

Urban Simulation Models: Contributions as Analysis-Methodology in a Project of Urban Renewal*

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Abstract

The recent urban transformations produced in cities indicate the need to propose new theoretical and methodological approaches in physical planning. Based on the idea of complexity, it is required to integrate, in the analysis, multiplicity of interrelated factors involved in urban development, moreover, to develop planning tools that can incorporate variables not initially considered (for example when the norms were sanctioned) and instruments that would provide assessment alternatives to planning decisions in real time. The simulation models are suggested as tools to detect the elements, relationships and the dynamics in a simplified form that allow experiencing on the results. That is to say, a theoretical position on to a computer model is translated to investigate (in an experimental way) possible solutions derived from manipulating the variables, before the phenomenon is materialized. In the case of urban planning, this condition is of particular relevance, given the importance to anticipate unwanted effects in the intervention context that may arise when urban projects are built. The paper evaluates the application of a simulation methodology, based on the dynamics of systems and the application of software that can anticipate the effects of certain decisions in an urban renewal project in the city of Córdoba, Argentina. It applies the General Systems Theory that is a contribution to the notion of complex thought and is trans-disciplinary. Based on the idea of complex and multidimensional city, the effects of a real estate development are analyzed and conclusions on the limits and possibilities of using this tool during the processes of urban management are provided.

Keywords

Simulation Model, Tool, Urban Planning, Urban Management

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1. Approach to Urban Analysis through Complexity

The city is complex and multidimensional. The change in the urban environment is permanent, is continuously produced and the actions are not easily predictable. In recent decades the cities observe significant urban transformation processes. In many cases, in response to global economic restructuring forces (with impacts in urban productive activities, employment and linkages with other urban centers), demographic changes (migration, population aging), impacts of new technologies (in communication, access to information, transport and modes of production), changes in the matrix of energy production by depletion of fossil fuels, among other factors, generated an unprecedented dynamism in the urban structure. We agree with Ramos (2004: p. 7) that the degree of complexity and the role that the manifestations of urban nature in the daily course of events have acquired converts any fact in potential expression or product of this invention urban laboratory that were and still are the cities.

The cities as scenarios of transformations present a variety of socio-spatial processes, which means understanding the new developments and urbanism without discarding the old conceptions, but also recognizing that the disputed and complex socio-spatial dialectic relations between social process and spatial form and vice-versa, increasingly are more different than they were during the period of import substitution. Inconsistencies, contradictions, disruptions, among other features, suggest the need to rethink and restructure deeply the inherited forms of urban analysis and to meet new approaches to face the theoretical, political and practical challenges presented by today's metropolises (Soja, 2004: p. 92).

In this line of thinking, theoretical and methodological approaches on physical planning to account for the complexity of urban dynamics are required. The understanding of the contemporary city requires a combination of micro and macro perspectives, integrating the multiplicity of interrelated factors involved in urban development that can provide alternatives to assessment decisions that guide intervention policies. Dematteis (2004: p. 171) explains this idea by saying that "it is not necessary to describe what happens in cities like the result of external changes, but to understand that the same description procedure is participating in the process of change that is happening". The author notes that in many urban and analytically-oriented studies, the new emerging forms of the city are still treated as if they were natural phenomena that an external viewer describes based on objective observations. The position of this author is that the description does not follow the changes but remains involved in its production. That is to understand that urban transformations are not the result of changes that happen before; if so, the description of the city and its transformations would be virtually a useless operation in scientific terms, only a superficial description of a phenomenon. The proposal is to assume the opposite assumption: nothing is thought or changed if it is not through the materiality of the places and their properties, because through these, things tied-down pass necessarily (but not deterministic) all social relations and their conceptual representations. Territoriality (while symbolic, cognitive and practical mediation materiality of places) determines that the disciplines that operate on urban space are positioned cognitively and operationally in a strategic way. As re-describing places and projecting its physical transformation re-conceptualize and restructure social relations (Soja, 2004: p. 172).

Urban dynamics, and the processes of transformation of space presented in the last decades, require theoretical approaches and planning methodologies that enable an approximation to the ongoing processes from a complex and multidimensional perspective. It is necessary to include planning instruments that can incorporate variables not initially considered and provide tools to evaluate hypotheses that might arise in the temporal evolution of urban development. Today, in the current context that developed physical planning in Latin American cities as the case of Córdoba, planners in many cases do not set up the impact of a change in a particular urban situation when a new one has already emerged, which tends to return obsolete the decisions and measures adopted.

