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Agent-based micro-simulation of business establishments

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Agent-based Micro-simulation of Business Establishments

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Abstract

This paper describes the development and testing of an agent-based micro-simulation of the evolution of individual 'business establishments' in a spatial economic system. The simulation uses comparatively simple, yet behavioural, rules and probabilistic models, using a Monte Carlo process to simulate behaviour from the probabilistic models. Establishments are represented by their consumption of commercial floorspace along with their production and consumption of other commodities. Markets for commercial floorspace are represented by spatially disaggregated "price landscapes", with the price at each point adjusted based on previous shortages or surpluses. Discrete choice models are used to represent establishments' choice of locations within this price landscape where they pursue their business of purchasing and selling commodities. These models provide a measure of the composite utility of selling or purchasing commodities from any business location, which are used to determine the degree of success of an establishment. This attractiveness measure is used to determine the probability of establishments growing, becoming bankrupt, leaving or splitting ("spin-off" or "duplication").

The system is fully integrated with a floorspace development simulation, which simulates the decisions of each landowner with regard to development, redevelopment or demolition. The price landscape (and vacancy landscape) for various floorspace types influences developer decisions.

The test system is represented using a 10x10 system of zones. This test system is used to test the role of the various parameters, to determine reasonable values for the parameters, how the model behaves when parameter values are unreasonable, and how each parameter influences the model system.

Acknowledgments

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1.0 Introduction

The advent of integrated land use transportation systems has created new objectives and requirements for micro-simulation models. The purpose of this paper is to present an agent-based micro-simulation model of the population dynamics of business establishments (BEs, a single physical location at which business is conducted, often a portion of a firm) and the development of commercial floorspace. There is an increasing demand in spatial planning for models based on the demographic processes that business establishments undergo. From the theoretical side, new models have been proposed that try to capture the behaviour of BEs and most specifically the factors that determine BEs' decisions about formation, death (closure), and growth (see for example, Wissen, 2000 and Collado, 2001).

Our focus in this paper is on the demography of BEs, called "Firmography" and location choices based on commercial floorspace development process. Firmographic events include birth, death (bankruptcy) and changes in establishment size and location. The system is built together with a floorspace development module that considers the decisions of landowners regarding how to improve their properties by building new structures, adding to existing structures, or converting structures to a different use.

The intent is to create a simulation that is useful for urban planning, transportation planning and economic scenario building. Thus these modules are designed to link together with other modules representing:

- 1) larger scale aggregate regional economic performance
- 2) spatial demographics of households
- 3) detailed movement of person trips and transport trips
- 4) transportation network performance under congested conditions

The goal of agent-based micro-simulation techniques is to use simulation as a tool for building theories to explain system behaviour. The intention here is to use object-oriented techniques to build in a set of representations of disaggregate behaviour, at the level of the individual business establishment, and allow these representations to interact to under what conditions there is an emergent simulation behaviour consistent with observed and/or theorized aggregate behaviour.

The expectation is that an object-oriented micro-simulation model based on comparatively simple, yet behavioural, rules and probabilistic methods of the urban system will exhibit emergent behaviour consistent with observed aggregate behaviour.

2.0 Classic microeconomic background

The central principle of classic microeconomic market theory (sometimes called "Walrasian Microeconomics, e.g. Katzner, 1988) assumes rationality of agent and maximization profit of a firm or utility of an individual. Production curves and production functions are the distinctive methods of economics to describe a firm's behaviour. Production function defines for every combination of inputs to the production process the maximum output that could be produced. In this research we use a simplified production function, which is the quantities of various inputs needed to produce one unit of output, conditional on "Zutilities". (Zutilities are described in

more detail below. They are in essence composite measures of the attractiveness of purchasing inputs, or selling outputs, that take into account the price landscape, the size of the markets, and the difficulty of transportation.

A problem with traditional microeconomic market theory is that it assumes each firm in the industry as being identical (i.e. with identical production and consumption functions). An important aspect of this research is to understand the spatial arrangements of various establishments, and why some establishments might locate in some locations even if they are in the same industry as a different establishment in a different location. Thus we synthesize a population of establishments, and allow for the production functions of each establishment to vary from the industry average.

Most studies of firm behaviour do not take into account the spatial aspects in reference to the behaviour of firms. The prices of each good and service are set for the region as a whole, so the spatial advantages of certain locations are not represented. For a spatial simulation it is essential the advantages of better access to factors and intermediate goods and services, and access to consumers, is represented.

When a firm has more than one establishment (i.e. operates in more than one location) it is likely because there is some advantage to splitting its operations. Perhaps certain parts of a firm's operations have a higher locational advantage in one location. Or perhaps the firm's customers are unwilling to travel long distances; so several retail sales outlets are required to serve the population. Classic microeconomic theory can ignore the separation of firms into establishments because it does not concern itself with space.

The traditional economic theory assumes that there is one specific market conducive for the exchange of each specific product. To represent the access to interactions provided by the spatial-transportation system, we represent numerous markets at different points with different prices where exchange of a particular type of "commodity" (a good, service or factor) takes place. Each BE interacts to varying degrees in each of the different markets, based on the Market Choice Model defined below.

