Integration of Simulations Models in Planning for Local Sustainable Development. The Case of Río Ceballos in Cordoba´s Metropolitan Area.

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Abstract

Latin American cities present an urban growth process that continues the metropolization started in ´70 and ´80 of the past century. But since the last two decades this process is showing different characteristics and as result the current urban conditions appear as critical and unsustainable in short term. Moreover urban planning currently has some tools such as simulations models through computer-assisted system (GIS) to visualize and to plan urban futures, incorporating citizen participation. This paper is based on experiences in using of simulations models as planning instruments in the Latin America context and discusses the experience in the construction and implementation of an urban growth simulation model for the small town of Rio Ceballos in the metropolitan area of the second largest city of Argentina, Córdoba. Finally, it considers the integration potentialities at local level of models in daily planning process to a sustainability horizon.

1. Introduction

Latin America is one the most urbanized regions of the developing world – in 2007, urbanization reached 78 per cent of its total population, according to the United Nations Population Fund (2007). After a century of explosive urbanization and demographic expansion, new urban trends are taking shape, presenting new challenges to urban research and development.

In this way until the ´80 of the past century Latin American middle and big cities showed an urban growth process to metropolization. But since the past two decades this process is showing different characteristics: changes in population structure (fall of the population growth rate, decline in growth of central cities and related to this the growth of small and medium towns in metropolitan areas), changes in land uses (monofunctional areas following connectivity criteria), fragmented spatial organization (neighborhoods with limits and controlled entrances) and associated with this a social segmentation (gated neighborhoods of homogeneous high incomes groups stand in contrast to slums, agricultural fields or industrial areas).

In this metropolization process Central cities decrease its growth rate showing punctual spatial transformations by private investments (densification, gentrification, big commercial or service nodes) or by state to resolve critical situations or to increase the local competitiveness in the global market (basic infrastructure improvement, new open spaces and cultural facilities in relation to touristic activities, inter alia). On the other hand small cities and towns in the metropolitan areas, developed around agriculture, mining or tourism activities, have experienced an explosive growth with arrive of new population and activities from central cities. This process responds to multiple reasons: changes in social choices, a better environment quality, and properties lower prices and faster connectivity. Add to this there is a lack of consideration of the territorial support with a consequent high impact on the natural systems. Floods in urban areas, landslides, pollution of waterways, drinking water scarcity, contamination of groundwater by sewage, open dumps are some of the environmental problems resulting from an inappropriate use of urban land and surrounding watersheds.

This variety of impacts is only reduced in some intervention areas with mitigation measures and in many cases with a cosmetic character. Associated with that, there is a historical resistance to investing on infrastructure by private actors now associated with the logic of the global economy (low investment in fixed capital).

All these factors lead to present the current urban conditions as critical and unsustainable scenario in the short term, with spreading illegal settlements, ill-regulated land use, low sanitary conditions and increased poverty and an urban life that is crossed by violence, poverty, and environmental problems. The physical manifestation of this process is a fragmented territory with a persistent horizontal growth of the metropolitan agglomeration, which cities requires a continuous extension of the network of public services to peri-urban areas, even when the infrastructure already in place in central areas is not used to its full potential.
In relation to this, planning has a weak tradition in Latin America, and is more associated with top-down models of citizen participation. Evidence of this is that, despite the wide acceptance of sustainable development to guide current and future urban growth, little progress has been made in the transition from statements to operational approaches that promote the desired balance in urban growth. The discussion over sustainable development in urban areas, in particular in Latin America, has been uncompleted and limited to a technical vision of planning and control of some local environmental problems. Sustainable development has not been able to transcend rhetoric except for some cases such as Curitiba or Medellin.
This urban dynamics becomes a major challenge for environmental and social policy management, especially in a context of inadequate information systems about urban expansion. Although we do not have comprehensive data to support this trend, peri-urban areas in large and medium cities are likely to have the major part of Latin American´s population growth in the coming years. (Sanchez Rodriguez, 2007)

2. Simulations models as instrument for urban sustainable development

The management of these complex processes of urban growth into the sustainability requires a number of instruments. Two areas appears as need and opportunity for sustainable development: one of the is the creation of governance processes that will include the participation of civil society and the private sector in managing the urbanization process and the other is to overcome the limitations of the current approaches that consider urban issues in a fragmented manner, in favor of multidimensional perspectives capable of creating an integrated perspective of the complex and dynamic urban reality (Almeida, 2007). Urban simulation models are presented as valid instruments that can contribute to the above mentioned issues and today researchers have at their disposal a wide range of models (agents

based models, micro simulation models and cellular automata) which show great potential and capability to represent the complexity of urban process and the ability to simulate and forecast changes in urban land use, that can provide clues to local managers to evaluate and make better decisions and information to citizens about their environment. (Pinto, 2007)

From these assumptions this paper addresses the following question:

Can urban simulation models that let view the deteriorated situation and possible ways of solution, serve as a tool to build appropriate policies, improve decision-making and increase the level of involvement of all stakeholders of this process in the Latin-American urban context?