As Morin (2007: p. 11) mentioned, we understand that complexity is a problem-word not a solution-word and what is sought when incorporating the idea of complexity in addressing urban phenomena is linking disciplinary domains usually separated by a dissociated logic of thought. Moreover, (following the same author) the idea of complexity not only refers to the interrelationships between multiple quantitative and qualitative variables involved in urban planning, but includes random phenomena and managing uncertainty. In a sense the complexity is always related to chance. This complexity matches an aspect of uncertainty either in the limits of our understanding, whether registered in the phenomena. But complexity is not limited to the uncertainty; it is the uncertainty within the richly organized systems. It has to do with the semi-random systems whose order is inseparable from the random they include. The complexity is thus linked to a certain mixture of order and disorder (Morin,

2007: p. 60). This aspect is considered critical when spatial planning takes place in the context of developing countries, with strong reliance on external macro-economic conditions, where both economic and social realities are changing frequently, and crisis are often presented in urban intervention scenarios. Thus, the interventions in the city are subjected to conditions that differed from the originally planned context and require a new evaluation (or adjustments) on project decisions during the course of its implementation.

On this principle, the idea of complex city is based on the ongoing research. We evaluate the application of a simulation methodology in a private urban project. The objective is to be able to anticipate the impacts of certain design decisions before the projects are materialized and also, anticipate potential crisis in prospective evaluation scenarios. We agree with Dematteis (2004: p. 172) that the most recent change in territorial science and planning is to move from the development of urban plans (i.e. set instructions, regulations and norms) to territorial policies. This field requires managing interactive processes and developing tools able to promote urban negotiations between the actors involved.

In the case of Córdoba city in Argentina, a turning point occurs in relation to the approaches on urban development and planning instruments since the nineties. Urban policies focus on improving infrastructure and services to promote the actions of economic agents, seeking to attract new investments to the city. With the incorporation of public and private actors in urban management new architectural works were built, which reflect the structural changes observed in economic, social and political fields. Regulatory planning subject to the changes in paradigms resulting from globalization, seem not to respond to the production of urban space driven by the dynamics of centralization/decentralization. New processes, spatial forms and the intensification of social segregation process, result in a more complex urban configuration characterized by territorial fragmentation. In this context, different instruments are required to evaluate the management of large urban projects, as well as to identify the effects of the implementation of certain proposals, both from the perspective of real estate agents and private promoters as well as from the feasibility, benefits, and disadvantages in terms of urban, environmental and social sustainability associated with them.

2. Urban Simulation Models

Batty (2009: p. 52) defines: “Models are simplifications of reality, theoretical abstractions that represent systems in such a way that essential features crucial to the theory and its application are identified and highlighted”. In the case of urban planning, we considered the model as a way to make experimentation (using different variables and analyzing the effects produced) and after this, the possibility to prediction future scenarios of intervention according to the performance of the different variables included in the modeling. Models are representations of a number of realities (conceptual or phenomenological), and make possible to intervene in this virtual reality as an experiment and operate it at different levels of analysis. In solving problems of design, modeling, rendering a particular case, is a widely used methodology. Usually when the information necessary for action is studied, it is considered that there is no development without representation. Models are used to produce descriptions (what and how things are), explanations (why things are like this) or predictions (how things will be).

In this context, the General Systems Theory is a contribution to the notion of complex thought and is situated in a trans-disciplinary level which allows to conceive, at the same time, both unity and differentiation (Morin, 2007: p. 42). While making possible to incorporate the dynamism of reality generated by the techniques of system dynamics (which is a discipline derived from the general system theory). It provides a planning tool that enables the quantification and qualification of the impact of an urban development in the city. System dynamics deals with the relationships between different subsystems as time passes. With the development of computer systems new simulation models, which detect the elements, relationships and the dynamics in a simplified form, allow to experiencing on the emerging results. That is to say to move a theoretical concept to a computer model and from there investigate in an experimental setting, by the manipulating of variables prior to the materialization of an urban project. They become projective instruments that incorporating uncertainty, allow studying different possibilities related to of urban interventions and become useful tools because allow to find remarkable results by generating qualitative indicators that can be associated to quantitative variables.

From this perspective, simulation models while producing images and information about future urban forms, becomes a useful instrument for urban management, particularly during the stage of evaluation of a specific initiative. Applying the model is also possible to include the perspective of different urban actors (as developers, social based organizations of the community, and representatives from the state in its different levels, among others) in the evaluation. By the time, it highlight the effects derive from a future intervention that could hypo-

thetically represent interest in conflict. Using a computer simulation tool in urban management has value, as far as make possible to have a methodology to address complex variables simultaneously; to make more transparent decision-making processes; to make known to all stakeholders the advantages and disadvantages associated with a project and contribute to the democratization of urban policy decisions.