3.0 Simulation method

3.1 Specific representation of time and disequilibrium

As a microsimulation, the system begins with an initial state consisting of a population of BEs, a description of prices for each commodity in each spatial market, a description of the physical space which consisting of zones, "grid cells" (smaller units of land within zones) and matrices describing the attributes of travel between zones. The system evolves, with firmographic events simulated for individual BEs. At subintervals of one year (currently twice per year) prices in each market are updated. At the end of every year all developer decisions are simulated, updating the supply of commercial floorspace. This is in contrast to , for example, equilibrium models which solve for equilibrium at a point in time. In this situation we do not assume that markets are in equilibrium, thus the need to update prices via a process. To investigate the steady state behaviour of the overall system requires model simulation runs of sufficient length to "reach equilibrium".

3.2 Probabilistic distributions

One important element of simulation modeling is identifying appropriate probability distributions that can adequately capture the randomness of behaviour. Often, this requires analyzing empirical or historical data and fitting these data into a distribution. For each event in this micro-simulation we used probabilistic distributions, but individual values are sampled from them, and behaviour of a BE at a particular time is based on the sample from the distribution.

The distributions are normally conditional upon the conditions, and may be estimated with a disaggregate process, so that each situation that exists in the model can have the same range of possible behaviour for the affected agents, but different probabilities for the different behaviours.

3.3 Monte-Carlo process

Since samples from distributions are used, the simulation can be envisioned as a "Monte-Carlo" process. To be useful for planning the planners will look at the aggregate distribution of various output values after a simulation run is complete. Thus, ultimately, we are interested in aggregate behaviour, but we do not want to define complex joint distributions and we do not wish to pre-define exactly which aggregate behaviour will be investigated. The system thus respects the spirit of the Monte-Carlo process: that is, a simulation is used to sample random values from relatively simple distributions, and these values combined together to understand the complex joint distribution of the whole system of interest.

These samples from relatively simple distributions are interpreted as being related to the decisions of particular agents at particular times in particular places, providing a behavioural interpretation of the model results and making the model system more interpretable. This also allows the use of data collected when observing individual agents undertaking small "conditional" decisions.

We distinguish (a) exogenously specified conditional distributions or (b) choice probabilities provided by models of choice behaviour that include an explicit representation of influences on decision-making. In (a) we use coefficients estimated based on the aggregate conditional behaviour of a large number of actors and not considering the unique situations faced by each individual actors. In (b) we use coefficients estimated using disaggregate choice models of conditional behaviour.

The emphasis is on conditional behaviour in initially establishing the parameters of probability distributions (models) since conditional behaviour is more easily observed and measured. The overall integrated system behaviour is measured in aggregate, and the overall system can be calibrated to match observed system behaviour (Abraham and Hunt, 2000).

4.0 Model foundations

4.1 Overview

The overall modelling system under development consists of a number of modules:

- 1) ED – a model of the overall economic performance of the region over time, and the shifts in technology and population
- 2) HA – a microsimulation of household evolution (demographics), household location choices, and the household supply of labour and other factors of production and

- household consumption of goods and services
- 3) EA – a microsimulation of business establishment evolution and location (the primary subject of this paper)
 - 4) PU – a price update module that is concerned with the representation of spatial markets, and is used to tie together the mid-level economic components of HA, EA and LD
 - 5) LD – the land development module that simulates the behaviour of developers
 - 6) PT – the simulation of trips made by household members as part of their personal activity
 - 7) CT – the simulation of commercial transport, primarily the shipping of factors of production and goods and services, but also considering business trips by individuals
 - 8) TS – the calculation of congested travel conditions, and the feedback of those travel conditions to achieve a Wardrop equilibrium in route choice.

The flow chart in the following Figure 1 illustrates the overall integrated land use transportation model components and their interrelationships. This figure shows several interconnected modules.

The ZU shown in the figure for year 2 represents a Zutility calculation. A Zutility is defined as the numerical measure of the access to inputs (factors, intermediate goods and services) and the access to consumer markets. In each zone there are sets of Zutilities that are calculated for each

commodity, for both buying and selling. A high Zutility indicates an attractive situation for that commodity, and a low Zutility indicates an unattractive situation. BEs thrive (and prefer to locate) in zones where relevant Zutilities are high, and BEs are more likely to fail (or move away from) zones where relevant Zutilities are low. The importance of each Zutility to each BE is dependent on the business that BE engages in, as described in its production function and consumption function.

The focus of this paper is mainly on EA and the behaviour of two closely related modules – PU and LD – as they adjust the prices and supply of commercial floorspace.

4.2 Business Establishment Representation

A individual BE is described by the following data attributes:

- consumption function
- production function
- age (number of years in business)
- amount of floorspace required
- industry
- current location

4.2.1 Classic “production function”

Perhaps the most important attribute of a BE is the description of its business – what it consumes and produces. These are represented by a consumption function (indicating what commodities are consumed by the BE) and a production function (indicating what commodities are produced). (Note that the "consumption function" in this model is considered the "means of production" and hence is often called a "production function" in classic economic theory. Classic theory has no need for a "production function" by our definition because in the classic framework each firm only produces one output – i.e. the categorization used for goods and services is the same as the categorization used for firms). Thus, BEs are described primarily by their business transactions – their purchases and sales of standard commodity classes. Make and Use tables from input-output models are used as the basis for these. Floorspace and labour are both treated as explicit commodity classes. Since floorspace is non-transportable (must be purchased in the same market location as where it is consumed) the Zutility of purchasing floorspace is particularly important.

4.2.2 Markets

Markets are assumed to exist separately in each “exchange zone” – each with its own price. BEs in a given location can sell or purchase their commodities in a variety of different "exchange zones" that they are willing to ship goods or services to or from.