An urban environmental model as tool for better governance has to follow the next requirements:

- The environmental analyses need to comprise the conflict of the social appropriation of the natural resources (Fernandez, 1999). The value and opinions regarding the future of urban growth of representatives groups and individuals of the local, state, and federal governments, the private sector, and non-governmental organizations, help to determine the types and extent of environmental problems Therefore, the model can ensure that the study reflects local values about the process.
- The environmental complexity will be discussed from pioneering planning concepts of "land aptitude and compatibility" (McHarg, 1967) to recent such as the "potential of sustainability" (Antequera, 2005). A multi-criteria methodology allows the integration of these concepts, facilitated by the ongoing development of Geographical Information Systems.
- Also, the approach "sustainable development" will depend, upon improvements in our knowledge of the cause, chronology and impacts of the process of urbanization and driving force (Bozzano, 2009), as well as future possibilities. Dynamic spatial urban models provide an improved ability to assess future growth and to create planning scenarios, allowing us to explore the impacts of decisions that follow different urban planning and management policies (Henriquez, 2007).

The way to precisely evaluate environmental and social consequences of landscape transformation is with an analytical hybrid framework of urban-ecological models that integrated:

- An interpretation model of quantitative and qualitative information to represent broad spectrum of values and opinions regarding the future of the process of driving forces and residents
- An environmental carrying capacity model,
- A model that spatially represents historical land occupation patterns and their tendency.

Finally it is convenient to simulate alternative futures build possibilities to a sustainable horizon.

Moreover it is necessary at this point to recognize that the development of models for urban management requires a political decision and the necessary human and material resources for its implementation. The Latin American scenario described above appears as unfavorable to these experiences. Some case studies analyzed show a possible way that emerges from the integration of academic studies with problems and needs of different local actors. Thus, the use of simulation models seeks to integrate to traditional planning and can increase citizen participation.

3. A local urban model experience

Based on the research question posed above, the requirements for environmental modeling and the Latin American context, it is developing an experience that seeks to link research, planning and citizen participation:
The experience has started with a general problematic, the metropolitan urban growth of the city of Córdoba (1.500.000 inh.) and the 20 towns and cities that form his area; but in a specific location and with concrete problems and actors: the occupation of old neighborhoods in vacancy or low occupied, in pressure of the expansive real estate forces, in hydric crisis, without a local planning strategy but with local organizations concerned about the problem.
It has continued in an academic context where was developed an urban environmental model that has assessed the concrete problem and was supplied with information obtained from previous studies and from the interaction with local actors.
At the moment with develop the integration of the models results with local actors (politicians, technical, social organization and citizenship) looking for a new way in planning process, where traditional planning tools such as regulations are combine with participatory planning and the interaction with the urban simulation model.

3.1. Study Area

The city of Córdoba, capital of the Province which the same name, is located in middle Argentine between the rich Pampa plain and the first foothills to the Andes and has experienced a rapid growth since the 1950s thus becomes the second largest metropolitan area in this country with more than 1.5 million people. The growth characteristics have changed over the last two decades as in many other Latin American cities: From a large central city growth has come to an explosive growth of small towns in the metropolitan area. In this area there are more than 20 places between 50,000 and 2,000 inhabitants. These were linked to agricultural production, mining or tourist activity, and today became dormitory towns, with consequent problems of mobility, lack of infrastructure, weak local governments and the arise environmental impacts.