Urban models are thus essentially computer simulations of the way cities function which translate theory into a form that is testable and applicable without experimentation on the real thing (Batty, 2009: p. 52). Based on this idea, in the research we follow the objective to evaluate a norm that looks for to renovate an area nearby the central city. We focus on a specific urban project financed by private investors and developed through a public-private partnership because of its particular conditions. The goal was to verify which could be the effects of a renewal project in the specific area of intervention and also the effects to the surrounding area. There is no tradition in physical planning in the city of Córdoba-Argentina to apply ex-ante evaluations, so to know the potential effects derived of the Project, could help to enlighten the weaknesses of the urban norm.

In the research Simulation Model is defined as the imitation of behaviors from a certain level of analysis or point of view of reality, studying its evolution over a period of time using a computer model. This model will only imitate the behavior of the considered reality and will be valid to the extent that achieves a behavior similar to reality. As a process, it has duration and dominant features which depend on the level of analysis (plane of analysis) defined in terms of the research objectives. The application of the simulation model implies the existence of a simulation time, feature that distinguishes it from other models as mathematical or statistical, etc.

The models are understood in this research, as quantitative tools for decision making. According to the scale of the solution sought and objectives of the research were used simulation models based on system dynamics developed by Forrester. A network of concatenated by first-order input and output information flows and differential equations are generated. This is done by graphic programming implicitly automatically generated which is then integrated in time series by different methods (such as Euler, Runge-Kutta) or other differential equations. These types of models are allowing less development time because their way of programming generates the equations used for simulation automatically, once it is only necessary to check the consistency of the results.

3. Urban Simulation Model Applied in the Case of Capitalinas Development

In line with the research objectives a case study in Córdoba city was delimited. The area is called “Portal del Abasto” and specifically the simulation focus on the real estate venture: Capitalinas (Figure 1). The urban sector where the project is located is subject of urban policy actions implemented by the local government through a program of renewal processes. It aims to revitalize public space and cultural heritage in the area through the enactment of a new Municipal Ordinance 10998/05.

It is worth mentioning that Capitalinas venture has a form of real estate development, where the modification in the project is permanent, in response to changing market demand. This situation has made a significant trend in the new scenarios of local private development. The project is divided into three stages: The first stage covers office buildings for corporation, with a parking for 330 vehicles, a commercial-gourmet area in the ground floor, locals for banks, a gym, spa, natatorium and the building of the convention center. The second stage involves the construction of a Condo-Hotel Radisson, in an international format. The third and final step is the residential area, which has also been modified from the original proposal (Marengo, 2010).



Figure 1. Capitalinas complex in Córdoba city. Source Córdoba Municipality.

The methodological development includes the following stages:

1) The starting point for the generation of the model is the identification and selection of variables (inputs) endogenous and exogenous to the problem, their relative weighting and interaction (co-relation) in a complex matrix applying different scenarios of renewal at different time periods. The temporary stage was considered in twelve years, and three scenarios were fixed in assuming that renewal process could reach at 30%, at 50% and at 100% of the initial architectural project. We proceeded to determine possible urban impacts that would result from the building of the renovation project in the sector, (in the three possibilities) using a simulation methodology that operates from hypothesis about reality, levels of residential occupancy estimated and values defined for different uses.

The occupation possibility of the project was defined based on calculating the residential occupancy and uses (m^2 assigned to different functions) in the area of the complex (Capitalinas) taking as initial parameter the maximum floor area that is allow to built in the urban norms. The number of residential typologies planned in the project and the total residential area were considered for estimate the number of inhabitants (permanent and temporary) in the complex it once built. Based on the density of population, the likely effects of the intervention (on the neighborhood surroundings and on infrastructure demands arising from the concentration of population and new functions) are evaluated. Occupancy status was modeled with all the interacting variables.

2) The choice of the type of simulation. The idea of simulation is to generate a simulation system that behaves in an isoform way to reality. For his achievement, in the logic of the model form was reflected the behavior of the variables (by their proper interrelationship), the units of measure were homogenized to avoid inconsistencies and was studied the best way to run the simulation time. Partial results were obtained in three temporary cuts overlapping with the renewal scenarios mentioned before. The values obtained as output from the model, were studied verifying its feasibility, rationality and individual cases. Finally, was made an analysis identifying critical situations and sensitivity points.

