Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

AN OPEN SOURCE SIMULATION-BASED APPROACH FOR NEIGHBOURHOOD SPATIAL PLANNING POLICY

Peter Lee

Centre for Urban and Regional Studies
School of Geography,
Earth and Environmental Sciences
The University of Birmingham, Edgbaston
Birmingham, B15 2TT,
UNITED KINGDOM

Georgios Theodoropoulos

IBM Research
Dublin Research Lab
IRELAND

ABSTRACT

We describe the development of a practical tool for urban planning, using innovations in agent-based modelling to reconcile conflicts at the local/neighbourhood level and designed to improve engagement in neighbourhood spatial planning to deliver optimal planning and regeneration solutions. Neighbourhood or 'place' is an important factor in deciding social and economic outcomes. Neighbourhood is also increasingly important for urban planning across Europe as communities are at the front-line in developing resilience to anthropogenic and natural shocks. The current financial crisis and public sector austerity measures across Europe represent shocks to local communities that require policymakers to maximize investments and resources delivered to local communities. Communities and citizens can therefore play a bigger role in contributing to the resilience of cities through local neighbourhood planning. However, there is a need to work differently as public and private finances are restricted and communities need to co-produce plans and delivery of services. Co-production can therefore be one contribution to solutions designed to foster resilience and deliver efficient neighbourhood planning and associated services. Co-production in this context requires an *open source* approach in which producers and consumers can observe viewpoints and react to the implications of simulated outcomes. Whilst there are numerous examples of Planning Support Systems (PSS) designed to assist urban planners there has been no significant progress made in developing a 'grounded' approach incorporating 'real-time' inputs from users and stakeholders at the neighbourhood level. This paper sets out the principles and objectives of a simulation-based *OpenPlan* system in which producers and consumers swap roles. This leads to a greater *co-production* of planning inputs designed to deliver optimal outcomes and more resilient cities.

1 INTRODUCTION

This paper sets out the principles for furthering the use of simulation and agent-based modeling in mechanisms of community and public engagement in urban planning. The aim of using simulation and agent-based modelling in a neighbourhood planning applications is to broaden the consultation engagement process by enabling a variety of stakeholders involved in planning and regeneration to *co-produce* neighbourhood plans and make it more cost-effective by isolating conflicts early on in the plan process thereby reducing waste.

Firstly, we discuss the drivers for greater public engagement in planning; this includes complexity of urban problems in large cities and urban areas and associated risks to security and resilience. Recent austerity measures across Europe to tackle budget deficits adds a further layer of complexity and threat to resilience of cities. Secondly, we define what we mean by public engagement in planning and identify the role for ICT and simulation before going on to consider the state-of-the-art in the application of simulation and other related technologies to enable greater public participation.

In the last section we outline the OpenPlan approach which aims to embed principles of *co-production* of the planning processes by incorporating *grounded* experience and sampled behavior and lifestyles into a real-time simulation that can engage with multiple end-users. An *OpenPlan* approach aims to broaden the reach of planning consultation by maximizing stakeholder inputs whilst at the same time deepening our understanding of potential *outcomes* and *conflicts*. *OpenPlan* aims to do this by providing a practical tool enabling a variety of stakeholders (e.g., residents, businesses, investors, land owners and policymakers) to interact with a planning 'model' and for those combined interactions to be visually displayed so that *consumers* and *producers* of an area can observe interactions and conflicts enabling *resilient* planning outcomes.

2 PLANNING, COMPLEXITY AND PUBLIC ENGAGEMENT

Continued urbanisation and growth of cities resulting from processes of globalisation, migration, segregation and polarisation bring greater complexity in the planning and management of cities, posing a threat to the resilience of urban areas. Resilience is an important emerging concept in public policy globally involving the adaptive capacity and coping strategies of social, economic and physical urban systems to withstand change and the ability to anticipate risks at neighbourhood or city level and 'bounce-back' from environmental, socio-economic or anthropogenic 'shocks' (Adger 2000, Coaffee et al. 2008, Rose 2007). Shocks, whether social, economic, environmental or anthropogenic, affect places in different ways (Figure 1). Translating complexity and its social consequences for neighbourhoods and cities remains a challenge for policymakers as it requires the incorporation of multiple narratives or viewpoints.

Figure 1: Lee Bank at Attwood Green - Park Central regeneration area[1], Birmingham, UK. Started as the biggest urban regeneration project in Europe. (Source: author's own image).