For the application of the model were selected three representative Cordoba´s metropolitan cities: Río Ceballos in the NW (fig.1), Punilla Sur Villages in the SW and Toledo in South. In this paper was presented Río Ceballos (31º 10' 16.3" South and 64º 31' 08,8" West) a little city located 30 km from Córdoba city and connected by highway with it. The current urban population is 18.000 inh. with a growth rate over 5 %. (INDEC, 2011) The city and its surrounding areas are blessed with great natural beauty: hills, forests, river, streams and an artificial lake in the proximity. The even limited extent of development has left the Río Ceballos region with much open space, offering a wide range of recreational opportunities for residents and visitors. A strong connection with nature remains vital aspect of life in Río Ceballos, attracting day tourists, in search of an alternative to the faster-paced and more congested capital city, Córdoba. The majority of the new population settled in the city in the last two decades has not roots in the place and works and socializes in the central city Córdoba. The 95 % of urban land was legal created between 1920 and 1950 and was only in the central areas occupied. This urbanization process was developed by private agents, in most of the cases as speculative investment with a weak legal control. Today about 80% of urban land is low occupied or vacant and without an adequate layout, without infrastructure and public open place. But in the last two decades occupation began increasing and the actually occupation is spatial very disperse and social fragmented with a long list of environmental problems like water scarcity, lack of sewers, floods, traffic congestion, criminality inter alia. This study examined 10 "**loteos**" (legal urbanization unit) in three different areas. The selection was done with criteria of representativeness: environmental (critical areas- steep slopes, water recharge areas, natural forest, etc.), social (permanent residents and new arrivals, high income groups- population under poverty

line) and historical occupation process (never occupied, occupied and abandoned, recovered and for sale).

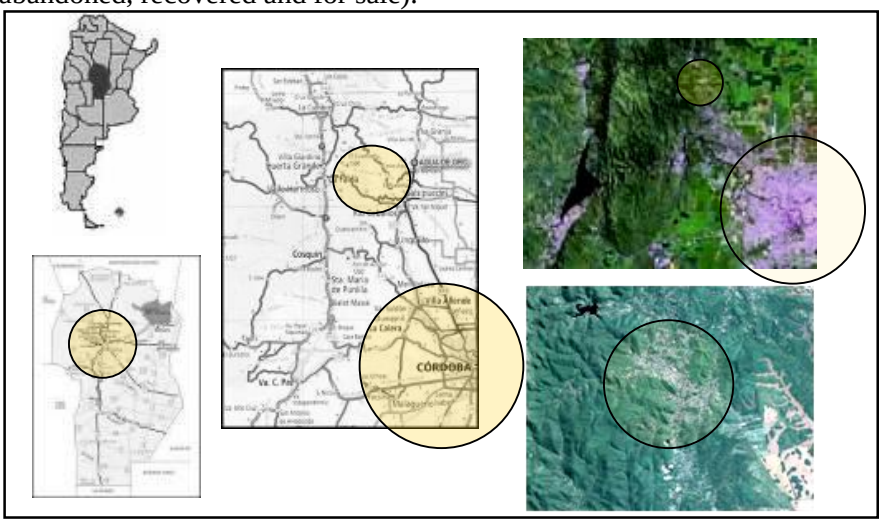


Fig. 1. The study area

3.2. The proposed model

The proposed model has a target the urban sustainability. It was built on a mesh of involved actors, environmental problems, history, land potentialities and possible futures. In this way the model will try to integrate complexity and participation. It is named Environmental Territorial Urban Model and is organized in two following phases (fig.2). The **first phase** starts with the organization of the information about environmental problems, in order to define the problems with precision and to systematize information for the model database. Here the task is collecting information of different sources, in many instances is necessary the digitalization and finally the information is homologated. Moreover, it is necessary the social validation of environmental problems: a series of depth interviews with key local actors, allows confirming or not this problems and delving deeply into their understanding. With these elements it is possible to develop the description and explanation of the urban growth process to define the Current Situation. Through the analysis of territory's carrying capacity using multicriteria methodology is defined the potential of sustainability and the restrictions for further growth. Beside is analyzed the historical development of the occupation to explain the forms of occupation and appropriation and to define patterns. The analysis starts with existing previous studies at local and micro regional level, but it focuses in the micro scale,

that of urban sector because is seen as more conducive to recognize environmental problems and possible solutions. The triangulation of social validated environmental problems, historical occupation process and territory carrying capacity, allows define synergies, potentialities and restrictions for a sustainable urban development. Thus is shape the initial state for the next phase: future scenarios.