3) Construction of the precursor model. This is the systemic (conceptual) model that precedes the computer simulation model allowing reflect the complexity of the modeled reality with a minimum loss of information and synergy. The software tool is Stella 5 which is fully adapted to the dynamics of systems and is a great advantage for the generation of the computer model (www.easysystems.com). In developing the conceptual model (precursor and systemic model that precedes the simulation model) the nature of the variables were defined (discrete or continuous, measurement units and state), assigning a range of variation for each variable and running the simulation with different values. Initially seven subsystems and six external elements that interact with them are defined. Among the subsystems were considered: population, covered area built, residential units, potable water, sewerage, electricity, gas. Among the external factors: potential inhabitants, the municipality, the service providers and urban developers. Two arrays were established (one with a reduced incidence and other of adjacency) which describe the value of the relationship between the subsystems and the external elements that is the synergy between the seven subsystems considered.

4) Finally, the last step is the visualization and interpretation of results in different model runs according the changes that are produced in the intervention context. The analysis of the dynamic behavior of the different subsystems in the simulation (residents, occasional visitors, employees, residential units, infrastructure demands and parking) allow to synthesize the sum of elements or entities (static and mobile, physical and social) interaction , which in turn have different modes of behavior.

Subsystem Development, Some Results

As an exemplification of the possibilities of the tool for analyzing the effects derived from large urban projects, is developed the subsystem drinking water that took part in the construction of the model (Figure 2). Initially the total demand was calculated according to time, a value between 50 and 100 liters per m^2 for residential area, based on the daily flow defendant. As a result, it was noted that with the current conditions of supply of the network, at 3.5 years the project cannot meet the demand of water supply.

After the initial run, new further adjustments were made to the model. Differentiated water consumption values were incorporated, allowing study and simulate in more detail the water consumption values, disaggregated more in line with each activity performed in the complex. Initial data were adjusted (specifically considering the consumption associated with each type of activity, a correction factor, and the period on demand, among other more specific indicators associated with this variable). Finally consumption demand approached 400 liters per