The rolling back of the state and cuts in public sector budgets will mean that services and public realm will have to be managed and funded differently: *coproduction* and community asset building will be a greater part of the delivery mix (Slatter 2010). This extends to the built form and how cities are managed and planned as there will be a greater need to build in resilience to the built form because of constraints on public and private sector budgets. Neighbourhoods, communities and residents are the first line of defence in response to external shocks (Edwards 2009) therefore, urban planning can assist in the

[1] http://www.optima.org.uk/main.cfm?type=PARKCENTRAL

delivery of resilience by identifying the appropriate planning solution that maximises the ability of communities to 'bounce-back'. As resilience begins with the community the ability of communities to absorb shocks (especially in the post 9/11 context) is a key concern for planners and urban policy makers and a more botton-up approach is required. In England, changes to the planning system have resulted in a more localized neighbourhood planning system necessitating "…early and meaningful engagement and collaboration with neighbourhoods, local organisations and businesses ….[proactively engaging] a wide section of the community…so that Local Plans, as far as possible, reflect a collective vision and a set of agreed priorities for the sustainable development of the area, including those contained in any neighbourhood plans that have been made" (CLG 2012, p.37)

Neighbourhoods are not uniform in size or function and are dependent on the type of households and geographical context of the city and region. For our purpose we refer to neighbourhood as a 'place' where the home area or locality for most residents provides a degree of psycho-social benefits, residential activities and bestows some degree of social status (Brower 2002, Kearns and Parkinson 2001). Processes of segregation and *socio-relational* forms of exclusion (i.e., access to networks, power and social capital) is resulting in greater social polarisation and a weakening of the ability of some communities to be resilient and withstand shocks; the role of neighbourhood and where you live therefore increasingly matters (Fitzpatrick 2004). The unevenness of place requires greater engagement with residents and communities to deliver resilience. However, public engagement is costly and the resources of local authorities to understand the complexity of local communities is limited and more constrained under conditions of austerity.

As systems of spatial planning and land use have become more complex they have become more remote from end users and residents despite an increase in the partnership and consultative hierarchy over the past 40 years and public engagement in planning, at least in in the UK, has relatively recent roots. The Skeffington Report (Skeffington 1969) on public participation in planning was commissioned during the 1960s following a turbulent period of British planning policy when large-scale demolition and renewal policies following the second-world were being implemented. The lessons from this period pointed to a greater need for engagement and the report advocated the involvement of public in planning from the earliest stage possible as well as making recommendations for the methods of consultation.

The relationship between local authorities and residents in communities deteriorated in the 1960s and the aim of public engagement in planning has been to improve this relationship as well as increase the efficiency and effectiveness policy Collaborative Planning principles developed in the 1980s led to changes in governance and the planning system in England and Wales in the 1990s-2000s and an enhanced planning participation practice and capacity building (CLG 2008, p.5.).

Despite increased public engagement in planning however, there has been a rise in authoritative and 'network' power and the transformative potential of planning has been "…undermined by serious imaginative weaknesses in addressing the concepts of relational complexity" (Healey, op cit, p.152). Conventional planning methods are therefore limited in their ability to incorporate the dynamic exchange of stakeholder attitudes and intentions which are influenced by the interaction of 'agents' within the social and economic system. Agents within a simulation or computational model are treated equally, but in the social sciences agency refers to the degree of autonomy that actors have to make independent decisions and effect change and therefore implies differential amounts of power. Irrespective of the degree of actual power that is held by agents outside the simulation, understanding how viewpoints interact is an important step towards increasing the 'adaptive capacity' and improving the resilience of communities as it reveals the dissonance between agents that can affect change in the real world by modeling behaviour in an 'idealized' simulation. By achieving this there is greater potential for identification of conflict resolution earlier on in the planning process.

The current process of engagement in planning systems is inefficient. Consultation exercises treat 'viewpoints' in isolation despite the propensity for like-mindedness, agglomeration and congregation effects in neighbourhood and economic systems (Schelling 1971, Peach 1996). Consultation responses are aggregated and, irrespective of the degree of consultation, viewpoints are equally weighted or under represented. Resilience requires the incorporation of the views and perspectives of difficult-to-reach groups - failure to do so can result in unintended or unsustainable outcomes. What is therefore required, and OpenPlan is aiming at providing, is the integration of agent-based simulation, visualization and human-computer confluence techniques with social scientific theories around 'place-making' (Trickett and Lee 2010) and sustainability to produce a practical planning tool that will enhance the prospect of delivering resilient communities.