4.2.3 Utility of buying and selling commodities

A discrete choice model based on random utility theory is used to simulate market choice. The expected value of the utility of each market m for a BE in zone z is:

$$U_{mz} = \mathbf{q}_s \cdot \log(S_m) + \mathbf{q}_t \cdot T_{mz} + \mathbf{q}_p \cdot P_m$$

Where the \mathbf{q} 's are parameters, S_m is a measure of the size of market m , T_{mz} is a measure of the

ease of transporting the commodity from (or to) market m from the BEs location z , and P_m is the price of the commodity at market m . Thus BEs prefer markets that are larger, closer and have better prices (higher prices if selling, lower prices if buying). Following discrete choice theory (Ben Akiva and Lerman, 1985), these are taken as the expected value of random variables that follow the Weibul distribution, giving the probability of choosing one particular market m^* for one particular transaction:

$$P_{m^*} | Z = \frac{\exp(\mathbf{I} \cdot U_{m^*})}{\sum_m \exp(\mathbf{I} \cdot U_m)}$$

The Zutilities are calculated as the expected maximum value of the individual random variables that describe the individual utilities:

$$ZU_z = \frac{1}{\mathbf{I}} \ln \sum_m \exp(\mathbf{I} \cdot U_m)$$

These probabilities are taken as shares (implying an assumption of the law of large numbers, e.g. an assumption that the BE makes many transactions in each commodity), so that the quantity of commodity that the BE ships to or purchases from a market m^* is $Q \cdot (P_{m^*} | Z)$ where Q is the total quantity purchased or sold.

4.2.4 the firmographic processes

A synthetic population of discrete business establishments is generated in the base year. These are then evolved over time using a number of relatively simple submodels.

4.2.4.1 Move or stay or leave

As each BE is considered, a decision whether to "move, stay or leave" is simulated. This is simulated with a nested logit model, with three alternatives at the top level.

"Leave" refers to out migration out of the model region. It is given a fixed utility. "Move" refers to moving to another location within the model region, probably to a different zone but perhaps also within the zone. The utility of this alternative is calculated based on the expected maximum value of the utility of all the possible locations, plus a constant:

$$MC + \ln \sum_z e^{U_z}$$

Where:

MC = Moving Constant

U_z = Utility of available vacant properties in zone z which is a function of floorspace price, Zutilities and floorspace vacancy rates.

"Stay" refers to remaining in the same floorspace area in the same grid cell in the same zone. The utility of this alternative is based on the Zutilities and the production and consumption function.

Thus, for instance, the probability of a BE leaving the region is:

$$P_{leaving} = \frac{e^{I \cdot MOTRU}}{e^{I \cdot MOTRU} + e^{I \cdot (MC + \ln \sum_z e^{U_z})} + e^{I \cdot U_{z^*}}}$$

Where:

$P_{leaving}$ = Probability of leaving the model region entirely

I = Move or Stay Or Leave Dispersion Parameter

$MOTRU$ = Moving Outside the Region Utility

UZ^* = Utility of current property which is a function of floorspace price and Zutilities, and does not consider floorspace vacancy rates.

Individual business establishments that decide to leave are removed from the population and the commercial space they occupy is then added to the vacant space pool in the appropriate zone. BE's that decide to "move" are added to the "moving pool", which tracks BEs that have decided to find a new location, but have not yet found one. The commercial space that they previously occupied is added to the vacant space in the appropriate zone.

4.2.4.2 Zone location choice

At each point during the year where the price update procedure occurs, the establishments in the "moving pool" try to find appropriate space, to update vacancy rates based on the new situation. The BEs choose zones using a logit model that has each zone as an alternative, and the utility of each zone is U_z . However the vacancy rates that influence U_z are updated as each BE consumes vacant commercial floorspace. Thus as the commercial space in a zone runs out the zone becomes increasingly less likely to be chosen as a business location, and when the vacancy rate becomes zero there is zero probability that the zone will be chosen.

4.2.4.3 Fixed growth rate – new BEs added every year

Currently we create new BEs every year according to a schedule. We do not have a spin-off model or entrepreneur model.

4.2.4.4 Future submodels: BE Death, Relocation and Growth Model Components

Growth (positive and negative) and the probability of death (closure) are based on the measure of location attractiveness. Large or successful firms are likely to split into two separate BEs. Two processes are identified: the first involves splitting the function of the BE into two more independent businesses in separate locations. In this first process the production and consumption functions are split. The second involves undertaking essentially the same business in a new location. In this second process the production and consumption functions are duplicated.

4.2.5 Simulation

The Simulation starts with a number of BEs in a base year, which are generated randomly, and BEs are evolved over time using probabilistic models. Each decision is selected from

probabilistic methods using random selection. The model represents dynamic decisions, and so requires a consistent set of inputs before it can represent reasonable trends. To achieve a consistent set of inputs the model is run for quite a number of years initially, so that all processes represented in the model could reach a long-term equilibrium. This equilibrium state is then used as a starting point to investigate the characteristics of the system in detail.

4.3 Commercial Floorspace Representation

The primary task of the land development module is to adjust the quantity of space over time in response to changes in price. It represents the behaviour of developers and landowners in choosing to change the nature of the improvements on land, by building new structures, adding to existing structures, or converting structures to a different use. Landowners / developers make their decisions based on current prices and vacancy rates.

4.3.1 Land divided into zones and grid cells

Within each zone, the land is represented as "grid cells", which are finite quantities of land with a particular type and amount of floorspace and a particular building age. Each zone illustrates how much building space in each zone, how old it is, how densely it covers the zone and what development is allowed there. The density is defined in terms of floor area ratio (F.A.R). This is the ratio between building floor space in square feet and land area in square feet. The prices for each floorspace type in each zone (age, type, quantity) are used to calculate the probability that the landowner will choose to undertake development, redevelopment, renovation or demolition in the grid cell. The land development module considers one grid cell at a time to be simulated.

