Modeling and Simulating the City: Deciphering the Code of a Game of Strategy

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This research includes a new teaching proposal for architecture and geography, based on Systems Theory and Dynamics Systems, aimed at improving the understanding of the complex structure and dynamics of the city. SimCity, a game of strategy that allows us to design and to plan the city, is used as the software, with the aim of conducting didactic experiments, and integrating the complex relations that configure the city. The methodology incorporated theoretical and experimental stages, and concluded with a simulation exercise. The exercise had a very good reception, as a method for learning and research, creating a great aptitude for generating good research questions, by making many variables visible simultaneously. The research has developed, and participants have, subsequently, been exposed to the second version of the course, where new concepts are being integrated (emergence and cellular automata) to deepen the theoretical base, and to allow further analysis and experimentation with the game.
1. INTRODUCTION

To wonder what models mean for urban studies is inevitably to carry out a critical reflection on the condition and the scientific situation of our discipline. Although, historically, there have been detractors of the science, of which one of the latest is the critique of postmodernity, any research, independent of its ideology, can be science[1].

Assuming the immature scientific state of urbanism, and understanding it as an essentially projecting discipline that is fed by social and political realities, there arises the need to reorient our efforts. In the sense that Marx meant, the mission of science cannot be only to contemplate the world but, on the contrary, its duty is to transform it.

Understanding that urbanism is a projecting discipline, we have the notion that it is not always possible to experiment in all the sciences. In our discipline, there has not been a process of prediction, because it is not possible to experiment in our research.

Then, what happens if the possible interventions in the future are studied, understanding that urbanism is an essentially projecting discipline? Is it not part of scientific research to study the solutions to the problems raised? Why in the case of urbanism, are only the problems studied and not the solutions?

The problem is undoubtedly one of the objects of study. Is it possible to experiment with possible “cures” for the problems of the city, as they do in the hard sciences with laboratory rats? The answer, in short, is a definite NO. This research pretends to relieve us of the importance of bringing urbanism into a state of explanatory science. This research attempts to tackle the formulae of didactic experimentation, which integrates, by the application of networks and systems, the complex and organized relations that sustain and create dynamic territorial formations. Also, it attempts to identify the causes, the theoretical principles, the ideological motivations and the other stimuli that promote, form and articulate the elements of the socio-spatial composition of urbanized territories. Finally, it attempts to take part in the exercising of methods of town-planning intervention, whose procedures could be compared with those of contemporary action.

2. STATE OF THE ART REVIEW: THE USE OF MODELS

The use of models for urban simulation comes from investigations in the development of computing and biology. In the first case, they have their origin in the use of Geographical Information Systems (GIS) and, in the second, in remarks about the organization of living organisms. In the evolution of these models, we might separate them into two major groups; i) static models, used fundamentally to describe and to understand the structure of a certain system, and ii) dynamic models, generated to observe and to simulate the behavior of systems across time.
In the first group of models (static), which come from the generation of generic scientific models and from the theoretical contributions of systems theory, we can observe three types of models that are related to the urban ambience:

- **Physical and environmental geography models**: behavior geography and the effects on the environment [2], models in geography and planning [3], models of the environmental urban effects and the behavior of heat islands [4].
- **Social models**: derived fundamentally from the German thinker Niklas Luhmann [5].
- **Urban models**: from the ancient city models of Choay, Wirth, Lefebvre and Christaller, to the tradition of ideas generated by the 'Cambridge School', in the construction of models for planning and urban design [6], [7], [8], models in planning [9], methods and models in urbanism [10] and, more recently, the models of dynamics and development of urban schemes [11]. Also, in this group, we can observe: mathematical urban models; mathematical models used to observe urban development [12], [13], and mathematical models used for planning [14], [15].