The context within which a simulation tool would help build resilience includes the redevelopment and regeneration of discrete spatial interventions such as neighbourhood renewal or city centre redevelopment. In both examples, processes of gentrification will involve the remodeling of brownfield land or public space for private profit. The economic crisis and credit crunch has demonstrated the vulnerability of the existing financial and governance models for regeneration and neighbourhood renewal; improving public engagement on masterplans and neighbourhood planning through simulation and related technologies can be achieved by: i) connecting networks of association; ii) identifying underlying conflicts and iii) simulating potential outcomes. To date there have been several attempts to use computing in planning applications and the next sections considers these.

3 ICT TO SUPPORT PLANNING AND RESILIENCE

The use of computing and ICT in planning consultation and public engagement has been limited. In a review of stakeholder consultation mechanisms the internet was identified as one of a number of engagement strategies; however, usage has generally been limited to information exchange rather than interactive visualization online (Petts and Leach 2001). This is however a fast moving area and more recently articles by Brabam (2008) and Haller (2008) have looked at the potential for social media to revolutionize participatory planning through innovations such as crowdsourcing. Crowdsourcing is a more bottom-up approach to participatory planning whereas Planning Support Systems (PSS), the generic term for integrated GIS-modelling and visualisation tools that assist urban and regional planning processes and strategy making, have tended to be top-down.

At the start of the millennium it was anticipated that an acceleration of technologically enhanced participatory planning tools would occur (Brail and Klosterman 2001). However, the formalisation of systems has not occurred at the scale or speed anticipated. This has partly resulted from a reticence of some stakeholders (planners, politicians, developers etc.) to invest in PSS; apprehension that PSS could cede power through its emancipatory potential; and a historical scepticism towards technological innovation in participatory planning.

Planning as a process has a political and democratic constituency which views 'technological shortcuts to social change' (Etzioni and Remp 1973) as a positivist threat to an essentially qualitative discourse. Critical to the slow progress in this field is the incompatibility of social and physical systems. Many PSS prototypes and visualisation models have been abstracted large-scale models. Typical examples have been in land-use, transportation, digital geometric modelling of large urban areas and models that linking geo-demographic data to virtual worlds such as Second Life (Brail 2008). Micro-simulation approaches which utilise large amounts of secondary data to maximise the fit between detailed survey data with low geographical resolution and census data (see: Ballas et al. 2007) have excellent geographical coverage and have proved valuable to policymakers. However, they have limited information on user profiles and lack an interactive agency-based simulation used to model and feed-back responses that could contribute to understanding complexity and resolving.

The application of visualization techniques in practice has been limited and their diagnostic potential of limited use to end users. Engagement with residents and other stakeholders in the planning process has been a marginal activity of PSS academicians and professionals. Vanegas et al. (2009) developed a 30-year simulation of a large area surrounding Seattle; the simulation was data intensive in using high-resolution aerial imagery data across 1.4 million geographical objects. From this the researchers inferred high level structural abstraction and produced a set of "automatic and interactive algorithms for generating a visually plausible urban layout from the data produced by an urban simulation" (op cit p.426).

The reason for this dissonance between professional discourses lies partly in the practical division of labour and disciplinary distinctions – highly abstract visualisation techniques can lead to results that many users may not find intuitive. What is absent from PPS models and simulations is an understanding of how different lifestyles interact and how these interactions can inform optimization in master planning exercises. Vanegas et al. (2009) have attempted to bridge the gap by proposing that input and output data of an urban simulation are combined with computer graphics techniques to "automatically and interactively infer urban layouts" (Vanegas et al. 2009, p.424) and claim that the method "…offers a substantial step forward in building integrated visualization and behavioral simulation systems for use in community visioning, planning, and policy analysis" (op cit, p.424).

The analysis and interpretation of urban simulations based on fractal geometry and patterns of growth synthesised from 'natural' systems are used to generate the appropriate 'content' for projected growth of the urban form (see: Batty 2005). Whilst they make a valuable contribution to the development of scenario planning and modelling of urban systems, such techniques underplay the authenticity of lifestyle informed 'content' i.e., they are based on a synthesis or abstraction which does not take into account human agency. The future is constantly a process of negotiation, classical methods of estimation and probability in the field of planning will need to be overhauled and supplemented by scenario planning and triangulation methods that incorporate foresight. The objective will be to anticipate and plan for potential outcomes by gauging the views of users and assembling models that represent their interactions which can be used to scale-up and validate simulations of multiple agents. There therefore needs to be greater emphasis on developing models which incorporate elements of both scaled up simulations and 'bottom-up' approaches (multiple perspectives of potential uses and stakeholder groups).