4.3.2 Development type

We considered three types of development in this land use model i.e.: residential, commercial, and industrial. We made a zoning map designating the location of zoning districts.

4.3.3 Change in development types

In this simulation logit model of change in development type/quantity are applied to each grid cell once in each year. Figure 2 illustrates three land use simulation decisions for each grid cell. The first is whether the cell should be redeveloped or not. The second is the choice of the category of space that the cell should be redeveloped into. The third is the quantity of new development in the cell. The changes to grid cells are assigned using Monte Carlo selection where the selection probabilities are determined using logit formulations with utility values that are functions of the current space type, the age of the existing floorspace, the zonal prices for space of difference categories and both zonal and model-area-wide vacancy rates. The utility functions for each of the alternatives in each choice set are based on rents and vacancy rates established in the equilibrium model. The first two are combined into a simultaneous nested logit model, with the top level being the binary choice of whether to change, and the second level being the various change alternative. One of the change alternatives is the adding of more space to increase the density in the grid cell. The other change alternatives represent replacing the existing floorspace with new construction. No special treatment is required for "vacant" space in the module – "vacant" is considered to be a "development type" with no rent associated with it.

The utility of developer choice is a function of price, vacancy and age of the structures. This is represented in the following utility equation.

Following are the utility equations for three land-use simulation decisions.

$$U_{nochange} = \mathbf{b} + \mathbf{b}_1(c_1 / c_2) + \mathbf{b}_2(z_1 / z_2) + \mathbf{b}_3p(a_1 / a_2) + \mathbf{b}_4age$$

$$U_{change} = \mathbf{q} + \mathbf{q}_1(z_1 / z_2) + (p - c).a\mathbf{q}_2$$

$$U_{add} = \mathbf{m}_1(z_1 / z_2) + \mathbf{m}_2(a_1 / a_2) + \mathbf{m}_3(a_3 / a_2).(p - c)$$

Where the parameters are defined as follow:

\mathbf{b} = keep constant;

\mathbf{b}_1 = cell vacancy utility coefficient;

\mathbf{b}_2 = zone vacancy utility coefficient;

\mathbf{b}_3 = rent per acre coefficient on current development;

\mathbf{b}_4 = age coefficient to keep;

\mathbf{q} = demolition not add constant;

\mathbf{q}_1 = zone vacancy utility coefficient;

\mathbf{q}_2 = profit per acre coefficient on new development;

\mathbf{m}_1 = zone vacancy utility coefficient;

\mathbf{m}_2 = rent per acre coefficient on current development;

\mathbf{m}_3 = profit per acre on new development;

c/c_2 = cell vacant sq.ft / cell total sq.ft;

a_1/a_2 = amount of development / amount of land;

z_1/z_2 = zonal vacant sq.ft / zone total;

$p-c$ = price per sq.ft – const. cost per sq.ft and

a_3/a_2 = amount of additional square feet allowed / amount of land.

4.3.4 Price influences probabilities of development/redevelopment

The developers see profit opportunity to develop more floorspace. Next year prices go down as the vacancy rate of newly developed area goes up. In each year developers see an opportunity to

develop, demolish or do nothing based on prices, vacancy rate etc.

4.3.5 Zoning regulations

In each zone, zoning regulations control what is allowed for future development in each grid cell, and can heavily influence development. Zoning regulations help project the future physical development of a municipality. Our regulations in each zone and grid cells include: allowed development type and density of each development type. For example, high density, low density and medium density of commercial, residential and industrial floor spaces.

4.4 Price Update Representation.

The price update function is used to update floor space prices in each zone. A similar process will also be used to update commodity prices in each exchange zone. Price update procedure changes price based on the shortage or surplus of commercial floorspace in a zone. The EA module performs dynamic price updates on commercial space types based on time-varying vacancy rates. In this simulation model we assumed structural vacancy rate. If the vacancy rate is above the "equilibrium vacancy rate" the prices go down.

4.4.1 Price Update Function/Procedure

$$Price_t = Price_{t-1} - Price_b(z_1 / z_2 - eqvr) \mathbf{q}_2$$

Where:

$Price_b = \max (Price_{t-1}, \text{minimum base price}).$

$z_1/z_2 = \text{zone vacant sq. ft} / \text{zone total size};$

$eqvr = \text{equilibrium vacancy rate}; \text{ and}$

$\mathbf{q}_2 = \text{portion vacant multiplier}.$

This is the simple equation to change the price by some increment based on the difference between the vacancy rate and the equilibrium vacancy rate.

5.0 Test scenario

The test system is represented using a 10x10 system of zones and a network of transport connecting the zones with reasonable travel times and costs. In each zone, we start with 24 grid cells with commercial space. However, there are 48 grid cells in each zone, 24 for commercial and 24 for housing. Thus 100 zones have 4800 grid cells and each grid cell is 1acre in size. Therefore, at the start of the simulation ($t = 0$) the total supply of land is 104.5 million square feet for commercial space as well as 104.5 million square feet for residential space. Thus, the total area considered in our simulation model is 209 million square feet.

We apply zoning regulations to each zone in terms of densities as shown below in Figure 3. It shows both existing (in red colour) and future developments. We also assign age range to each existing developed zone. Each zone starts with 10000 square feet of buildings allowing up to 20000 square feet of buildings over time plus another 24 grid cells with residential space each 1-acre in size. We start with a fixed number of BEs and assign each BE floorspace ranging from

1200 - 20000 sq ft.