In the second group of models (dynamic), based on the methodologies of System Dynamics [16], we can observe three types of models that are related to urban development:

- **Optimization models**: among which we find models for transport and land use planning [17], [18], and mathematical models of the urban economy, geometry and location [19], [20], [21].
- **Control models**: for operations, organizations and research control. They are used in an urban ambience principally to control public and private transport.
- **Simulation models**: among which we can separate two types;
  - Spatial evolution models, which are used to carry out simulations of land use, transport and environmental impacts [22], [23], [24].
  - Dynamic models based on agents and cells, based on emergence and self-organization concepts [25], they use cellular automata systems as a whole with geographical information systems [26], [27], [28].

### 3. EDUCATIONAL EXPERIENCES USING SIMCITY

Although we assume that these exercises are novel and innovative, we also know that some teaching exercises have been carried out using the SimCity game, in some in university education and, especially, in secondary education.

A case of the use of the game in universities was presented for the academics of the Department of Geography and Environment of the University of Texas in Austin, by Assistant Professor Paul Addams. From this
experience, he concludes that the use of the game is an excellent tool for teaching concepts of urban geography [29], where the software helps to teach computing literacy, along with geographical knowledge and critical exercises. Also, he points out that its dynamism and visual refinement provides considerable entertainment and motivation, facilitating the learning of the complex, dynamic and interrelated nature of urban problems.

For exercises in schools, and in secondary education in general, the use of games makes a large contribution since the internal relations that arise while playing can be observed and it can be learned how the software works through a process of constant demythologization [30]. In fact, the game has had so much success as an educational tool in schools that the quantity of licenses that have been sold for educational use almost reaches the number that have been sold for individual use.

From the point of view of the pedagogic contents and methods, the teacher Andrés García [31], of the Technological Observatory of Education, of the Education and Science Department of Spain, points out that the game allows us to design didactic activities from numerous pedagogic concepts, since it takes as its starting point the principal features of self-regulated learning.

In his text, he makes the point that the tasks and targets must combine the logic of learning by discovery and the methodology of problem solving. From this perspective, the ‘microworlds’ of simulation are made compatible with the methodological principles of Interactive Pedagogic and Constructivism. The following feature sums up the main stages that are carried out in the pedagogic exercises and the educational skills that are generated in each one [31].

<table>
<thead>
<tr>
<th>Stages</th>
<th>Skills</th>
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<tbody>
<tr>
<td>Agreement on the context and presentation of the study object</td>
<td>Disposition skills, analytical intelligence</td>
</tr>
<tr>
<td>Searching, making and exchanging of information</td>
<td>Analytical thought, discursive intelligence, social intelligence</td>
</tr>
<tr>
<td>Interaction in virtual environments</td>
<td>Instrumental skills, convergent thought, metacognition</td>
</tr>
<tr>
<td>Simulation processes</td>
<td>Cognitive-perceptive skills, instrumental skills, analytical thought, creative thought, social skills, applied intelligence</td>
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4. THEORETICAL FRAME OF THE RESEARCH


The origins of systems theory are closely related to those of the analytical method and, in general, of positivism. The aim is the homologation of the ‘hard sciences’, in a different way from that of dialectics and hermeneutics. In this way, there is a search for the common properties of entities (or
systems) at all levels, thus trying to build a "meta-theory". For this purpose, it establishes four basic steps: to reduce, to understand, to model and to predict.

In synthetic terms, the object of study of the systems theory is complex systems, its method is the analytical study of essential behavior, and its aim is to facilitate theoretical development in fields of difficult abstraction of the object. One of those 'fields of difficult abstraction', and the nearest that we have, is that of town planning and the city. Nevertheless, few studies have derived their subject-matter from systems theory.

In the field of this theory, a key concept that is necessary to analyze, is 'autopoiesis' [32], or the property of an entity that supports a stable structure. When it remains stable in a dynamic situation it turns into a system.

In the social sciences, arising from the theories of the German Niklas Luhmann [5], systems theory has helped in the study of the always increasing complexity of societies, where new systems are constantly being generated. The social systems, in particular, are defined as self-related, which means that they only communicate with each other if they need. This leaves behind the relation between the whole and the parts, and produces a dichotomous relation between the systems and their environment. In turn, these systems are characterized by a progressive differentiation and specialization, in a spiral of complexity: differentiation, specialization, fragmentation and a later increase of complexity.

