ENHANCING PARTICIPATIVE POLICY MAKING THROUGH MODELLING AND SIMULATION: A STATE OF THE ART REVIEW

Yannis Charalabidis, Assistant Professor, University of the Aegean, Department of Information and communication Systems Engineering
yannisx@aegean.gr

Euripidis Loukis, Assistant Professor, University of the Aegean, Department of Information and communication Systems Engineering
eloukis@aegean.gr

Aggeliki Androutsopoulou, Research Assistant, University of the Aegean, Department of Information and communication Systems Engineering
icsdm08022@icsd.aegean.gr

Abstract

While previously public policy making was predominantly technocratic, based mainly on 'first generation' approaches employing mathematical optimization algorithms, in the last thirty years it has become much more participative, adopting 'second generation' approaches which involve the affected citizens to a continuously increasing extent. This trend has been reinforced by the explosive growth of the information and communication technologies (ICT) and especially the Internet, resulting to the development of e-participation. Public participation provides to the competent government organizations useful information on citizens' interest in and acceptance of public policies under formation or application, and also numerous proposals for changes, improvements and enhancements of them. It is therefore necessary to support and enhance participative policy making with technocratic mechanisms and tools for screening these proposals and analysing them as to their outcomes, and also for forecasting the future evolution of citizens' interest in and acceptance of them. The use of simulation can be a very useful tool for these purposes. In this paper we present a state of the art review of existing modelling and simulation approaches from the above perspective. In particular, we examine Discrete Event Modelling and Simulation, Monte Carlo Simulation, System Dynamics, Dynamic Systems, Cellular Automata and Agent-Based Modelling and Simulation. From this investigation it is concluded that System Dynamics seems to be the most promising for the above purposes, followed by Agent-Based Modelling and Simulation, and that both can contribute significantly to the technocratic enhancement of participative policy making.

Keywords: public policy, public participation, e-participation, simulation modelling, system dynamics, agent-based modelling - simulation.

1 INTRODUCTION

It is widely accepted that the nature of public policy problems and the approaches followed by competent public organizations for public policy formation have changed considerably in the last 30 years. As argued in the highly influential paper of Rittel and Weber (1973), previously public policy making was predominantly technocratic, based mainly on 'first generation' approaches which employ mathematical optimization algorithms and aim at the achievement of some predefined objectives with the lowest possible resources. This approach has been successful for long time in solving some important well defined problems of societies, such as the creation of basic infrastructures (e.g. roads, electricity and water provision networks) and services (e.g. healthcare, education). However, after the end of Second World War in many countries their societies became gradually more heterogeneous and pluralistic in terms of culture, values and lifestyles, and this made their public policy problems 'wicked', being characterized by higher complexity and many stakeholders with different and heterogeneous problem views, values and concerns, and lacking clear and widely agreed problem definition and objectives. For this new class of public policy problems the above first generation technocratic methods were not any more sufficient, as they require clear definitions of the problem and the objectives to be achieved (being used as decision making criteria). This gave rise to a 'second generation' of approaches to public policy making, which are based on the extensive involvement of stakeholders; this includes consultation, argumentation and negotiation among them, which aims to synthesize different views on the problem and to formulate a shared definition of it and the objectives to be achieved. These approaches resulted in the development of public participation in government organizations' policy making processes in the last thirty years, through various mechanisms (e.g. public hearings/inquiries, public opinion surveys, citizens' juries/panels, focus groups, citizen/public advisory committees, consensus conferences, negotiated rule making and referenda) (Held, 1987; Fishkin, 1997; OECD, 2001; Rowe and Frewer, 2004). This trend has been reinforced by the explosive growth of the information and communication technologies (ICT) and especially the Internet, which provide huge opportunities for a wide and cost effective application of the above participation ideas, resulting to the development of e-participation (OECD, 2004; Saebo et al, 2008; Loukis et al, 2010).