Computational systems related to the field of spatial planning therefore fall into two broad categories, systems that increase participation and transparency in the decision making process (Kingston 2007) and those that improve efficiency and save money. Rarely, do such systems assist in the decision making process by processing data in real-time or in an interactive setting whilst combining this with simulation and visualisation techniques to deliver an optimal planning solution and deliver efficiency and transparency. Whilst there are examples of simulation and agent-based modelling based on theoretical models of how cities evolve (eg Batty 2005), there has been little attempt at synthesising computing technologies and social scientific theory for the purpose of increasing participation and delivering more resilient outcomes for communities as well as reducing costs for local authorities, particularly important in the context of financial austerity across many parts of the EU.

The absence of grounded approaches engaging multiple users in ongoing simulations raises the question of whether such tightly structured, Boolean 'rules based' systems such as computing and GIS-visualisation are capable of reconciling diverse, pluralistic and non-linear social systems. Setting rules and parameters for social systems and formalising these is part of an ongoing challenge and requires tools that are tested in the 'field' with real communities in order to advance the state of knowledge and develop a tool that has practical and policy relevant for a range of stakeholders. In this context, agent-based models can provide a powerful paradigm for capturing social behavior.

Three paradigms governing PSS that support urban simulations have been identified:

1. Models that utilise cellular automata to represent emergent dynamics (eg: the Urban Growth Model) which emphasise long-term changes in land use;
2. Agent-based models that focus on examining cities as self-organizing complex systems (eg Batty 2005);
3. Combinatorial models - urban economic analysis and statistical modelling of choices made by agents in the urban environment (eg: Utility Theory and Discrete Choice Models) (Vanegas et al. 2009).

Our goal is to reach somewhere in the middle of these approaches – utilizing and agent based model approach to simulate neighbourhood plans by populating data from producers and consumers and build knowledge of co-producers in order to simulate potential uses and conflicts in 'real-time'

In the next section we describe how we would propose to bridge the gap between scaled up simulations and 'bottom-up' approaches by means of a framework that would have practical applications and developmental potential initially at local neighbourhood level but which could be scaled up to different city-regional contexts.

4 THE PROPOSED FRAMEWORK

The proposed OpenPlan system and framework is illustrated in Figure 2. It would utilize advanced human-computer confluence approaches (such as touch-screen and web 3.0 technologies) to increase the reach and engagement of planning participation and innovative agent-based simulation techniques to assist the policymaker in analysing the combinatorial impact of stakeholder views. The framework provides the functionality to transparently and inclusively address the problem of incorporating the multiplicity of views inherent in master planning and urban regeneration strategies. Two groups of users of the system can be identified: decision makers; and users and residents. Decision makers include the owners of the land to be developed, politicians with a stake in the development, and governmental policy makers guiding the planning process. The other group of users include the current and future users of the development categorised according to their different lifestyles, households, businesses, etc. Future uses of the site could be modeled in order to identify the range of consequences and unintended outcomes arising from different viewpoints. For example, in the case of Optima (see Figure1) the intention to build a balanced and sustainable community with homeowners and social rented tenants interacting and sharing communal space has been undermined by the role of external investors and the provision of short private sector lettings where the residents are not interested in community engagement. Had these viewpoints been factored into an initial simulation of users reactions to the financial investment model, a different set of planning provisions may have resulted.

The overall objective of the OpenPlan is therefore to provide a 'Noosphere' which will bring different user groups together into an inclusive consultation process where their interactions remain both transparent and visible. Several important challenges have been identified in relation to Noosphere realization (FET 2007): How can very large groups of experts best collaborate? What is the most effective way to organize communication and sharing of understanding? How can we facilitate cooperation of experts with different expertise? OpenPlan proposes to address these challenges through interaction in a reflexive virtual world which would facilitate the assembly of a large number of human stakeholders and simulated agents: different stakeholders make interactive changes to a collective set of agent-based simulations in order to make their wishes and preferences clear.

The OpenPlan process consists of three stages: preparatory stage, short term trajectory and long term trajectory. In the preparatory stage both user groups provide the initial parameters for the planning process, such as needs and demand requirements, planning regulations, political ambitions and site characteristics. These initial parameters are collected in a database from which an initial planning scenario set is derived. The OpenPlan system, in both the short and long term trajectory, allows consultative real-time planning through interactive changes to these initial parameters and subsequent scenarios.