6.0 Important parameters

Certain parameters that we used in various modules have been found to be important in terms of how they influence the overall system behaviour.

6.1 BE Firmography parameters (EA Parameters)

- Leave constant (movingOutsideTheRegionUtility) – is the alternative specific constant for the "move" alternative in the 3 alternative logit model of "move or stay or leave".
- Moving Constant – is the constant utility of the alternative to move outside of the model region entirely.
- Move Or Stay Or Leave Dispersion Parameter – is the dispersion parameter for the logit model for whether the establishment chooses to stay in its current grid cell, move to a new grid cell, or leave the model area entirely.

6.2 Land Development parameters (LD Parameters)

- Age Coefficient To Keep – This parameter is used to calculate how the age of the building influences developers decisions
- Keep Constant – controls overall rate of redevelopment.
- Rent Per Acre Coefficient On Current Development – This parameter increases or decreases the response rate for developers. This increases how sensitive developers are to price. So it means they respond more to changes in price. It's not that they respond faster, it's that they respond more. (rent sensitivity of developers)
- Cell Vacancy Utility Coefficient – how developers respond to vacancy rates. It is the coefficient that gets multiplied by the portion of the floorspace in the grid cell that is vacant.

6.3 Price update parameters (PU Parameters)

- Equilibrium vacancy rate – The equilibrium vacancy rate is an equilibrium level of inventory of space, in the sense that both the matching process (demand and supply) between the landowners and tenants is facilitated, and that landowners hold an optimal buffer stock of inventory to meet future demands. In this micro-simulation model long run equilibrium vacancy rate is determined along with rent and quantity of space.
- Minimum base price – This is the price at which the linear price update function becomes a percentage price update function. In most cases a percentage price update function is preferred, to make changes independent of the unit of measurement. But during iteration prices can be pushed to zero, after which a percentage update would have no effect. The available compromise is to use percentage update only above a certain price, and linear update below that Minimum Base Price
- Portion Vacant Multiplier – this is the speed of price response to vacancy rates that differ from the equilibrium vacancy rate.

7.0 Results

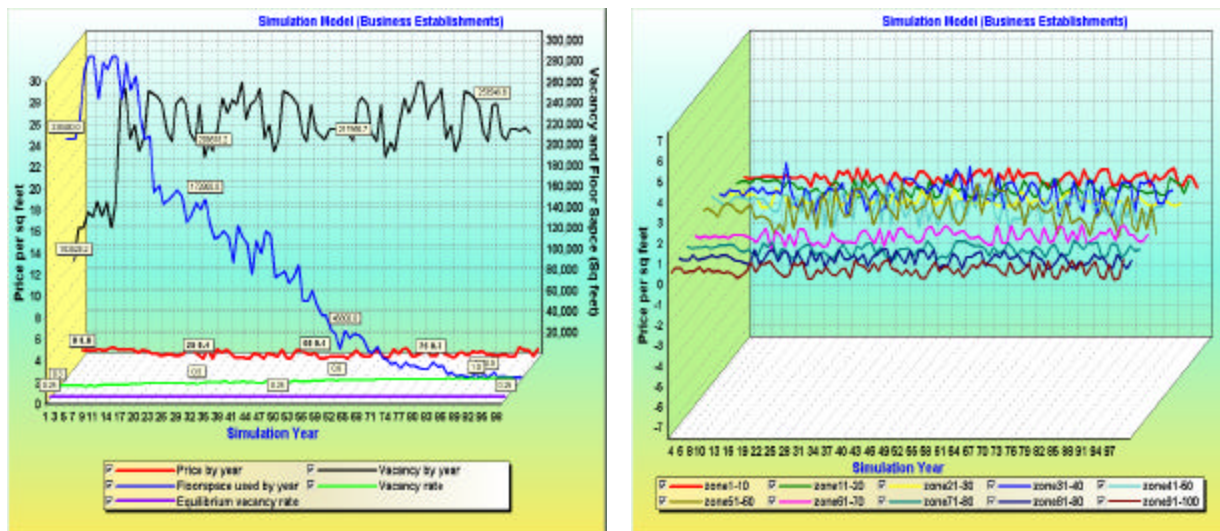
In this section we discuss some results to illustrate how the simulation model behaves when certain parameter values are changed. We are particularly interested in tracing prices for different zones as well as tracing the number of BEs in each zone. This will demonstrate the role of various parameters in the micro-simulation model. The test is conducted using initially unreasonable values and to see what happens. From here we can predict the better values. For the following results we demonstrated the use of ‘Move Or Stay Or Leave’ Dispersion Parameter. The results shows some interesting features regarding BEs’ behaviour.