In **the second phase** the model simulates three futures development scenarios. The complexity of environmental systems and their inherent degree of uncertainty and indeterminacy require addressing the future with its dynamics of change and possible impacts trough future scenarios. They do not claim to be predictions, but the generation of a range of possible options for awareness of stakeholders and to hold the decisions they will made. Future scenarios are attempts to perceive futures in the present ... are stories about the future with a logical plot and a narrative that organizes the events (Gallopin, 2004). In this way the future scenarios help to clarify general views and values of involved actors, tests the limits of conventional thinking and encourages debates, and so become a tool that contributes to building a socially validated emerging environmental knowledge. Three scenarios were selected, that describe the likely range of possible changes. Scenarios A and C represent the extremes. Scenario **A** assumes the continuity **"status quo**" of the actual tendency in the metropolitan areas (social and economic fragmentation, spatial dispersions, economic speculative forces as single driving force, low investment and low policy regulation). This scenario is expected to result in the most change in land use and the greatest impacts, although with higher potential economic benefits in the short time. Scenario **C**, the "conservative scenario", follows the concept of **hard sustainability** (Fernandez, 1999) (social community organization, long term local economic development, high investment, high policy regulation). This scenario is expected to produce the lowest environmental impact and least landscape change. Scenario **B** forms a midpoint, with a realistic mix of possible changes between the tendency and the total change. In the concept of **soft sustainability** (Fernandez, 1999) the key word is development.

These three scenarios provide a range of incremental policy changes, serving as basis for comparative policy analysis. The projected configuration for each scenario is unique, varying in the extent, direction, and pattern of growth. Finally, the model asses the different impact of the future scenarios on a suite of environmental indicators in relation with the local environmental problems. A Computer-based Geographic Information System (GIS) is used to organize the data and to model and represent complex processes at work. The software use is ArcGis 9.3 and their applications such as Spatial Analyst.

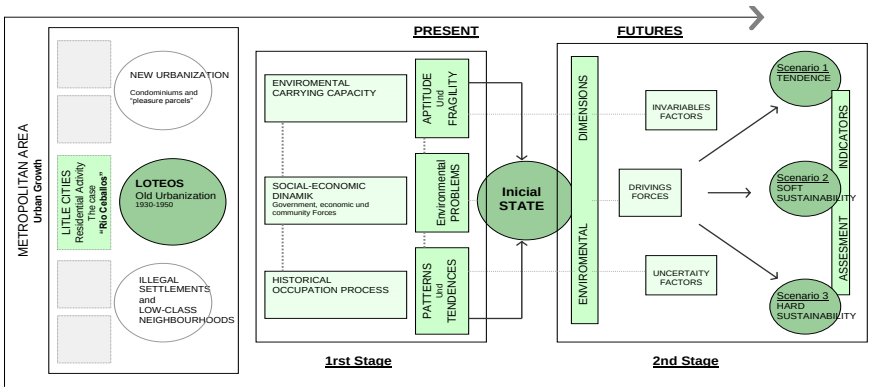


Fig. 2. The Environmental Territorial Urban Model

3.3. The application in the case study Río Ceballos

Social and economic information about Río Ceballos dynamic was explained in previous study (Foglia, 2000). This information was crossed with a series of interviews and discussions with local and regional government-, mark- and community- members, with direct connection to the urban residential growth and the environmental consequences. The qualitative interpretation of this information result in a table (Table 1) of environmental problems, that ensures that the study reflects local values.

To define the **carrying capacity** was used data of different sources integrated in a Geographical Information System and produced environmental aptitude maps, first for the studies areas and then pro lot of each urbanization.

The historical occupation changes are determined through the digital interpretation of aerial photographs from 1970, 1996, 2005 (all in scale1:5.000). Occupation polygons were interpreted, digitalized and processed to define occupation patterns.

The scenarios are defined by seven strategically important variables: Economic dynamic reflect in type of activities; Spatial distribution of activities and materialization of buildings; Mobility; Public policies that guide future land use; Open Space and Natural areas conservation; The amount of money the government has available for spending on public projects and investments. Among the many factors that will shape the future of the city, these variables represent the most important sources of uncertainty (Terreno, 2010).

Table 1. Environmental Problems Classification

PARAMETER	ENVIROMENTAL PROBLEMS
Productivity	Acceleration of economy around residential activity
	High demand of urban land for buildings
	High increase urban land price
	High potential increase of urban infrastructure
Natural Environment	Drink water scarcity
	Ground and surface Water contamination because not wastewater treatment
	Destruction of natural habitat trough new building and garden arrangement. Visual obstruction. Loss of sense of place
Economical Fragmentation Habitability	Dormitory city
	Inequitable infrastructure distribution
	Increase social and spatial fragmentation and segregation
	Scarcity of public space and community equipment
Governance	Powerless legal frame
	Low local and regional political management
	Absence environmental policies

The population growth projection assumes a continuation of last decade's growth rates (averages 4.2% per year) (INDEC, 2004). This level of growth assumes a demand for home in the average 3.5 persons pro dwelling. The projection adopts a recommended time lapse of 30 years for environmental scenarios study (Gallopín, 2004). The analysis of different scenarios allows to test and to study the consequences of different possible futures for the city.