The scenarios are handled by a simulation engine which provides each individual user in both user groups with a planning scenario with which to interact. In the short term trajectory stage of the planning process each individual user is allowed to interact and make changes to the planning scenario in real time, so as to make it confirm with the needs, demands, wishes, and preferences, all from his point of view. At regular intervals the expressed points of view are collated into consensus based versions of the scenarios, stored in a scenario repository. This iterative process is guided by the decision makers, with conflicting views resolved in real-time by consulting the constraints collected in the parameter database, and at each collation iteration by selected users from the decision makers' user group. During the short term trajectory of the planning phase, the OpenPlan system provides a set of evolutionary scenarios from which an end project or master plan emerges. The scenario repository then provides a sequence of scenario versions from which the decision makers will be able to derive data to support their decision making process. The OpenPlan planning process ends when data collected from the various scenarios are collated into the end project master plan and with one final round of consultation and sign-off of the process.

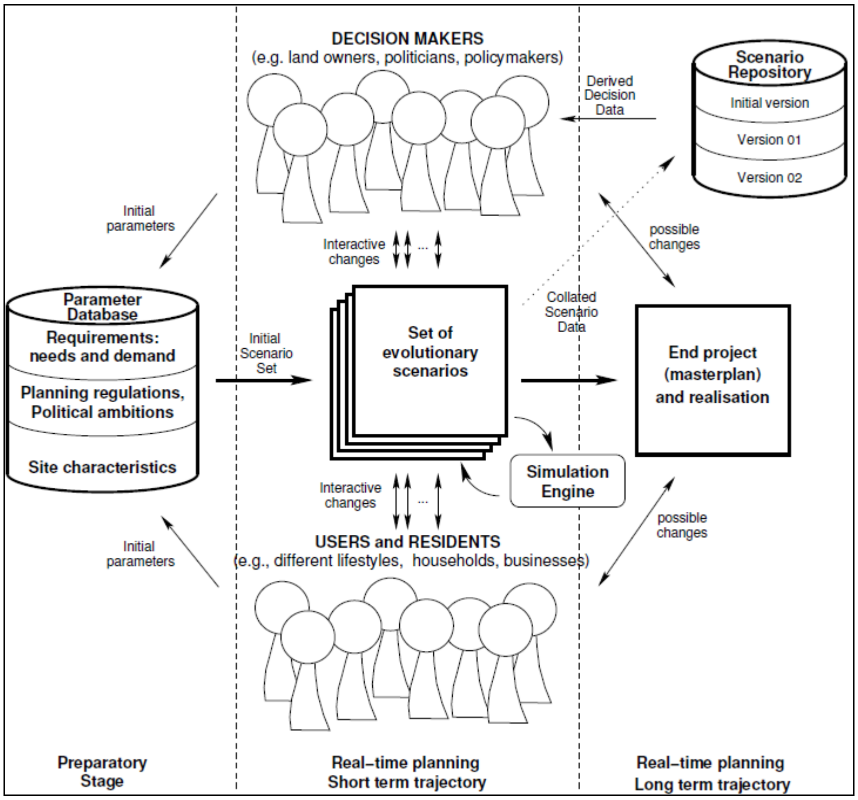

Figure 2: The OpenPlan Framework.

This real-time and continuous feedback environment provided by OpenPlan will allow users (residents, policymakers, investors) to identify potential outcomes from the planning consultation process arising from the interaction of agents and their use of the tool. This would provide a reflexive planning tool linking stakeholders together so that they can swap roles as both consumer and producer in the process. Real-time user and sensory information would be used to assess the impact of proposals matching previous and future scenarios with intentions and interaction of agents (users and decision-makers). Parameters constraining the model will be incorporated such as land-use, land ownership, budgetary constraints and economic and political changes. In the following sections we provide an outline of the basic technological drivers and challenges of the OpenPlan approach.

4.1 OpenPlan Agent-Based Models

A key component of the OpenPlan system are large-scale agent-based social simulation models, which provide predictions of the impacts of policy actions. In the social sciences, agent-based modelling is increasingly recognized as a valuable tool that can provide a means to "generate" an explanation of an observed phenomenon in society. Agent-based simulations may be used to predict policy impact as well as to predict the effects of individual actions of agents on other agents. An agent in the simulation can be understood as a "sense-process-act" loop where actions are determined by internal processing as well as the state of the environment. Most existing work tends to emphasise interactions between very simple agents and the emergent properties that arise from them (based on the "swarm" concept). However, large-scale agent models with a cognitively rich architecture are required in order to capture agents' internally generated beliefs and motivations and reflect the complexity of real life circumstances. The ability of agents to plan ahead and generate hypothetical states (deliberation) is important as well as understanding themselves and others. Social groups may be collectively modelled as having a "prevailing" set of beliefs or values, which may be due to their shared experience of similar environmental circumstances. Additionally an organisation can be modelled as a single agent with goals and beliefs.

