Gaming the Sustainable City (and Region)

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Abstract

This report explains the results of a seed grant from the Kleinman Center to investigate the development of a game about energy sustainability for a city or region. There were 2 prior game prototypes that were taken as points of departure—Dr. Braham's emergy balance in the New Chautauqua Game (www.ladybug.tools/SettlementEmerge/) and Dr. Silverman's students' agent based model (ABM) of transportation mode choice. With this grant, we merged ideas from both games, and considered what would be needed to make the game more engaging and realistic. We developed and tested a sequence of ABMs that allow players to explore the kinds of unexpected consequences that occur in the real world from the choices made by individual households about their spending and adoption of technologies. This pre-prototype is described in this report. We halted progress when time and budget were used up, but reached two useful conclusions: first, that a realistic experience could be achieved with a simplified number of "zones," e.g central business district, urban residential, suburban commercial, etc., and second that a simple model of "awareness" was not sufficient to capture the dynamics of choice among households of different income, occupation, and location.

Introduction

Energy is the ultimate driver for urban growth and development, providing the engine for all its economic activities and underlying many of the choices that urban designers, city managers, and citizens make every day: where to live, where to work, how far to drive, and how much to buy? Except for a few activities like automobile driving, the connection between energy and everyday life is neither direct nor especially visible. The goal of the project is to model the basic interactions between energy supplies (renewable and non-renewable) and the characteristic activities in a city, using an agent-based simulation to capture the social and economic choices made by the different players.

Urban designers have long recognized the value of simulators and games to help evaluate the tradeoffs that city residents and managers must make to improve the sustainability of cities. These can make more vivid the choices among modes of transportation and settlement patterns, the sizing of city services, and the demands of different energy sources. The prototype simulation is based on classes of households, incorporating the effect of different "values, knowledge, and worldviews" [1] with the dynamics among segments of the population. With the incorporation of critical feedback loops the results becomes non-linear and less intuitive, making a more rewarding game for playing.

The game began with an existing city, loosely based on Philadelphia, so that the choices are constrained by services and infrastructure already in place. For either case – new or existing – the design questions is how a region will respond to changing energy regimes, can it become a more self-sustaining "biosphere" that reduces its carbon footprint while improving quality of life, job opportunities, and income (and hence tax base) for its inhabitants.

Game Rule and Possibilities

The **Game** prototype is based on a system of agents interacting with and modifying land uses on a spatial map

The **Game could be played in three variations (at least).**

1. Changes to an existing arrangement based on agent characteristics and system wide parameters (energy or currency flow, prices, etc.) to study effects or try to reach a goal

2. Formation of a new settlement based on agent characteristics and system wide parameters to study effects or try to reach a goal

3. Design (or formation) of a settlement to achieve a goal of all-renewable resource supply

Energy (or currency) could be treated as

1. A resource constraint, studying the patterns of distribution and intensity that emerge for different fixed rates of flow

Or 2. without flow constraints, as the outcome of agent structure and map characteristics.

In both cases, changing energy prices could be introduced to the exchanges among agents to examine the effect on distribution and intensity in the first case, and on rates of flow in the second case.

The result of game play will be different patterns of settlement and energy use of transportation, building density. The game could also be expanded to include other resource flows (ala the New Chautauqua Game) including food and stuff (non-durable consumption…).

Agents (households) are treated as semi-rational actors, exploring budgetary options about where to live and work based on relative costs (of housing and transportation), but modified by their specific worldview (like De Vries' worldviews [1]), which emphasizes certain values about density, proximity, and other factors. Worldviews could in turn be changed by crossing certain thresholds of wealth, density, proximity, etc., so that population clusters would be self-reinforcing. To make energy work as a currency, the household agents would need some method of differentiating the energy income they receive from businesses.

A first game might focus on a model of an existing settlement (Chautauqua) with existing patterns of settlement, wealth, etc. that would then be altered by changes in rates of energy availability and pricing.

Background

To start this project, we began with an Agent-Based Model (ABM) of transportation mode choice that the Dr. Silverman's students created in his course. In practice, agent based modeling approach is used to model the behavior of a complex system when equations and principles cannot adequately describe and predict a complex system's overall macro-behavior [2].