Public participation, both 'traditional' and ICT-supported, provides to the competent public organizations on one hand rich information on citizens' interest in and acceptance of public policies under formation and application, and on the other numerous proposals for changes, improvements and enhancements of them. However, many of these proposals might be just 'wishful thinking', or have not so positive outcomes as the proposing citizens think (or even have negative impacts from some other perspectives) or have too high costs exceeding benefits. Furthermore, citizens' interest in and acceptance of public policies are not static and evolves over time, due to exchange of information and opinions on them among citizens (e.g. through 'word of mouth' or Internet). Therefore it is necessary to support and enhance participative policy making with technocratic mechanisms and tools for analyzing these numerous proposals as to their outcomes, and also projecting in the future citizens' interest in and acceptance of public policies. The use of simulation can be very useful for these purposes. In this paper we present a state of the art review of existing modelling and simulation approaches from the above perspective, and examine them as to their suitability for the above purposes. This research has been conducted as part of the project PADGETS ('Policy Gadgets Mashing Underlying Group Knowledge in Web 2.0 Media – www.padgets.eu), which is supported by the 'ICT for Governance and Policy Modelling' research initiative of the European Commission.

In the following section 2 the background of this analysis is presented. In section 3 the definitions and objectives of Modelling & Simulation for policy support are provided, while in section 4 the main approaches to it are reviewed. In section 5 there is a discussion of them from the above perspectives, and finally in section 6 the conclusions are summarized.

2 BACKGROUND

In many countries governments have made considerable investments in order to apply the above ideas, promote public participation and strengthen their relations with the citizens, by supporting three types of interactions with them in various stages of the public policy-making cycle (OECD, 2001):

- Information Provision: an 'one-way relation', in which government produces and delivers to the citizens relevant information.

- Consultation: an asymmetric 'two-way relation', in which citizens provide opinions on issues and questions that government has previously defined.

- Active participation: a more symmetric 'two-way relation' between government and citizens, in which citizens have a wider role of proposing new policy options and discussion topics, in addition to the ones proposed by government, and in shaping the policy agenda and dialogue in general.

The increasing penetration of ICT, and especially the Internet, offer huge capabilities to widen and intensify the above interactions at a low cost (OECD, 2004). In particular, ICT enable governments to make available through the Internet large amounts of information concerning their activities, decisions, spending and financial situation in general, and policy whitepapers, promoting transparency, accountability and fighting corruption. Furthermore, the huge interactivity capabilities offered by modern ICT has the potential to expand the scope, breadth and depth of government consultations with citizens and other stakeholders on public policies under formation or application. Many ICT tools have been developed and are available to governments for collecting citizens' opinions on important issues, such as online surveys, government consultation spaces and online discussion forums, online mediation systems for supporting higher quality deliberation, etc. Finally, ICT can also support and facilitate a more active participation of citizens, through online tools enabling them to set the agenda for discussion (e.g. raise new issues that have to be discussed, in addition to the ones raised by the government), submit their own proposals and policy options and in general shape the final outcomes (e.g. e-petition tools (Santucci, 2007; Cruickshank, 2010)).

The emergence of the Web 2.0 (O' Reilly, 2005) with the increased capabilities it provides to users for creating content and expressing political views, needs and problems, leads gradually government organizations to exploit it in order to increase the quantity, quality and inclusiveness of e-participation (Osimo, 2008; Punie, 2009; Mergel, 2009). Governments start using the Web 2.0 in order to make a step towards citizens, instead of expecting them to visit the “official” e-participation spaces created by government organizations. The use of Web 2.0 by government organizations concerns not only ‘soft’ tasks, such as public relations and public service announcements, but also ‘core’ tasks as well, such as intelligence services, reviewing patents, knowledge management, cross-agency collaboration, public services evaluation by citizens, regulation, law enforcement and public participation (Osimo, 2008). Research work is in progress as part of the abovementioned PADGETS project in order to advance the existing situation of individual and fragmented use of a few Web 2.0 social media by government organizations, through a central platform enabling a systematic and centrally managed exploitation of a wide range of Web 2.0 social media (Charalabidis et al, 2010a and 2010b). This central platform will enable the publication of policy-related content and the deployment of relevant micro-applications (termed policy gadgets - padgets) in many Web 2.0 social media at the same time, and then the retrieval of various forms of citizens’ interactions with them (e.g. views, ratings, comments, opinions, etc.).