4.2. Systems Dynamics: from Engineering to City Models

Systems dynamics arises as a later development of systems theory. In synthetic terms, systems dynamics comes from industrial engineering, its object of study is the evolution and interaction of systems across time, its method is modeling (incorporating analysis and synthesis), and its aim is to understand organized and complex systems, to make more effective decisions [33].

Organizations are understood here as complex, dynamic and non-linear social systems, in contrast to the classic analysis of static, local and linear systems. If previously there was an attempt to predict and to optimize the future, systems dynamics tries to study multiple possible futures with regard to different strategies.

The organization and planning of dynamic systems cannot be based only on the past. It must discover the causal structures in systems, their logics of behavior, in order to relate decisions to their consequences. In this way, systems dynamics shows, beyond prediction, the importance of revealing the secret assumptions that lie behind the obvious or socially assumed interpretations.

From the idea that a model is an idealization of a reality, that is used to analyze the nature of a problem in a simplified way, the operative modeling
in the systems dynamics perspective represents a laboratory free of risks, expressed in terms of causality diagrams, defining the limits of each system and incorporating exogenous and endogenous variables.

Can the city be understood as a dynamic system? If it is understood as a sum of elements or entities (static and mobile, physical and social) in interaction, that have different kinds of behavior, in a certain space, we are in the presence of a dynamic system whenever we consider some aspects to be irrelevant.

What is the contribution of studying the city in terms of a systemic dynamic model? First of all, it enables us to face the divided vision of the parts of the discipline (the transport system, the housing sector, the public spaces, the infrastructure, the services, etc.) The systemic approach, with the help of technological tools for the resolution of complexities, allows us to analyze both the totality of the city as a system, and the small sectors as subsystems which are not isolated.

5. METHODOLOGY

The experience considers the completion of an undergraduate course in architecture and geography, in parallel with a research between the teaching staff and the students. For this purpose, we use skills of learning and the simulation of urban systems, interpreting their development, direction and control.

A software package, created as a game of strategy, called SimCity, is used in this research. The models that it includes, that contain information, variables, and three-dimensional expressions, allow us to isolate factors and to represent strategies of action in the framing of a variety of possible scenarios, combining common skills in the use of Geographical Information Systems, tools of law, management, planning and urban design [30], [34], [35].
In terms of programming, SimCity is a game based on ‘agents’ and ‘cellular automata’. These can be elements of landscapes, units of housing, units of commerce, units of industry, infrastructure of transport, infrastructure of energy and sanitation and civic equipment. The principal characteristic of ‘agents’ is that they have forms of internal logical behavior in relation to other stimuli and/or other agents, which means they form a system, according to the previously discussed theoretical framework [36].

As we can see in Figure 1, every agent has internal properties and a behavioral logic. The internal properties generate effects on the environment (general system). In this way, the environment generates new determinants that collide with the behavioral logic of the agent, modifying his initial properties.

In figure 2, there appears the nature of each of the variables of the previous problem, pointing out that to form a system the endogenous and exogenous variables must be related. In this way, all these elements interact to form a system, generating different developments with different decisions of design and urban planning and with different ways of managing them. Also, the interface of the program has a set of indicators that show the situation of the created city.

We can classify the most useful urban indicators into four groups:
- Measurement of desirability; values of residence, commerce and industry.
- Geographical information views; zoning of danger of fire, crime, education coverage, housing desirability, water supply, power supply, traffic volume, zones for land use, land value, mayor ‘rating’, inhabitants’ age, health coverage, air pollution, water pollution, garbage collection and garbage treatment.
- Time behavior graphs; values of crime, power supply, water supply, air pollution, employment and population, water pollution, garbage collection, education coverage, education by age, population by age,
life expectancy, incomes v/s outcomes, mayor funds, RCI demand (residence, commerce and industry), mayor ‘rating’, traffic volume.

