income distribution and tolerance levels of the 18-34 year age cohort of the city. Moreover, the model's starting agent population was based on recent estimates that the city's population has crossed 21 million; hence each agent in our simulation represents approximately 10,000 real-world urbanites (Kotkin and Cox, 2013). Monthly rent estimates were obtained through data mining from Pakistan's largest real estate web portal Zameen.com. Moreover, the Pakistan government's latest census data was utilized to estimate population size, growth rates and income distribution.

3.3 Submodels

Several sub-models interact with each other to constitute the model as follows.

3.3.1 Agent Mobility

The seemingly random movement of agents in the model is dictated by their desire to acquire satisfaction, without which they continue their movements. The first component of satisfaction is rent affordability, measured by their ability to afford housing within the user-defined rent percentage of income threshold, as defined by the following condition:

$$R_{im} \leq \alpha\, \rho_{im} \qquad (1)$$

Where R_m is the monthly market rent in any given neighborhood, α represents the user-specified rent percentage of income threshold and ρ_m is the level of monthly income any given agent. The second determinant of satisfaction applies when segregation is applied, and requires each agent to reside exclusively in neighborhoods with similar-agent majorities as discussed earlier. To determine similarity, each agent accesses whether the majority of agents on the eight surrounding cells are within 25 percentage points of their own tolerance level, which is assigned through user-specification. The satisfaction condition is defined as follows:

$$-1.125\left(T_j\right) \leq \tau_i \leq +1.125\left(T_j\right) \qquad (2)$$

Where T_j is the tolerance level for any given eight-patch local neighborhood and τ_i represents the individual tolerance levels of specific agents. Together, the satisfaction of these

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two conditions allows agents to reside on a given cell; if these conditions are not met the agent will continue moving in search for satisfactory conditions.

3.3.2 Diffusion of Creativity

Although every interaction between agents will not produce economic value, the likelihood of increasing income may occur when two highly creative agents interact in a high creative value neighborhood. This captures perhaps the fundamental insight from Glaeser (2011) and Florida (2002, 2012) who believe that urban neighborhoods endowed with mixed land-use, walkability, transit accessibility and great public spaces etc. cultivate a culture of entrepreneurship and innovation. These areas are therefore endowed with creative potential, and as medium and high creative agents interact in this space, it raises the creative value of the location.

Given the theoretical nature of this model and our desire for generalizability, we have created a proxy for measuring urban amenity endowments of neighborhoods, i.e. the creative value. In essence, it is a summation of the creative values of agents which can be expressed as follows:

$$\sum_{i=1}^{n} CV = \sum_{i=1}^{n1} 10\,(ch_n) + \sum_{i=1}^{n2} 5\,(cm_n) + \sum_{i=1}^{n3} 1\,(cl_n) \qquad (3)$$

Where CV stands for the total creative value of each patch while ch_n, cm_n and cl_n represent the number of highly creative, medium creative and lowly creative agents respectively. Moreover, the total number of agents is merely a summation of the three categories of agents as follows: $n = n1 + n2 + n3$. Given that creativity is an inherent human characteristic (Simonton, 2012), we allocate one creative value point to low creativity agents, five points to medium creative, and 10 points to high creative agents. However, the cell will lose creative value it does not continually attract creative agents and as such it may decay back to zero. The resulting pattern is that some creative clusters may emerge and exist for a short time span, but not all of them will persist through model runs stretching over several years.

3.3.3 Income and Rental Markets

Real-world urban income data based on multiple countries reveals that per-capita income mostly follows a two-peak distribution, one each for lower- and upper-income stratums of society (Quah, 1997). Therefore, the income of agents in the model is distributed either by gamma (Salem and Mount, 1974) or bi-modal distribution depending on user preference. At the initial

setup, each agent is allocated an annual income level which updates throughout model runs in several ways. First, agents who change their creativity state (this occurs after interacting with a higher creativity agent) receive a five and two percent income increase respectively. This is a reflection of the real-world reality that creative class agents enjoy higher per-capita income levels (Florida, 2012). In recognition of the real-world phenomenon of demand-supply dictating rental prices, the model assumes that high creative value neighborhoods are more desirable. Thus greater demand and static supply results increases rents. At each model cycle, neighborhood rents increase automatically as shown in Table 3 below:

Neighborhood Creative Value Range	Rent Increase (%)
1 – 50	0
50 – 100	5
100 – 300	10
300 – 500	50
500+	100

Table 3: Creative Values and Rents

3.3.4 Population Growth and Brain Drain

The user-defined population growth rate, representing both natural growth and inward migration, impacts all agents irrespective of their creativity level. On the other hand however, brain drain is by definition the loss of creative and educated professionals from the workforce hence it does not impact lowly creative agents in the population (Stark, 2004). The following equation explains this as follows:

$$P_t = [(p_{t-1}^c \Delta P) - \Delta \beta] + (p_{t-1}^{nc} \Delta P) \qquad (4)$$

Where P_t is the total agent population in the current time period, and p^c and p^{nc} represent current populations of creative and non-creative agents respectively. In addition, ΔP is the user-defined annualized population growth rate and $\Delta \beta$ is the rate of brain drain, the later applying only to highly creative and medium creative agents. In many developing countries, the continual

loss of highest quality talent to foreign country poses significant challenges for economic development (Haque, 2007).

4 References

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