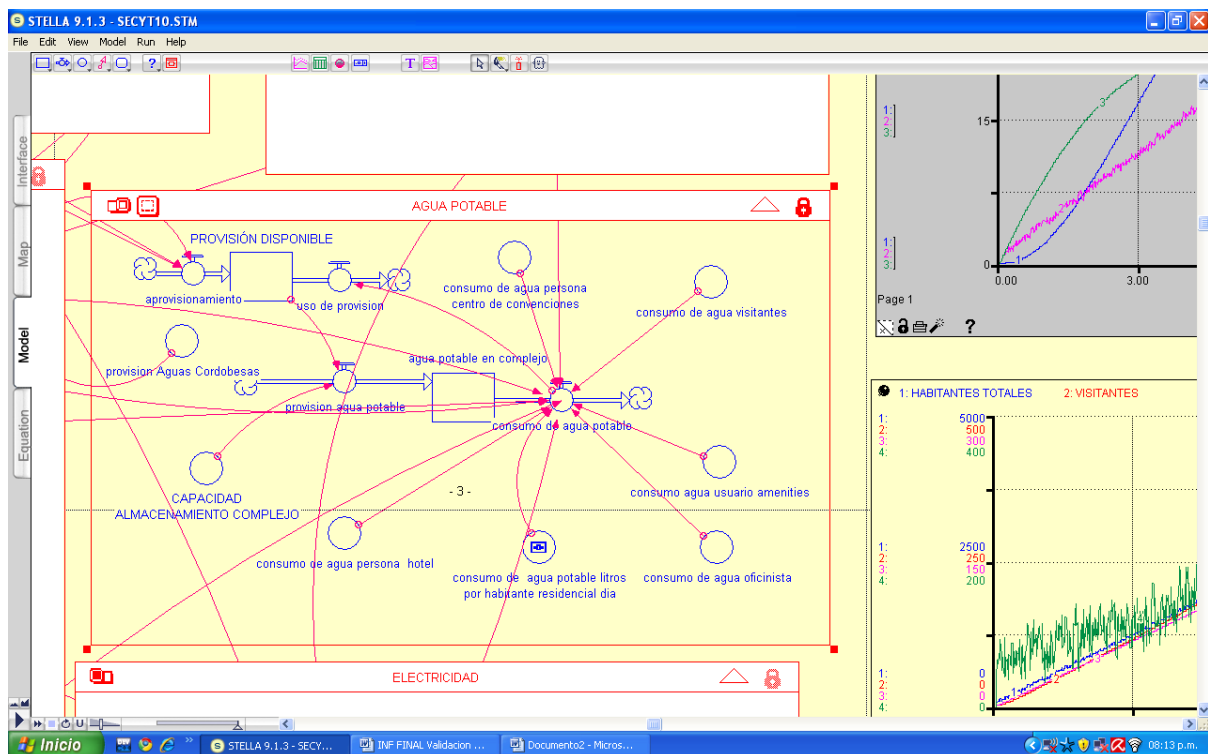


Figure 2. Interrelationships of variables in the case of drinking water subsystem. Relationship inhabitants—water demand. Software Stella 5. Source: (Marengo, Ambrosini, Bonetto, & Ochoa, 2009).

capita per day. Various model runs were performed and with the latest run (Run N°10) was possible to notice that the drinking water subsystem presents a clear tendency to collapse. This hypothesis would take place during the eighth year in the period of simulation since the project begins to be occupied, when the population incorporated tends to be maxima and also the level of occupancy in the complex.

The analysis of the graph (Figure 3) in the Run N°10 of the model shows increasing consumption (see curve N°2 in pink) independent of the supply (curve N°3 in green) or the drinking water in the complex (curve N°1 in blue). In the eighth year of simulation a break is observed (mathematically a discontinuity) due to shortages in the provision of water. The model shows a second stage where the curve of consumption and provision of water overlap (curves number 2 and 3, indicating that the subsystem has no possibility of water storage for the remaining simulation period. Note that curve 1 (blue) drops to zero on abscissa axis which indicates an isomorphic behavior with reality in the model run. The isomorphic behavior with reality is a valuable element to validate the model and the precursor system that originated it.

The data obtained with the simulation contributes to the discussion on urban interventions and investment demands that are necessary to sustain the project. Here lies the most valuable contribution of the methodology: the possibility to transfer results to urban management and make possible to discuss on investments that are needed. Some questions may orient the discussions in this case as to mention: How should the Municipality proceed in this case? Not allowing the new construction? Requiring investments from private developers due to the project and its effects on urban systems? Is it possible to capture urban plus-values, and redirected to the investments on infrastructure that are required in the city? In short, the value of the tool lies in enabling discussion and consensus between the different actors involved in the development of the large urban project.

4. Research Conclusions

In conclusion it can be argued that the simulation model is validated as a tool used for the analysis of complex urban processes. It allows for prospective evaluations on possible scenarios of urban development, and highlights the limitations and possibilities implicit in the decision making process.

The systemic methodology, its flexibility and possibilities to anticipate the trajectories of the different va-