- Monthly budget; values of incomes and outcomes.

The methodology of the course [37], considered three theoretical stages: i) the city as a dynamic system, ii) systems and subsystems; ideological constructions of models, and iii) strategies of design, management and urban planning. Also, three experimental stages were realized: i) introduction to SimCity, models experimentation and discovery, ii) subsystems work, and iii) modeling and simulation of urban problems.

In terms of the generation of research products, the first stage was about problems of research, analyzing and modeling their structural relations, in order to observe some critical points of possible intervention and/or simulation.

Then, the second stage was about taking the problem of research from the first stage and modeling its structural relations in the SimCity platform, in order to visualize possible consequences with different interventions of urban design. More than getting the best solution, what really was interesting in this case, was the research around the process of decision making, the effects that each one had, the multi-causal comprehension of urban processes, and the conclusions that came to feed the theory. To document the above mentioned processes, the initial situations, the steps of intervention, and the final situations were registered by every class by the software indicators and the images of the urban configuration of the created city.

6. RESULTS

Next, we present three chosen pieces of work (two architecture students and one geography student), showing the course experimentation.

6.1. Miguel Aguilera, architecture student

Aim: Test the location of health and education equipment in two zones of a city, across the handling of the attention radio of every unit, and registering how those services affect the land value, the housing desirability and the access to those services.

Initial situation: 200,000 inhabitants of city with health and education equipment distributed homogeneously.

Intervention 1: Reorganization of health units according to high density zones.

Effect 1: Reorganization of residential occupation. Its principal variables were cleared up: action radio and attention capacity.

Intervention 2: Complete elimination of health and education coverage.

Effect 2: Slow and widespread city abandonment.

Intervention 3: Redistribution and concentration of equipment in two zones that didn’t have good coverage in the past.
Final situation: Land value doesn’t suffer drastic changes. Strong development of commerce and high wealth housing in well equipped zones. Residential abandonment in not covered zones.

6.2. Sebastián Vivero, geography student

Aim: Experiment in improving the mechanisms for air pollution levels of a city, handling the industry type and placing green areas.

Initial situation: Low pollution dense city.

Intervention 1: Pollution increasing by interventions (land use changes, taxes decreasing for pollutant industries and pollutant energy plants placing).
   Effect 1: Population decrease.

Intervention 2: Tax rise for pollutant industries and tax decrease for clean industries.
   Effect 2: Industrial restructuring, pollution decreasing, but some focus persists.

Intervention 3: Biomass incorporation by placing of trees.
   Effect 3: Pollution doesn’t get lower. The game doesn’t consider the ecological effect of trees.

Intervention 4: Green areas incorporation (squares and parks)
   Effect 4: Nearby pollution reduction, focus improving.

Final situation: The city improved its environmental pollution indexes. Nevertheless, the final result had generated an increase of unemployment, an increase of local government expenses, land value and land use changes, etc.

Figure 3. Miguel Aguilera’s urban experiment (effects of the above mentioned interventions)
6.3. Arturo Palma, architecture student

Aim: To test the development sustenance of an urban outlying area, by handling the transport systems.

Initial situation: A city sector without housing, with labor and services activity. Another isolated sector, mostly residential, with some services.

Intervention 1: Development to create an industrial nucleus on the periphery, added to a subway network that links them. It relocates industry fundamentally, to satisfy the demand for employment and goods.

Effect 1: The created industrial nucleus doesn’t affect either the pollution or the land value.

Intervention 2: Creation of a peripheral and a central station.

Effect 2: Low and inefficient use of the subway. It produced losses to the city budget. Subway use was concentrated only in dense zones.

Intervention 3: Improving of central station and placing of commercial nucleus next to peripheral station.

Effect 3: Percentage of subway use had risen.