The ABM proposed model depicts how the rich and poor choose their mode of transportation to work based on distance, gas price and the traffic congestion. The model, which we denoted as model 1 (M1) baseline version (V0), considers agents who locate themselves around the workplace based on preferences for low distance between their home and workplace, price, and quality of land. Agents decide for a new living location that maximizes their utility according to a utility function. After selecting the location, they decide on the transportation mode they use for commute. The two selected transportation modes are walk/bike and car.

In the considered model, a workplace is in the center of a city where all agents go to work. The model assigns home to each agent based on the land price and land quality according to economic disparity theory and transportation mode choice. Initially, 1000 samples (including 500 poor and 500 rich) are distributed randomly in the considered locations. The dynamics of the urban clusters changes based on the tradeoff in preference of poor and rich people for quality of the location versus the ease of transportation to the work. As the gas price changes, the distribution of poor and rich people changes accordingly in the environment. Eventually, each group affects the price and quality of the patch around it. Therefore, in equilibrium there are segregated clusters of rich and poor people. As we mentioned, the rich people raise (and the poor people decrease) the price and quality of the patches under and around them. In practice, the nearer a patch is to an agent the greater the change in price and quality.

Multiple combinations of preferences are considered by the modelers. (1) In normal (baseline) conditions in which rich and poor has similar preferences for quality and ease of transportation and different preference for price, rich and poor people both drive and walk. However, the distance to work for the poor is greater than the rich and they should walk or drive further. Moreover, in this model the central area around workplace is a cluster for a rich neighborhood. (2) In a model with a heavily decrease gas price, the clusters are intertwined around the central area and everyone is driving. However, the segregation between rich and poor neighborhoods remains. (3) In case gas prices are very high, rich people again form a central cluster around work area, and the number of people who use walk/bike substantially increases. The surprising result is that some people will use driving at very high price because they are place far from the central region. (4, 5) The clustering around central work place phenomena increases with the increase in preference for quality for both rich and poor. (6) In case rich people have higher preference for driving, the central cluster will be accommodated more by poor people and rich population will move to the suburban area.

Using the student project as Version 0 of the agent based model (ABM), we designed and implemented a new model and a total of three versions. The goal of this research was to implement and study the value of alternative theories and approaches to the agents, their behavior, and landscape segmentation. This was a seed grant to allow us to study how to go about modeling the gameworld so that we could then author a proposal for a larger grant that would allow us to scale up the gameworld into the desired policy analysis tool. Important changes in each model and the related versions of the simulation are summarized in Table 1.

Table1: The different steps of the model

Model / Agent	M1 (V0)	M2 (V1, V2, V3)
Theory Investigated	Economic Disparity Theory & Transportation Mode Choice	Economic Disparity Theory & Impact of Cognitive Learning & Info Awareness (Transportation)
Agent Archetypes Modeled	Poor Rich	*Negative Awareness *Unaware *Aware *Informed (only in V1) *Activist
Landscape Segmentation	One zone (with varying land quality based on residents)	5 Fictional Zones: A B C D E

Behavior	Dynamic Land Value Transportation Mode Switch	Awareness Level Quality & Value of Land Mode Switch
Map	No Map	Hand-drawn Map

In the first version (V1) of Model 2 (M2), five archetypical personalities (Negative Awareness, Unaware, Aware, Informed, and Activist) and five zones (A, B, C, D, and E) are assumed. The five zones are fictional and don't represent any actual region on the city. As the results of modeling, clusters of similar arc-types are formed within separate zones. For example, the central zone has a population of people with higher awareness because this zone includes the workplace and people in this zone prefer walking or biking based on economic disparity theory and impact of cognitive learning and info awareness [3]. Similarly, in the outer zones clusters of less aware people are formed and there is a negligible mix between different arc-types.

In the second version (V2) of Model 2 (M2), one of the arc-types (Informed) is removed to simplify the model. However, the result of simulating the model in this condition is similar to the former model (V1). The segregation between different categories of awareness levels persists and the area new to workplaces are populated by activists and aware people. Although there is not a meaningful different in distance to the nearest workplace, separate patches of negative aware and unaware people are formed in each zone. This separation is because of homophily preferences between members of each category.