All the above off-line and on-line public participation mechanisms provide to the competent public organizations useful information on citizens’ interest in and acceptance of public policies. For instance most government e-participation websites include online surveys asking citizens to rate how important they find various issues or problems, and also how appropriate and useful they find various alternative public policies and actions for addressing them; also, most Web 2.0 social media provide such rating capabilities. These allow an estimation of current interest in and acceptance of public policies under formation and application, which is useful. However, this interest and acceptance are dynamic and evolve over time, due to exchange of information and opinions on them among citizens. So it is necessary to provide public policy makers with estimates of not only the current values of interest and acceptance, but also their future evolution. Furthermore, many government e-participation websites include online consultation spaces and discussion forums, which enable citizens to express not only their interest in and acceptance of public policies under formation and application, but also make comments and proposals for changes, improvements and enhancements of them (both of ‘consultation’ and ‘active participation’ form); also, many Web 2.0 social media provide such capabilities for expressing comments and opinions. These can offer to the policy makers large numbers of such proposals, which however might vary in quality, usefulness and applicability, so they need a careful screening in order to find out which of them should be seriously taken into account. Many of these proposals might be just ‘wishful thinking’, or have not so positive outcomes as the proposing citizens think, or even have negative impacts from some other perspectives, or have too high costs exceeding benefits. Therefore participative policy making needs support with technocratic mechanisms and tools for analyzing these numerous proposals as to their outcomes. Modelling and simulation can be very useful for all the above purposes. So in the following sections existing paradigms are reviewed from the above perspective, and then evaluated as to their suitability for the above purposes.

3 MODELLING AND SIMULATION FOR POLICY SUPPORT: DEFINITIONS AND OBJECTIVES

Modelling is defined as the construction of a simplified representation of a part of the real world, which includes only some of its elements on which our study is focusing (Lave & March, 1975). Therefore, for the same real world system we can construct various different models for different purposes, each of them including a different subset of system's elements on which our particular study is focusing, and possibly having a different level of detail. We consider a model as an artificial world giving the user the unprecedented opportunity to test interventions and improvements, aiming to increase its performance; as such it can be viewed as a laboratory, safe from the risks of the real environment, for testing out hypotheses and making predictions (Dolley, 2002). Modelling allows us to deal with the complexity of the real world in an effective incremental manner; a model may begin as a simple approach to the system under investigation and gradually be improved and perfected, as our understanding of the particular system we are dealing with is growing. This "gradual improvement" enables a good approximation of very complex problems. Modelling allows a better understanding of a complex system and a more substantial communication and dialogue about it among interested researchers and practitioners. This approach may be applied for purposes of forecasting, planning and decision making support in policy issues of great complexity, and also for education, if the access to the real system is costly or impossible.

According to Borshchev & Filippov (2004) modeling is a very useful tool for understanding complex systems, predicting their future behaviour and designing improvements of them that increase performance, especially when prototyping or experimenting with the real system is impossible or costly. It includes three steps: i) mapping of a real world system on a simplified model (process of abstraction), ii) analysis of its behaviour and optimization of it, and iii) mapping of the improvements of the model back to the real system. The second step (analysis and optimization) can be performed either through analytical solution, which results in an equation Y=f(X) connecting output Y to input X, or, if this is not possible or quite difficult, though Simulation.

Law and Kelton (2000) define Simulation as a method of using computer software to model the operation and evolution of "real world" processes, systems, or events. In particular, Simulation involves creating a computational representation of the underlying logic and rules that define how the system changes (e.g. through differential equations, flow charts, state machines, cellular automata, etc.). These representations are then coded into software which is run repeatedly under varying conditions (e.g., different inputs, alternative assumptions, different structures), calculating the changes of system's state over time (continuous or discrete) (Davis et al., 2007). So while other research methods aim to answer the questions "What happened, how and why" (trying to understand the past), Simulation aims mainly to answer the question "What if?" (i.e. what will happen if some particular changes of system structure or rules take place, trying to "move forward" into the future).

Using the Simulation approach necessitates initially to determine the manner in which a real system works, as part of its modelling. Then Simulation evolves in Simulation time (continuous or discrete), which corresponds to real time; while the Simulation time runs, the model determines whether there have been changes in system's state and if so recalculates its values. If simulation is valid, the results should reflect the actual behaviour of the system. In this case it allows us to understand how a real world activity is performed under different conditions, testing different assumptions and minimizing the cost of execution of the real activity. The interaction with the model instead of the real system reduces the risk and uncertainty, so better- informed and timely decisions can be made. A very important advantage of Simulation Modelling is that it can be used even by people without extensive experience in the field: all modern Simulation software packages include a graphical user interface allowing the representation (modelling) of the system/process the user is interested in, and also the graphical display of Simulation results.