7.1 Verification of ‘Move Or Stay Or Leave’ Dispersion Parameter

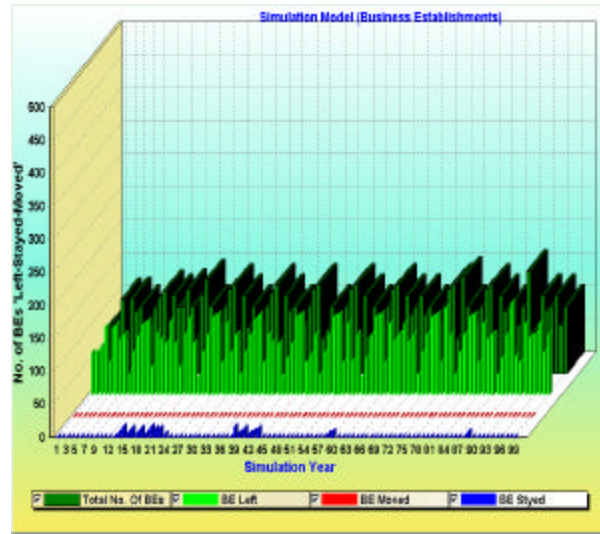
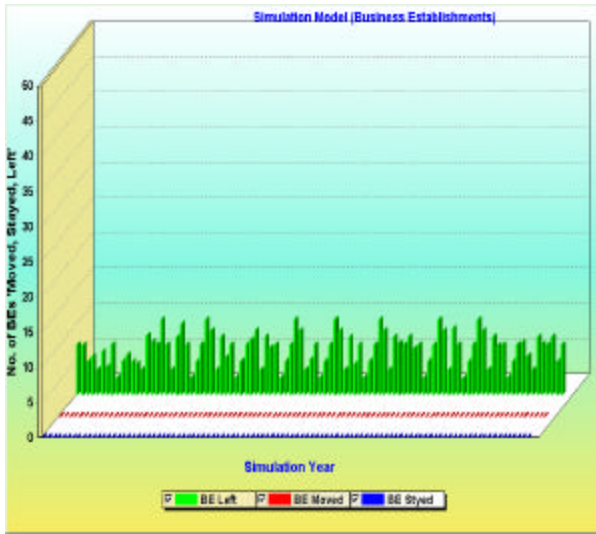
Hypothesis for moving out parameter: If prices of commodities are constant, then: if the utility of the “rest of the world” is too high, then all BEs will eventually leave the region. If the utility of the “rest of the world” is too low, then BEs will continue to grow into the region until the price of space becomes so high that they are forced out by unrealistically high rents. In between these two extremes, there system should eventually evolve to an emergent steady state with a stable population of firms and realistic rents. In the base case simulation run the moving out parameter was set to 7.0 (unreasonable value – too high). The results include in each zone: prices per square feet, vacancy rates, floor space used, vacancy rate and equilibrium vacancy rate. The results show that system is not in stable state. Prices are continuously rising and are higher in central zones (21-30, 31-40, 41-50).

Following Figures 4-6 illustrates three simulation results using three ‘move or stay or leave’ dispersion parameter values.

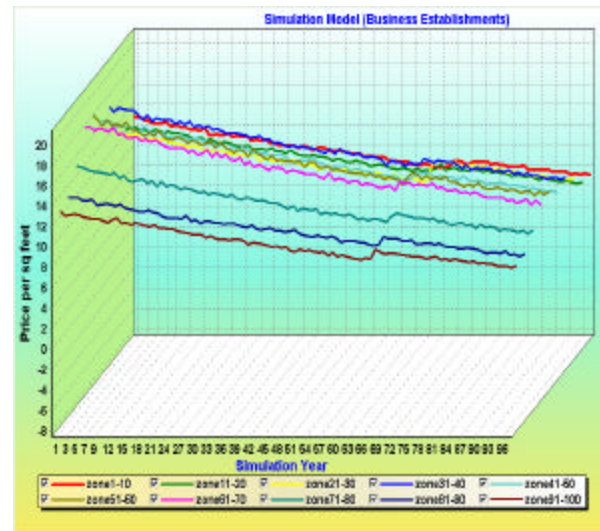
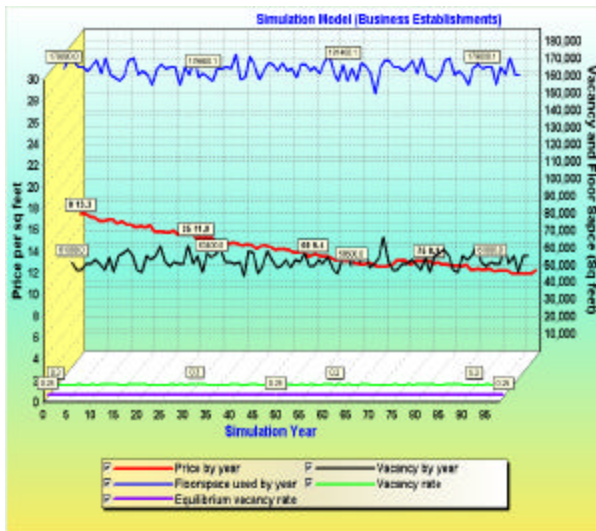
Test scenario-1: Choosing an unreasonable value for ‘move or stay or leave parameter’