The demographic projections, and the seven variable and his alternatives has been combined to create the three in model proposed possible scenarios (Tendency, Soft and Hard Sustainability) for the analysis. The allocations are based in spatial patterns and the previous variable set.

The consequences of each alternative future are assessed using a series of interlinked Indicator come out of the selected of the most important problem parameters, and very easy to quantify and evaluate (Venturini, 2002).

With the results of the first phase of the model in hand, was taken up contact with local stakeholders to build the plot of the future scenarios. There was detected the difficulty to understand the mapping language and the need to adjust this variable for greater effectiveness of the model in its second phase. Therefore it is decided to incorporate the visualization as cross-cutting concept for the model.

Landscape visualization techniques enable the qualitative interpretation of landscapes and can be powerful decision support tools in landscape

planning. Landscape visualization is often used for communicating complex information about the state of a landscape and how it might change, and can be particularly effective when communicating to community groups and policymakers (Steinitz, 2005).

Starting from this conceptualization, the three future scenarios, the growth and their distributions in space and the associated impacts evaluation were represented in the model on a digital elevation model and displayed in three dimensions.

3.4. Results

The results of the simulation for each scenario based on the first stage (initial state) and the impacts evaluation were presented in 3D graphics and data analysis (fig. 3).

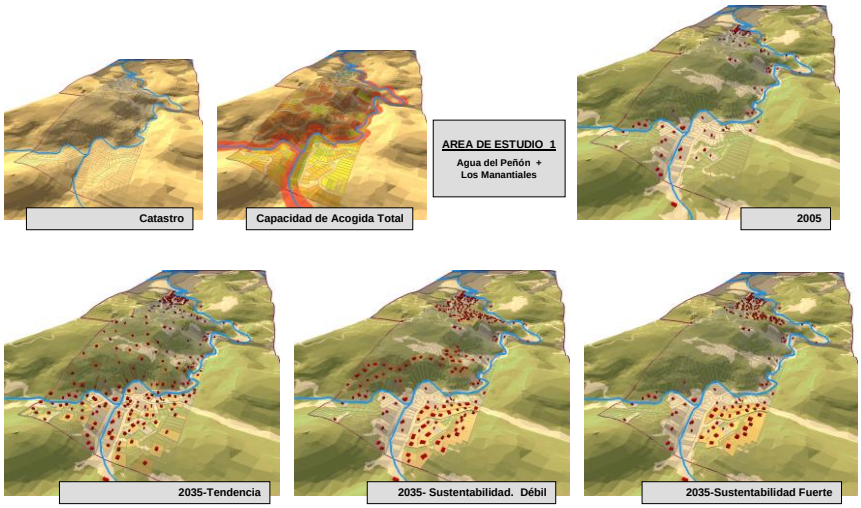
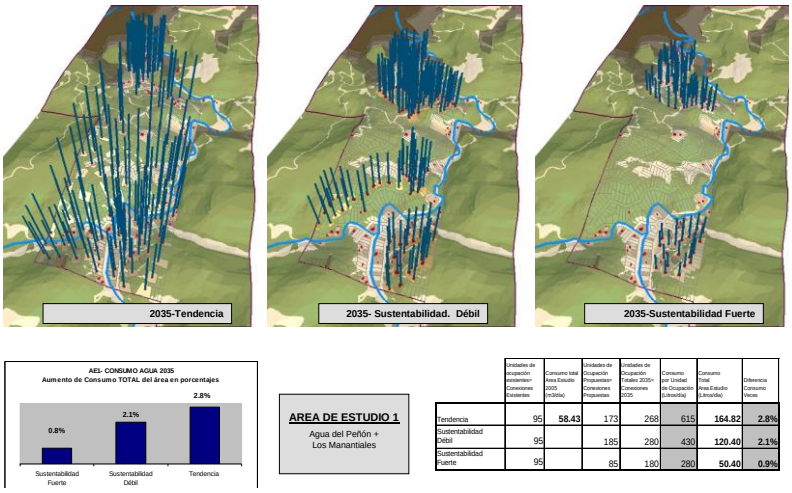