4 MODELLING AND SIMULATION APPROACHES

A classification of Modelling and Simulation approaches proposed by Borshchev and Filippov (2004) is shown in Figure 1. It is based on the level of modelling detail/abstraction (we can have high abstraction/less detail, medium abstraction/detail or low abstraction/more detail) and on the way time is modelled (as continuous or discrete time).

Figure 1. Major approaches of Modelling & Simulation (from Borshchev and Filippov (2004))

In particular, we can have Simulation Modelling of high detail and low abstraction, which includes representations of individual objects (e.g. people, houses, animals, products, vehicles, etc.) and their characteristics and interaction; on the other extreme we can have Simulation Modelling of low detail and high abstraction, which focuses on aggregate values (covering large numbers of individual objects, number of adopters of a particular new product or public service) and relations among them. Also, with respect to the modelling of time there are two basic types of Simulation: continuous and discrete. In continuous Simulation we consider a continuous time advance in time steps, and for each of them the new state of the system is calculated; on the contrary in discrete Simulation we focus on some discrete times in which particular events happen (e.g. a new citizen arrives in a government agency office), for which the new state of the system is calculated, so Simulation progresses from event to event rather than in continuous time. There are also hybrid Simulation models which are based on both discrete and continuous time.

According to this classification of Modelling and Simulation approaches, shown in Figure 1, based on the above two dimensions, we can distinguish between four main modelling paradigms: Discrete Event, System Dynamics, Dynamic Systems and Agent Based Modelling. Agent-Based and Discrete Event simulation are discrete time approaches, while in System Dynamics and Dynamic Systems simulation time is continuous. These four approaches differ also in the level of abstraction: while aggregative System Dynamics present the highest abstraction, on the contrary Dynamic Systems present the lowest one, Discrete Event is used at low or middle abstraction and Agent-Based modelling range across all levels of abstractions accordingly the nature of the problem.

Another categorization of Modelling and Simulation approaches can made based on their origin (Troitzsch, 1997). We can distinguish between two types of computer Simulation: top-down equation-based ones, derived from previous mathematical modelling research, and bottom-up agent-based ones (Figure 2), derived from more recent artificial intelligence research.