The novelty and challenge of the OpenPlan approach lies in the fact that these models should be able to capture multiple perspectives of potential uses and stakeholder groups in order to enable an understanding of side-effects and unintended outcomes of planned actions on the realities of others.

Conventionally, in simulation modeling, the model development process starts with an initial model, which is iteratively adjusted until it is consistent with the data. The model is determined and revised by "experts" (e.g. public policy researchers who advise policy decision-makers). There is typically no allowance for the representation of different views of the world (pluralism). Moreover, the actions of the system and the nature of the final model may depend considerably on the initial model. This means that one view of the world and the starting point of the model is arbitrarily favoured over alternatives. This problem is related to the disadvantages of a single (formal) ontology to classify social science data, because it imposes a single classification hierarchy (a taxonomy) which does not allow for differing interpretations (Theodoropoulos, 2011).

Using multiple model ontologies to represent multiple perspectives of all the stakeholders involved enables the models to represent all stakeholders in a collaborative decision-making exercise to improve transparency and view impacts that are outside of their domain. Actor understanding of potential side effects and unintended consequences of actions requires an understanding of the experience of other groups who will be affected and is a central feature of the OpenPlan philosophy. This issue is related to the "other minds" problem and how agent actions and decisions depend on perceptions of what other agents will do (Theodoropoulos, 2011). The result of sharing others' realities may be the generation of knowledge in the form of new concepts and shared vocabulary (ontology extension). In a policy decision-making context, interaction with another's reality might give rise to the discovery of new policy options that seemed not to "exist" previously.

The behaviour rules of agents in the simulation will be based on theories in cognitive and social sciences. However, the focus of the simulations (in the sense of *what kind of things* are simulated) should be determined collectively by the stakeholders in a 'bottom-up' fashion and rule setting determined through experimentation and engagement with local users. This also means that the choices presented to agents and the kinds of things they can perceive are not pre-determined in advance. Similarly, the choices and preferences of agents may be determined by stated preferences of survey respondents. Participatory model determination (*determination of concepts and ontologies* on which the simulations are based) can be achieved in two stages: (i) initial "capturing" of concepts and values that are important to stakeholders and translating them into formalisms that can be represented in simulations (ii) participatory evaluation and adaptation of simulations.

4.2 Linking Models to Data

Although agent-based simulation exploits human expertise in the building of models and can have a significant impact for decision support in policy making, such models are often based on a priori simplified assumptions and therefore their reliability for the explanation and prediction of complex policy outcomes can be limited. The user can adapt the models iteratively by validating the simulation predictions off line, but such an approach can be cumbersome and users may overlook an emergent property of the model that they were not expecting due to, for example, their preconceptions. This problem is exacerbated by the requirement for cognitively rich models that can accommodate multiple perspectives as in the case of OpenPlan.

An extremely large number of variables may be generated to explain the observed phenomenon, rendering the adaptation of these models an extremely challenging endeavour. Techniques such as machine learning and data mining can be used to discover significant patterns that humans would overlook, which can in turn be used to refine the agent-based models and increase their predictive accuracy and reliability. However, configuring the data analysis and learning tools to make sure that they ask the right questions and focus on the most relevant data is a complicated process and suffers from similar subjective perceptions.

An integration of agent-based models with data and data analysis tools would allow the adaptation of the simulations based on the data while at the same time would enable the behaviour of the data analysis and learning tools and the selection of data to be directed by the simulation, since the hypotheses generated by the simulation could direct and focus the data queries. Such data-driven simulations can provide more accurate analysis and prediction through dynamic augmentation of models with dynamic data inputs and can enhance understanding of how social systems respond to policy interventions. These are capabilities not feasible with the traditional simulation approaches and today's methodologies and tools. In previous work, we have reported an info-symbiotic framework to achieve this integration, as part of the AIMSS[2] system (Theodoropoulos, 2011).