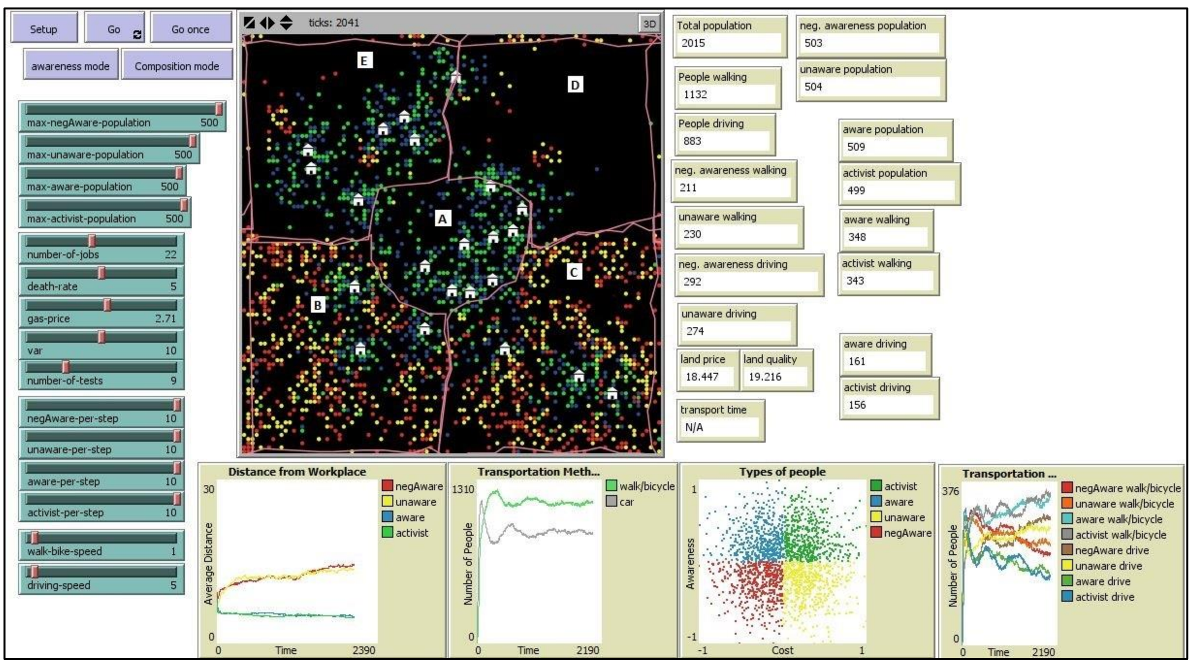

Figure 1: Simulation of Model 2 (V3)

In the last version (V3) of this model, each arc-typical personality is distinguished with a separate color to highlight the results. In this version, roads divide the region into five fictional zones including center city (A), south east old city (B), south west old city (C), north east new city (D), and north west new city (E) as shown in Fig. 1. Different workplaces (house shape) are shown in the region. Initially, 2000 people are divided equally for 4 personality archetypes (500 for each personality archetype) and distributed randomly in the considered locations. Similar to other models, the dynamic of the urban clusters changes based on the tradeoff in preference of the arc-types for quality of the location versus the ease of transportation to the work. Figure 1 presents each arc-type with a color to highlight the segregation: (1) green represents activists,

(2) blue is used for aware people, (3) yellow represents unaware arc-type, and (4) negative awareness is painted as red.

The chart in Fig. 1 highlights the choice of each transportation mode of different arc-types; walk/bike is shown in green and car is shown in gray. The people who live in the central zone A have higher awareness and they prefer more walking or biking (more green and blue dots rather than red and yellow ones). We also have two dimensions (cost and transportation) and four different colors to represent each of the four possible agent states.

Conclusion

Through this exploration of possible gameworlds for simulating urban energy behavior we reached two useful conclusions: first, that a realistic gaming experience could be achieved with a simplified number of "zones," e.g central business district, urban residential, suburban commercial, etc., and second that a simple model of "awareness" was not sufficient to capture the dynamics of choice among households of different income, occupation, and location. There are a number of alternate ways to model the dynamics of choice in households, which will be tested in future versions.

References:

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