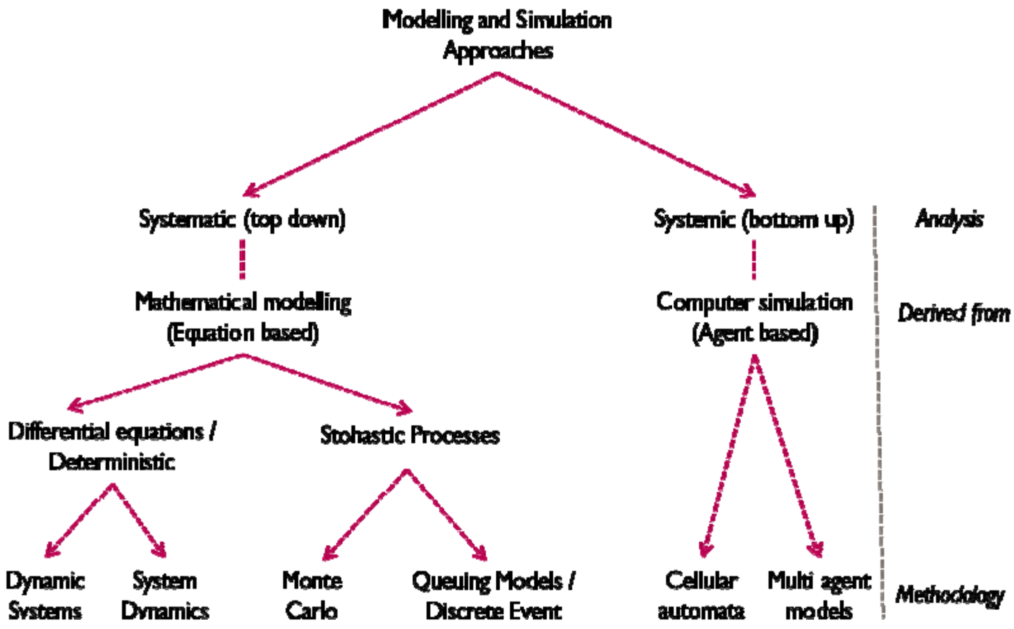

Figure 2. Categorization of Modelling and Simulation Approaches

Both System Dynamics and Discrete Event modelling are typical examples of equation-based approach, which uses equations that determine the future state of systems. The former models are deterministic, so they unfold exactly as specified by some pre-specified logic, while the latter are based on stochastic processes, since they include stochastic differential equations (involving random numbers generators for simulating uncertainty). On the other hand, agent-based modelling takes the agent perspective, in contrast to the process-based perspective of the former category. Agent-based models unfold according to the interactions among individual units, with each of them having its own intelligence and behaviour rules.

In the following sections the main Modelling and Simulation approaches are briefly reviewed and discussed.

4.1 Discrete Event Modelling and Simulation

In Discrete Event models time is not viewed as continuous and does not advance in equidistant discrete steps, the main focus being on discrete times at which some events occur and change something in the state of the system, so practically time proceeds from event to event. They are used for modelling systems characterized by a number of discrete variables (e.g. state of a service point that can be busy or free), and events that occur and change the values of these variables in a rule-oriented but stochastic manner (Dooley, 2002). Discrete Event Simulation Models are discrete, dynamic and stochastic (Law and Kelton, 2000). They are suitable for systems which can be defined by a set of discrete variables that at any given moment characterize the “state” of the system, and only change a finite number of times, at specific instances in time when some events occur. These variables are piecewise continuous, making discrete jumps at particular times and then remaining constant for other periods of time. Such models are usually stochastic, since their behaviour is determined by one or more random variables modelling various types of uncertainty existing in the real world. Also, they are dynamic, since their main output of interest is system behaviour and evolution over time. As mentioned above they are used for constructing models at a low or middle level of abstraction.

The most widely used models of this category are the queuing models (e.g. Cayirli and Veral, 2003; Winston, 2003), which are used to model and optimize systems containing queues. A queue model consists of three types of objects: servers, customers waiting to be served by them and queues. It is stochastic, since the times of appearance of customers are random and follow a probability distribution (usually the Poisson distribution). Here, the primary purpose of the simulation is the prediction of the system's output, for example the mean duration of customers waiting in a queue or the mean time needed by the police cars to reach their destination. The main focus is on the detection of bottlenecks in complex environments, and on the achievement of better system performance by altering the structure of its design. Discrete Event modelling is appropriate for both public and private sector, for solving problems concerning services, manufacturing, logistics, business processes, call centers, etc.

Similar is the **Monte Carlo** stochastic simulation approach (Clemen and Reilly, 1999; Winston, 2003), which is used for modelling systems with significant uncertainty in their inputs, for which we want to calculate the mean and the distribution of the output. Its basic idea is that for each input an appropriate random number generator is set-up (with the appropriate probability distribution and relevant parameters). These random number generators produce a first set of values, and based on them system output is calculated; this is then repeated for a very large number of times, which allows the calculation of the mean and the distribution of the output. The application areas of Monte Carlo simulation include engineering, telecommunications, finance and business, service management, etc.

4.2 System Dynamics

System Dynamics is an equation-based approach that represents real-world systems and processes in terms of stocks of individuals or resources (e.g. adopters of a new technology or government service, materials, etc.), flows between these stocks (which increase or decrease these stocks) and information that determines the values of these flows. It has been developed from the work of Jay W. Forrester (1961). It is a "top-down" modelling approach and examines how causal and feedback relationships among the elements of a system (i.e. system structure) can influence the behaviour of it. System Dynamics abstracts from single objects and events, and takes an aggregate higher level view with less detail (focusing on stocks of them), which allows concentrating on higher level policies. It is suitable for systems having numerous interdependent variables, whose rates of change interact with one another.