OpenPlan is based on the integration in real time into the model of new data related to the space and feedback of other stakeholders. The input of the users into the envisioned to be realized utilizing Web 2.0 technologies (tagging, folksonomies) via touch screens. The models consist of invariant and variant assets. The former may remain unchanged during the simulation. An example might be an important road network. The latter are susceptible to spatio-temporal transitions (relocation in space and in time, construction and destruction, transformation by the supported spatiotemporal operators). A Tag for example is such a variant type that is referencing another geographic asset type (a road, a point, an area, an object e.g. a tree). Tags can be created, deleted, de-reference the given object and reference another object, be assigned a given lifetime, while their creation or destruction may be triggered by a condition. Each user owns and maintains individual data model instances of the simulation through their own configured view (views might consist of various alternative visualizations of the data model of the simulation). Each user controls their own data model of the simulation through their own controller. In OpenPlan, controller instantiations may vary from deployment platform to another, in terms of modal input and output devices available. In the general case OpenPlan front-end should support

- Different views based on model aggregation selected by the user (aggregating overlaying parts of the user's simulation with another user's simulation, or aggregating overlaying parts of all simulations, or of models of users that conform to a set of criteria)
- Semantic definition of new assets, substantiation of their relations with other assets, assignment of their spatiotemporal properties
- Managing of the track of simulation updates (navigation through the simulation steps)
- Branching of simulation outcomes based on user-specified alternate events
- Monitoring simulation branches

4.3 Distributed Simulation

OpenPlan simulations will involve multiple complex scenarios, modelling different viewpoints at different temporal and spatial scales. The scale and complexity of the models render distributed simulation the only viable approach for their deployment. Distributed Simulation of large-scale MAS models has received substantial attention in the last few years as it introduces challenging problems related to load, data distribution and causality management (Theodoropoulos 2009). These problems are exacerbated in OpenPlan by the need to aggregate and reconcile multiple simulation scenarios and the need for real-time interaction and data assimilation.

5 CONCLUSIONS

Planning is a process which is necessarily concerned about the future (Field and MacGregor 1987), however, conventional forecasting and consultation techniques tend to project problems into the future, are constrained by path dependency of the past and thereby limit creativity of thinking or embed a multiplici-

[2] http://www.cs.bham.ac.uk/research/projects/aimss/

ty of potential outcomes in the process. The complex environment in which planning operates requires greater understanding of potential outcomes of planning interventions (as opposed to measuring outputs). A cornerstone of developing resilience strategies at the city, region and state level, therefore, is the effectiveness of urban planning consultation and ensuring that there is a pluralist approach to consultation and the incorporation of multiple views in spatial plans. The absence of simulation and visualization techniques in public engagement strategies for planners reflects both an ontological dissonance and a resistance to introduce what are seen a positivist methods into the essentially multiple-ontological and qualitative world of urban planning.

Aiming to close this gap, this paper has proposed OpenPlan, a framework that utilizes advanced simulation and human-computer confluence technologies to create a participatory space that enables a variety of stakeholders (e.g., residents, businesses, investors, land owners and policymakers) to achieve *resilient* planning outcomes i.e., planning outcomes that are adaptive to changed circumstances (adaptive capacity) and accommodate conflicts in the consumption and production of space (mitigation).

A number of technical challenges need to be addressed for the realization of such an approach. In terms of simulation, the extreme scale and computational complexity of the underlying models requires a parallel approach that would also support the integration of continuous and discrete event models at different temporal and spatial scales and data assimilation in real time. Other challenges include the availability of data, the specification of stakeholder behavioural rules and the infinite regression problem when tackling the multiple perspectives.

In the future, we plan to implement an OpenPlan prototype, dealing with these challenges, and evaluating it in realistic scenarios in the context of complexity and resilience strategies in neighbourhood planning.

REFERENCES

Adger W. 2000. Social and ecological resilience: are they related? Progress in Human Geography, 24: 347–364.

Ballas, D. Kingston, R. Stillwell, J. Jin. 2007. *Building a spatial microsimulation-based planning support system for local policy making*, Environment and Planning A, vol 39, 2482-2499.

Batty, M. 2005. Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals, MIT Press: Massachusetts.

Brail, R.K., Klosterman RE (eds.), 2001. Planning Support Systems; Integrating Geographic Information Systems, Models and Visualisation Tools, ESRI: Redlands, California.

Brail, R.K. (ed.), 2008, Planning Support Systems for Cities and Regions, Lincoln Institute for Land Policy.

Brabham, D.C. 2008. *Crowdsourcing as a Model for Problem Solving*, Convergence: The International Journal of Research into New Media Technologies, Vol 14(1): 75–90.

Brower, S. 2002. The Sectors of the Transect, Journal of Urban Design, Vol. 7, No. 3, pp.313–320.CLG. 2008. *Participation and policy integration in spatial planning: Spatial Plans in Practice: Supporting the reform of local planning*, Department for Communities and Local Government: London.