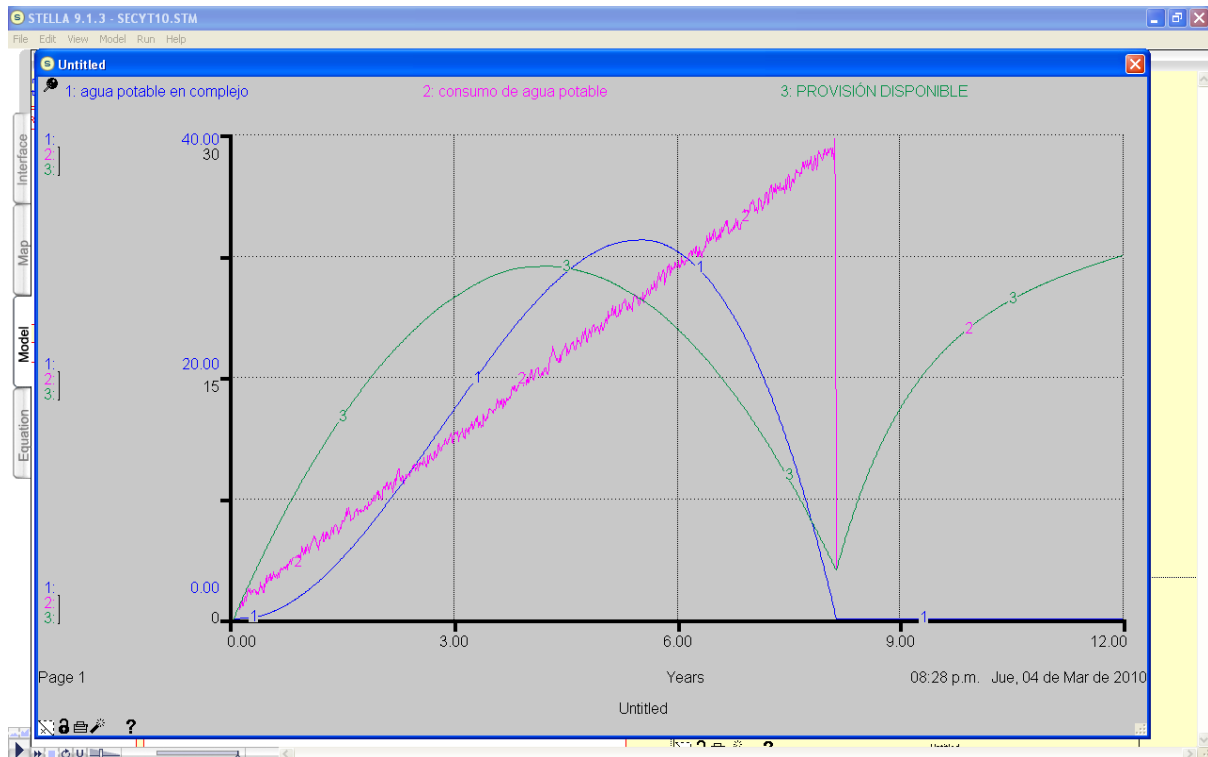


Figure 3. Subsystem drinking water. Relationship between supply, consumption and availability of water in the complex. Source: (Marengo, Ambrosini, Bonetto, & Ochoa, 2009).

riables that integrate the model, provide a quick view of the impact of specific interventions in urban space. Moreover, it requires a comprehensive adjustment in terms of the values associated with the variables involved in the model. Although this condition could be considered a disadvantage (since any error in assigning the values of the variables influencing the consistency of the model) we consider it an advantage as it allows to test different scenarios and values during the experiment. This way enables to project different results and evaluate different decisions that could be applied to achieve a specific goal in urban policy. It is remarkable that the tool is validated even in a specific case as Córdoba city, in a peripheral country. This is seen as a significant contribution, as it is generally considered that this type of tools can be used only in the most developed countries, due to the availability and systematization of data.

Simulation models developed during the research are likely to be applied with a higher level of detail, and are valid tools to be used in negotiations between the Municipality (as city regulator) and the private developers. The inclusion of the systemic view (which converge different aspects like economic, population, infrastructural, urban regulations, among others) that describes the logical and quantitative links between different aspects and a concrete reality, generates a quantitative model to decision making. It helps to seek the optimal point, which corresponds to a system configuration in which the entropy is minimal during the simulated period.

It is a tool for the validation of the urban norms in terms of the possibilities of provision of urban infrastructure standards. Allows for example, evaluating a new project in terms of the demands on public infrastructure that will be required when construction completed and negotiate between public and private actors required investments. For the regulation of urban land values, the simulation model allows trade-offs among architects, investors and developers limiting the discussions and encouraging the negotiations. It enables an external arbitration between public authorities and private developers to avoid falling into infeasible negotiations, providing data to evaluate an adequate return on the future investment and contribute to the discussion on design variables.

If the system has been developed in a reliable manner consistent with reality, their results may have the following characteristics:

- Shared vision of the model-logic and the behavior of the reality.
- Shared vision of the future, to understand the interaction processes between logical systems over time.

- Sensitivity analysis studies the occurrence of thresholds for different variables, generating a set of alternative actions and policies.
- View the relevance of suggested policies anticipating the consequences and understanding the behavior of the system without reducing the complexity.
- Easily understood by urban actors.
- Facilitates the detection of problems and allows defining secondary lines on research based on simulation modeling.

The difficulties derived from the application of the simulation model are mentioned:

- The variation on data ranges has a high impact on the plausibility of the simulation model.
- There are numerous hidden variables produced by the recursion of the described systems.
- The full validation of a simulation model applied to urban development requires more time of work than others.
- It is always possible to develop a model with a greater level of detail. This must be balanced with an approach consistent with the goals of the designers of the simulation model. In our case ten simulation models were developed, progressing in each version in considering a different aspect.

Finally, the development of the simulation model requires resources and a learning process for the actors involved. If the model works as a tool of negotiation and arbitration, it is necessary to implement steps that facilitate agreements between urban actors. Possible transfer in an interdisciplinary discussion of results is perhaps one of the most significant inputs for addressing the inherent complexity of urban processes.

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