The concept of feedback is at the core of System Dynamics, and refers to the situation of X affecting Y, and also Y in turn affecting X, perhaps through a chain of causes and effects. One cannot study the link between X and Y and, independently, the link between Y and X, in order to predict how the system will behave. The causal loops, formed in this way within the system, can be positive so that feedback is self-reinforcing and amplifying, or negative so that feedback is dampening. System dynamics is a methodology for studying and managing complex feedback systems, such as the ones found in business and other social systems. System dynamics is a mature methodology for modelling complex processes and systems both in the private and public sector, and then through simulation, estimating the evolution of critical variables and indicators, such as sales of a new product in the private sector, or pollution, poverty, unemployment, etc. in the public sector, in cases of applying various policy options. It is an effective technique for framing, understanding, and discussing difficult problems and policy options for addressing them.

The methodology of System Dynamics consists of the following steps:

- identify and define the problem,
- develop a dynamic hypothesis explaining the cause of the problem,
- build a computer simulation model of the system at the root of the problem,
- test the model by examining to what extent it reproduces the behaviour seen in the real world,
- devise and test in the model alternative policies that alleviate the problem,
- select the best policy/solution,
- implement this policy/solution,
- validate and revise the model.

System Dynamics, although its initial application area was the analysis of industrial production problems, it has found wide application in several areas, such as corporate planning and policy design, public management and policy, biological and medical modelling, social sciences, energy and environment (ecological systems). The relevant literature review we conducted provided many examples of the use of System Dynamics for addressing various social phenomena and policy making problems. For instance, under the "Swiss Priority Programme Environment» (SPPE) of the Swiss National Science Foundation (SNSF) a research project has been implemented using System Dynamics for analysing policies aiming to improve various aspects of the environment (Schwaninger, Ulli-Beer and Kaufmann-Hayoz, 2008). Through a model for solid waste management at local level the ecological behaviour of citizens has been studied in order to identify and assess various public policies under examination. A recent application of System Dynamics in the area of electronic government aims to understand better the factors affecting development and success in this area (Luna-Reyes and Gil-García, 2009). A System Dynamics model has been developed based on a theory about how institutional, organizational and technological elements interact to produce different technological outcomes and enactments. This model has been used for simulations of four different networks of government and nongovernment organizations engaged in the creation of Internet portals and content in the areas of education, health, economy and government. Based on the results of these simulations it has been concluded that differences in institutional arrangements and organizational factors resulted in quite different technology enactments. Various other examples of social simulation with System Dynamics have been identified in the areas of national security (military organization), adoption of automation technologies, changes in socio-political structure and energy, indicating the usefulness of this approach in analyzing public sector and social problems.

We should also mention here the **Dynamic Systems** approach, which is regarded as the 'ancestor' of System Dynamics. The method uses block diagrams with feedback loops to model and design "physical" systems, and its main application areas have been in the mechanical, electrical, chemical and other technical engineering disciplines. Dynamic System models consist of state variables (e.g. position and velocity of particular mechanical parts) and differential equations connecting these variables. A similarity with System Dynamics is that they are both conducting continuous time simulation. Their difference lies in the nature of their variables, which in Dynamic Systems are of lower level and have direct "physical" meaning (e.g. location, velocity, acceleration, pressure, concentration, etc.); so the mathematical models connecting them are of lower level (i.e. more detailed, modeling particular units/objects, instead of the higher level aggregate variables that characterize System Dynamics) and of higher complexity than in Systems Dynamics.

4.3 Cellular Automata

Cellular automata are discrete time models focusing on multiple actors, which are characterized by a rules-based behaviour and have local interactions in a physical space (Chopard Droz, 1998; Jarkko, 1999)(http://en.wikipedia.org/wiki/Cellular_automaton;http://mathworld.wolfram.com/CellularAutomaton). In particular, a cellular automaton is a collection of "coloured" cells (i.e. which can have different colours, this denoting different states) on a grid of specified shape; each of them evolves through a number of discrete time steps depending on the states of neighbouring cells being influenced by them. The grid can be in any finite number of dimensions, but one–dimensional or two–dimensional cellular automata have been mainly used. The term "colour" refers to the state of each cell which is determined by a set of predefined rules. Usually each cell is binary (i.e. it can have two states, such as "on" or "off"), however cellular automata having a continuous range of possible values may also be considered. The internal rules of cells are applied iteratively for as many time steps as desired and may change the state of the cell. In addition, the neighbourhood over which cells affect one another must also be specified. Transition rules, which are major components of the model, and possible states of each cell, are usually uniform for all cells, which makes the cellular automata homogenous systems. The approach of Cellular Automata relies on the division of the entire model into sub-models, in sense that different sets of cells are sub – models representing parts of the whole system.