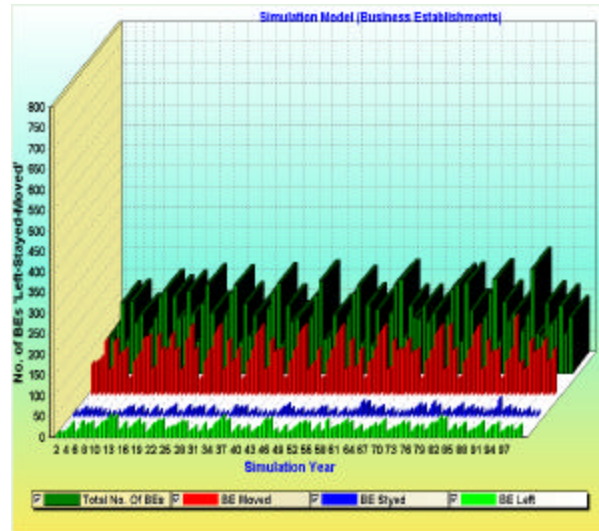
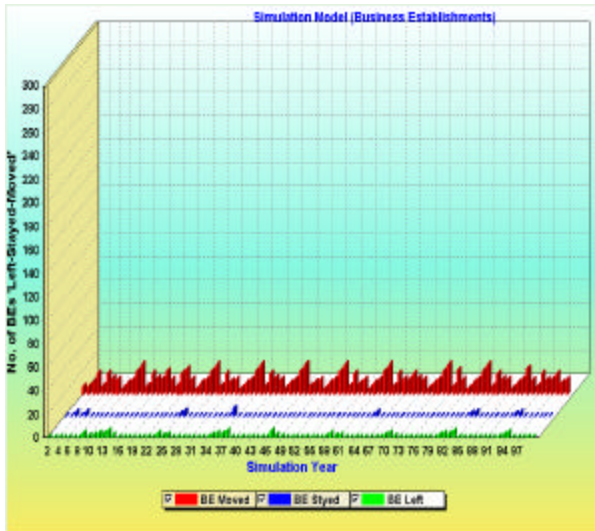
The above figure shows that there is little or no economic activity in each zone and prices falling to near zero. It indicates that all BEs are leaving and the quantity of vacant space is about constant. The vacant proportion (vacancy rate) consistently stays above the equilibrium vacancy rate, which drives all the prices to near zero. It appears that the total quantity of space (blue line + black line) is going down, so the developers must be converting commercial space to residential use.



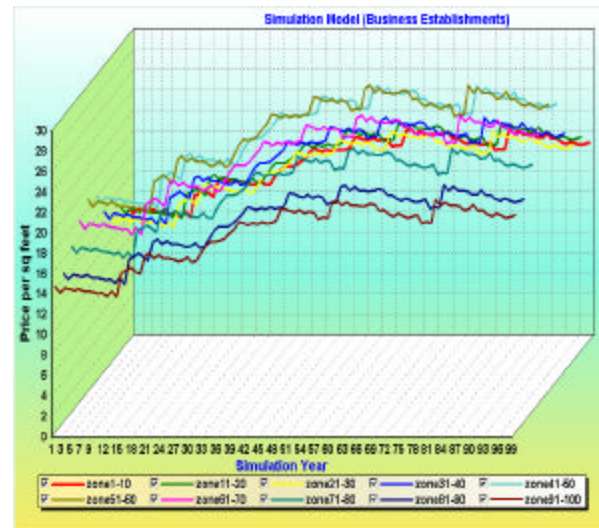
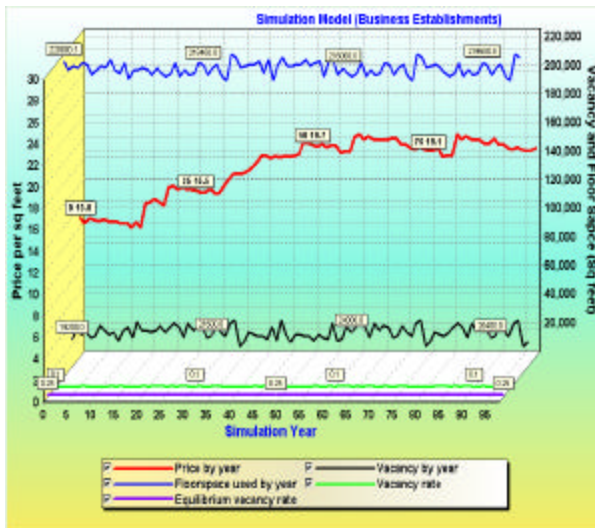
Test scenario-2: Choosing an intermediate value for 'move or stay or leave dispersion parameter.



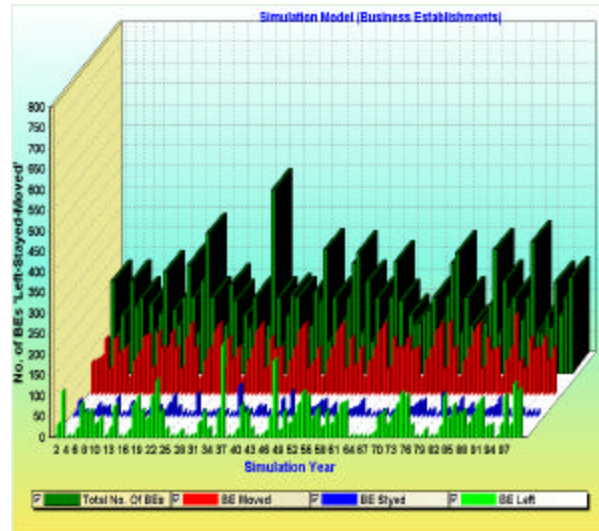
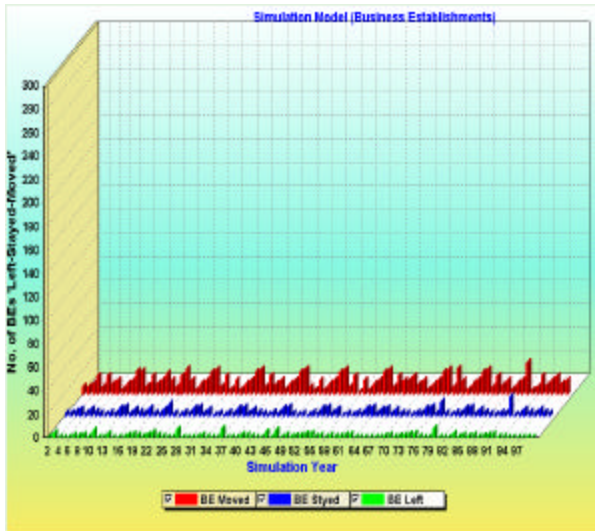
The above figure shows that prices are falling slightly, as vacant proportion (vacancy rate) is constantly above the equilibrium vacancy rate. More and more BEs are moving into nearby zones where economic activity is high. Central zones have higher prices due to their locational attractiveness. The existing BEs stayed where they were and a small numbers of BEs left the region perhaps due to initial higher prices.