CLG. 2008. *National Planning Policy Framework*, Department for Communities and Local Government: London.

Coaffee, J., D. Murkami-Wood, P. Rogers. 2008. The Everyday Resilience of the City, London: Palgrave.

Edwards, C. 2009. Resilient Nation, Demos: London.

Etzioni, A. and R. Remp. 1973. Technological shortcuts to social change, Russell Sage Foundation: New York.

FET 2007, Human Computer Confluence Consultation Workshop Report, Future and Emerging Technologies Proactive, 16 November 2007.

Field, B. G. and B. D. MacGregor. 1987. Forecasting Techniques for Urban and Regional Planning, Hutchinson Education, London.

Fitzpatrick, S. 2004. *Poverty of place*, plenary presentation at the Joseph Rowntree Foundation Centenary Conference, December.

Haller, C. 2012. *Crowdsourcing Platform Enables Citizens to Document Crisis Information*, accessed 28 March 2012 at: http://engagingcities.com/article/crowdsourcing-platform-enables-citizens-document-crisis-information

Healey, P. 2005. Network Complexity and the Imaginative power of Strategic Spatial Planning, pp.146-160, in Albrechts L, Mandelbaum, S J, 2005, The Network Society: A new context for planning, London: Routledge.

Kearns, A. and M. Parkinson. 2001. The Significance of Neighbourhood, Urban Studies, Vol. 38, No. 12, pp.2103–2110.

Kingston, R. 2007. Public Participation in Local Policy Decision-making: The Role of Web-based Mapping, The Cartographic Journal Vol. 44 No. 2 pp. 138–144.

Peach, C. 1996. Good segregation, bad segregation, Planning perspectives, Vol 11, pp.379-398.

Petts, J. and B. Leach. 2001. *Evaluating methods for public participation: literature review*, R&D Technical Report E2-030, University of Birmingham.

Rose, A. 2007. Economic resilience to natural and man-made disasters: multi-disciplinary origins and contextual dimensions, Environmental Hazards, 7, 383-98.

Schelling, T. 1971. *Dynamic Models of Segregation*, Journal of Mathematical Sociology, Vol 1, pp.143-186.

Skeffington, A. (1969) *Report of the Committee on Public Participation in Planning*, HMSO, London.

Slatter, P. 2010. *Looking Sideways: A Community Asset Approach to Coproduction of Neighbourhoods and Neighbourhood Services in Birmingham*, Chamberlain Forum: Birmingham

Theodoropoulos, G., K. Catriona, P. Lee, C. Skelcher, E. Ferrari, and V. Sorge. 2011. “AIMSS: Data Driven Simulations in the Social Sciences” in “Dynamic Data Driven Applications Systems”, by Frederica Darema and Craig Douglas (Editors), Publisher: Springer. Invited Paper. To appear.

Theodoropoulos, G., R. Minson, R. Ewald, and M. Lees. 2009. “Simulation Engines for Multi-Agent Systems” in “Multi-Agent Systems: Simulation and Applications ”, by Adelinde M. Uhrmacher and Danny Weyns (Editors), Publisher: Taylor and Francis. ISBN: 9781420070231 ISBN-10: 1420070231, Pages: 77-108 Invited Review Paper.

Trickett, L. and P. Lee. 2010. *Leadership of ‘subregional’ places in the context of growth*, Policy Studies, Vol 31, No. 4, pp. 429-440.

Vanegas, C. A., D. G. Aliaga, P. Wonka, P. Müller, P. Waddell and B. Watson. 2010. *Modeling the Appearance and Behavior of Urban Spaces*, Computer Graphics Forum, Volume 28 (2009), No. 2 pp. 1–18.

Vanegas, C. A., D. Aliaga, B. Beneš, and P. Waddell. 2009. *Visualization of Simulated Urban Spaces: Inferring Parameterized Generation of Streets, Parcels, and Aerial Imagery*, IEEE Transactions on Visualization and Computer Graphics, May/June 2009, vol. 15 no. 3, pp. 424-435.

AUTHOR BIOGRAPHIES

PETER LEE is Senior Lecturer in Urban and Regional Planning at the University of Birmingham; p.w.lee@bham.ac.uk.

GEORGIOS THEODOROPOULOS is currently a Senior Research Scientist at IBM Research in Ireland. The work presented in this paper was initiated while he was a Reader in Computer Science at the University of Birmingham; geortheo@ie.ibm.com.