Cellular Automata were originally conceived by Ulam and von Neumann in the 1940s to provide a formal framework for investigating the behaviour of complex systems, which consist of numerous elements with extensive interactions among them. Since then, the theory of Cellular Automata has been proved immensely rich, with simple rules and structures being capable of producing and therefore explaining a great variety of unexpected behaviours. It can be applied in various disciplines (e.g. mathematics, physics, complexity science, biology, etc.) in order to model various kinds of natural and social processes. The simplest type of Cellular Automaton is a binary, nearest-neighbour, one-dimensional automaton. Such automata were called "elementary cellular automata" and have been found to have amazing properties.

4.4 Agent-Based Modelling and Simulation

The main concept of Agent-Based Modelling and Simulation is the construction of multiple agents (i.e. individual programs that simulate the behaviour and interaction of individual persons, firms, etc.), which are characterized by rules and intelligence, and the calculation-simulation of the interactions among them and finally the emerging from them system macro-behaviour. Agent-Based Modelling and Simulation has been based on abovementioned concept of Cellular Automata. An agent can be defined as a self-contained program that can control its own actions based on how it perceives its operating environment and also its pre-determined behavioural pattern. The environment of an agent refers to its neighbouring agents, from which agents have the ability to learn by continuously monitoring it. An agent responds to local information produced by its contact with the other neighbouring agents. It has its own properties and follows specific decision-making rules, ranging from simple reactive rules to complex adaptive intelligence. The key feature for a component of a model to be considered as an agent is the ability of adaptation to its environment. In this context, Casti (1997) argues that agents should contain both base-level rules for behaviour as well as a higher-level set of “rules to change the rules”, which enable them to adapt their behaviour over time based on the experience they gain. Basic characteristics of agents include that they are identifiable, situated in an environment, autonomous and self-directed and finally, they have goals to achieve.

According to Epstein (1999), Agent-Based models are characterized by five attributes: heterogeneity, autonomy, explicit space, local interactions and bounded rationality. ‘Heterogeneity’ refers to the fact that agents differ in their preferences or rules that determine their behaviour during Simulation, which often produces unexpected effects on the macro level; this is used to simulate the existing differences among individuals (e.g. genetically, culturally, by social network, by preferences, etc.), which finally create unique interactions between agents. The term ‘autonomy’ means that monitoring or enforcement of any order is not imposed from above (in a top-down manner), and the restrictions may be put only in rules that agents follow in the micro-level and not in collective macro-level, which is emerging from the individual rules and the interactions. Hence, the macro level evolution and change result from local interactions and from the micro-level to the macro-level, and not vice versa. When an initial population of agents is released into an artificial environment in which, and with which, they interact, an ‘artificial society’ of agents is formed. Artificial society refers to the fact that multi-agent systems try in general to create “micro-worlds” or “would-be worlds” in computational environment in order to investigate the mechanism, by which interactions and various behaviours of autonomous agents produce macro-level structures and self-organization (Casti, 1997). This “artificial society” of an Agent-Based model takes place in a strictly ‘explicit space’, which is usually an n-dimensional cellular automaton. In addition, agents present social ability, interacting only with neighbouring agents and not with remote ones. This is described by Epstein with the attribute of ‘local interactions’, which simulates the nature of human interactions that take place mainly in a defined geographic or cultural area. Finally, the term ‘bounded rationality’ has two components: bounded information and bounded computing capacity. In particular, agents follow simple rules based on local information, ignoring global information; furthermore, they do not have infinite computational power, and this generates limitations as to the computations they can do. This bounded rationality of agents simulates the existence of limits in the rationality of individuals, which is subject to stress, time pressure, and emotive forces, as concluded by recent research in the domain of cognitive psychology (Elliott & Kiel, 2004).

Agent-Based modelling and simulation can be applied in a wide range of complex social, economic and political phenomena. There are many good examples in the literature, such as an application of Agent-Based modelling for studying humanitarian assistance policies executed by governments and NGOs that provide the health and safety to refugee communities (Anderson et al., 2007). Another interesting example is the use of Agent-Based modelling in order to investigate the relationship between age and technological diffusion, as part of an attempt to assess the impact of the aging on the diffusion processes of future technologies and in general on the innovation absorption capacity of socioeconomic systems (Ferro et al., 2010).