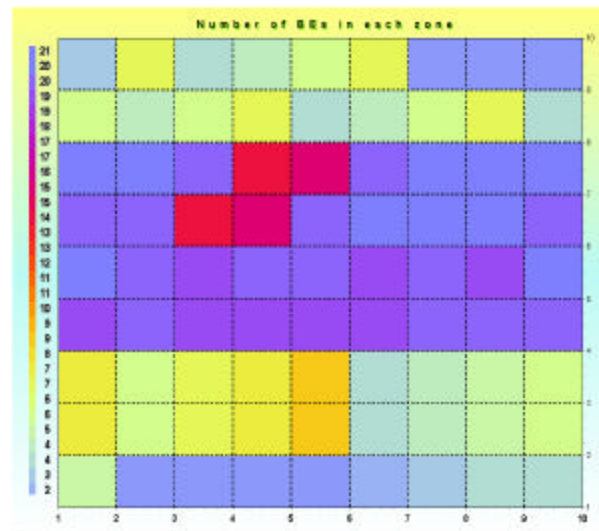
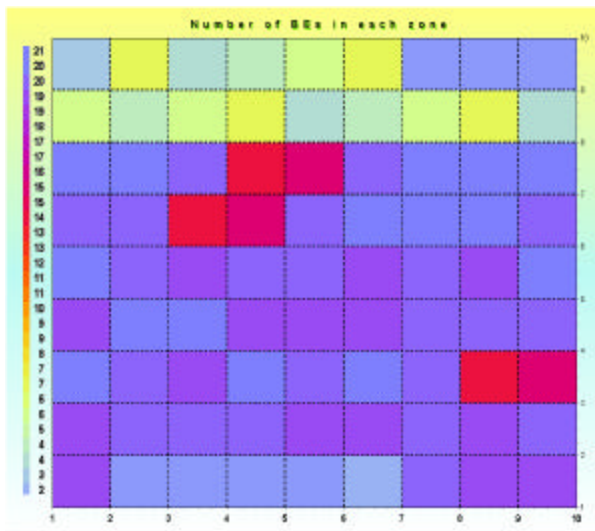
Test scenario-3.: Choosing low value for the ‘move or stay or leave dispersion parameter’.



By choosing low values for ‘move or stay or leave’ dispersion parameter we are making zones more attractive for the BEs. As shown above the vacant proportion (vacancy rate) is constantly below (but near) the equilibrium vacancy rate. Prices are rising initially and then remain somewhat stable. So More BEs moving in and some BEs left the region where they felt that the prices were ‘too high’ or they simply went out of business. The existing BEs stayed where they were in the previous year.



Tracking number of business establishments between test scenario-2 and test scenario-3.



The left hand side of the picture shows that more BEs moved to central locations when the prices fell. Prices are still higher in central zones as well as in some outer zones. When the prices increased as in test scenario-3, due to low moving out constant. The right hand side figure shows that that a many BEs moved out to other zones of lower prices. But in the outer zones many of the existing BEs stayed and a few of them left in the middle zones.

8.0 Conclusions

The examples described in this paper have been selected to illustrate the main aspects concerning the use of agent-based microscopic simulation for the analysis of land-use system, namely those accounting for business demography. The work in this category is rare and the authors hope this paper can contribute some knowledge to relevant researchers to make a further in-deep analysis. The order of events in the microsimulation is fixed. This means that the probabilities that we are using are conditional probabilities: migrate, spin-off, conditional upon survival etc. However, in reality, they are competing risks, and the order may be random. The simulation model does bookkeeping of floorspace in each region. If there is no floorspace available, a BE will choose another region to start. The sectoral division of the population of BEs is done using production and consumption functions, and implemented by a sectoral economic sub model. This model reflects behaviour of small and medium sized firms. The large firms (1-2% of the population) employ by far the most employees, are governed by other processes. We kept them out of our model because our model will not capture their behaviour.

8.1 What went well

Oregon Department of Transportation (ODOT) funded development of a base framework – we didn't have to start from scratch (EA is based on HA and is integrated with LD and uses Zutility calculations from an aggregate production allocation module called PECAS. Development of PI, HA and LD was funded by ODOT).

8.2 What didn't go so well

For this micro-simulation model, we realized there were real problems we felt Java could solve such as its object orientation supports and integration of large numbers of object classes. By eliminating explicit pointers, Java allows programmers to write more maintainable code. So it seemed to us that Java as a language is likely to be a better choice than C and probably better than C++ for large scientific computations. However we found that for high performance computing Java code needs to be "tuned" substantially, to reduce resource use. The initial advantage of Java of faster development and easier maintainability allowed for faster prototype implementation, but as the computational scale of the test scenarios increased we spent considerable time wrestling with performance issues. Thus the researchers are divided as to whether Java was a good choice for this project – with some saying that the language features that sped initial development were essential to achieving a working prototype within a reasonable time frame, while others complain about slower execution speed and/or never ending "performance tuning".

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