Final situation: The peripheral poles developed with a slow rhythm. To promote the subway activity, it was necessary to generate dense commercial poles at every station, creating an industrial development pole away from the city, maintaining the land value of the most demanded areas and satisfying the needs for work and consumer goods of the peripheral zone. The subway connection was an essential factor in the whole development of the city and the industry, because it was the only way that they were joined.
6.4. Students open evaluation

At the end of the course, there was an open and free questionnaire (without mentioning names), inviting the students to think about the teaching experience, and to understand the experimental character of this type of practice in a university.

“In the beginning, it seemed a little strange trying to simulate city models with a game, but then, when I realized its complexity, it turned out to be quite an interesting exercise”.

“It’s interesting to simulate real circumstances and discover why they happen in the city. It's a practical exercise that teaches more than a theoretical one”.

“The modeling of the structural relations of an urban topic in a SimCity game, in spite of presenting several conceptual and methodological problems in the application, turned out to be a very novel experience”.

“I believe that the content of the course is good, it take urbanism in a different and didactic way, where it’s possible to have a more real appreciation of different problems of the city, and how the different factors influence its functioning”.

“I liked the course and the experience of working as a whole with architecture and geography students, and I appreciate the innovation of the learning method”.

7. DISCUSSION AND FINAL CONSIDERATIONS

The research helped to re-open and to study in depth a field of study that turns out to be very useful in urbanism today: the urban simulation models field. Also, it favored the improvement of and innovation in educational
processes. In this way, the completion of the course, although it had disadvantages from the point of view of administrative management, that led to problems in the planned times for theoretical and experimental expositions, it nonetheless had a very good reception from the students, as a method for learning, for research and for interdisciplinary study.

The experience had the particular incentive that it represented the teaching and learning of systemic-dynamic simulation models by means of a strategy game. In a beginning, it seemed strange to study urban dynamics using a game, but then the complexity and the conceptual innovation turned out to be very attractive and novel.

The experimentation with causal models and with the SimCity game, used as software, generated in students an important aptitude to realize good research questions, and it was a big incentive to education and study, because it exhibited in a very didactic way a large quantity of variables for every urban problem, and the dynamics of using it meant that, the students could learn the relations between each of these variables.

They learned how to simulate real problems, and in the exercise of making them work, it was possible to discover the reasons of the occurrence of these problems. The exercises were understood as practical works, which could deliver more results than theoretical exercises. In this way they could obtain, paradoxically, a more real appreciation of city problems, and how the different variables influence its functioning. Also, it’s necessary to emphasize the importance of being provided with new technologies with a large capacity for information handling, for experimentation, as a laboratory of future city scenarios.

Although this research has tried to penetrate into new technologies for modeling and simulation, the most important, undoubtedly, has been the interaction with the students, who are finally those who, by their gaming, can decipher the SimCity code, and help us to put in question the North American city model that inspired the software, and some of the most important theories of urbanism. In other words, this investigation could not be carried out without the essential feedback from the ‘human factor’.

The “human factor”, represented in this case by the interaction between human beings and computers, is related, on one hand, to the motivations and the stimuli that generate this type of education methodology, from the point of view of a technology centered on the user and, on the other hand, with the need for error reduction, which is always present in any planning and project exercise.

The research at this moment is centered on the second version of the course and on the new knowledge that could be obtained from it. There have integrated such new concepts as “emergence”, which describes the spontaneous organization of elements giving form to intelligent behaviors, and the systems of “cellular automata”, which represent mathematical models for observing the evolution of dynamic systems. The above
mentioned concepts have integrated both the deep development of urban theory and the analysis and experimentation with the game. Also, the whole material of the course (class presentations, required bibliographies, links of interest, ordering and results of exercises, etc.) has been gathered, published and updated for the whole scientific international community in a blog (http://urbanismosimcity.blogspot.com).

For future developments, the research raises the question of the integration of simulation skills, as rigorous and transverse methodologies for any projecting discipline, in order to be able to evaluate the possible effects of any design. In the urban field, specifically, it hopes to be able to penetrate the programming of simple simulation applications for open code geographical information systems.

References