Fig. 3. A sample of spatial distribution and their impact analysis (indicator: water consume)

Some of the most important issues displayed are: Scenario **A Tendency**: new growth patterns in the form of disperse expansion, ever more distant from the city centre and in many of then the gravitational effect of access routes is noteworthy. The physical fragmentation of the urban landscape is closely connected with the social fragmentation of the corresponding areas, since higher income groups tend to be located at increasing distances from the city centre in urban patches with the highest environmental quality and low income in the areas without infrastructure and environmental

conflict areas. The projected tendency of this spatial pattern proofs the hypothetic sustainability critical future. Scenario B **Soft Sustainability**: more compact growth patterns, nearer urban city centre improved vehicle circulation, but does not solve social fragmentation. Mitigation measures can reduce the impact of some environmental factors (e.g. wastewater, vegetation) but in others is very low (e.g. water consumes, open space, road investment). The different environmental carrying capacity of the analyzed areas shows a greater or lesser impact of this scenario. Therefore it is proposed a carrying capacity zoning, where some environmental problems can be solved from the guidelines from this scenario in the short and medium term. Scenario C **Hard Sustainability:** compact growth patterns, spatial urban continuity, open space und community infrastructure, privilege of pedestrian mobility, change household consumption patterns generate urban continuity, a sense of community and low environmental impact. The economic costs and the process of the social behaviour change required to think this proposal in the medium and long term, although some aspects will be addressed in the short term to prevent an environmental crisis, especially in low-carrying capacity areas and in some factors as water consume (fig. 4).



	Unidades de ocupación existentes= Conexiones Existentes	Consumo total Area Estudio 2025 (m3/día)	Unidades de Ocupación Propuestas= Conexiones Propuestas	Unidades de Ocupación Totales 2025= Conexiones 2035	Consumo por Unidad de Ocupación (Litros/día)	Consumo Total Area Estudio (Litros/día)	Diferencia Consumo Vecas
Tendencia	95	**58.43**	173	268	615	**164.82**	**2.8%**
Sustentabilidad Débil	95		185	280	430	**120.40**	**2.1%**
Sustentabilidad Fuerte	95		85	180	280	**50.40**	**0.9%**

Fig. 4. A sample of spatial distribution and their impact analysis (indicator: water consume)

Moreover there are a few situations which have generated a higher impact than the previous scenario for example larger lot areas with greater distances to travel and lower degree of social interaction. This will lead to review the structure of sustainability scenarios.

4. Conclusion

This model application as well as the studied cases in the Latin American context, although they are in a first stage of development, show many potential as well as limitations.
Their development and improvement raise a positive perspective as useful tool for understanding the current situation and future developments. Greater interaction between other experiences can contribute to a homologation of criteria, data and methodologies. But the biggest challenge arises in the relationship between models research, the use by planners and the implementation by politicians next to the recognition-validation by different social actors. Here are the major difficulties and the explanation about this issue exceeds the objective of this paper, although it is important to highlight some aspects that can serve as clues to future developments. Planners need tools to operate with limited amounts of data in relatively short periods, because they have limited resources and need to respond quickly to government actors. Local politician think with short term logic, periods of four years, which is the duration of most of the political mandates. During that time should be solve the problems that arise everyday life, in the way to give positive responses to citizens to ensure their future candidacy and thus remain within the political system. The stakeholders and general public recognize many of the environmental problems at a level of generality, both procedural and spatial, but not in their own environment and not as a result of their daily practice. Therefore their involvement in the solutions is always relative. Modelling for sustainability requires a complexity approach, long term thinking and participation. Some clues to bridge the gap between the already developed models and future projects, may arise from: -That the models allow the visualization of solution paths for the short, medium and long term. In this way may appear nearby points of interest to political timing (short term) and prospects for the medium as a political strategy for continuity. - Associated with that, the model operation with a reduce amount of data for a first approach may help planners in a resource limited context. -To assess specific policies to implement or already implemented. - Deepening the educational dimension of models as tools for review established social values that pug up the construction of a sustainable future. - A major level of participation and involvement in the modelling process.
And as final words, Paegelow concisely exposes the key ideas about the future of the subject: “Nevertheless, a lot of work has to be done to improve, validate and generalize models for spatio-temporal simulation of complex environmental dynamics, in order to create standard tools, which

can be used by non-specialists. Consequently, the actual context may be described as how to transform advances in research to operational tools" (Paegelow, 2008)

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