Agent-Based models are useful in relating the heterogeneous behaviour of agents with different information and decision rules with the macro behaviour of the overall system. This makes them often more significant in conditions of great uncertainty when forecasts are not possible and the classic methods of prospective analysis are less effective.

5 DISCUSSION

In the previous sections have been briefly reviewed the main approaches to Modelling and Simulation, together with their main characteristics; an overview of them is given in the following Table 1 with respect to modelling of time (discrete/continuous), type of simulation (static/dynamic), type of processes/systems addressed (deterministic/stochastic) and level of detail (micro/meso/macro).

Methodology	Time	Simulation	Process/System	Level
Queuing models	Discrete	Dynamic	Stochastic	Micro-Meso
Monte Carlo	Discrete	Dynamic	Stochastic	Micro
System Dynamics	Continuous	Dynamic	Deterministic	Macro
Dynamic Systems	Continuous	Dynamic	Deterministic	Micro
Cellular Automata	Discrete	Dynamic	Deterministic	Meso-Macro
Agent-based	Discrete	Dynamic	Deterministic	Meso-Macro

Table 1: Overview of Modelling and Simulation approaches

Taking into account that participative policy making, as mentioned in sections 1 and 2, needs tools for i) screening the numerous proposals made by citizens on public policies under formation or application and estimating their outcomes, and ii) projecting in the future the interest in and acceptance of such public policies, the following conclusions can be drawn:

- System Dynamics seems to be one of the most promising approaches for the above purposes, which require high/macro level modelling and simulation of complex social or economic systems in continuous time for assessing the impacts of different policy-related proposals (e.g. proposed changes, improvements and enhancements of public policies under formation or application), focusing not on individual objects/units, but on aggregate variables. Such systems include various individual processes with 'stocks' (e.g. users and non-users of various services or new technologies, employed and unemployed citizens, citizen groups of various income levels, etc.) and 'flows' among them, which are influenced by public policies, so System Dynamics is well positioned for modelling and simulating them. Another advantage is that as mentioned above Systems Dynamics has been successfully used in the past for assessing the evolution of a number of critical variables of economy and society, such as unemployment, economic development, taxation income, technologies penetration, pollution, poverty, etc. So it is not any more in an 'experimental phase', it has reached a maturity and knowledge and experience has been gathered from its use the above areas.

- Agent-based Modelling and Simulation can also be useful for the above purposes, as it can be used for modelling and simulation at both meso and macro level. This approach does not require us to define the basic structure of the system in order to estimate its macro behaviour (as in Systems Dynamics), but the behaviour and interaction rules of the individual units (e.g. persons, firms, etc.) instead. Taking into account that usually for social and economic systems it is easier to define the former than the latter, we can argue that Systems Dynamics might be more advantageous than Agent-based Modelling and Simulation in most cases. However, in cases that it is easier to behaviour and interaction rules of the individual units Agent-based Modelling and Simulation might be the preferable approach. Also, Agent-based Modelling and Simulation is more recent than Systems Dynamics, so there is less history, knowledge and experience on its use for analyzing both private and public sector systems and problems.

6 CONCLUSIONS

Public participation in policy making has considerably increased in the last thirty years, initially in off-line mode (e.g. through public hearings/inquiries, public opinion surveys, citizens' juries/panels, focus groups, citizen/public advisory committees, consensus conferences, negotiated rule making and referenda) and later in on-line mode (e.g. through government e-participation websites providing online surveys and e-consultation spaces, and recently exploiting the emerging Web 2.0 social media). It is quite valuable, as it provides to the competent government organizations useful information on citizens' interest in and acceptance of public policies under formation or application, and also numerous proposals for changes, improvements and enhancements of them. However, it necessitates technocratic mechanisms and tools for screening these numerous proposals and analysing them as to their outcomes, in order to identify which of them should be seriously taken into account, and also for projecting in the future citizens' interest in and acceptance of public policies. In the previous sections of this paper we have presented a review of existing modelling and simulation approaches from the above perspective, and examined them as to their suitability for the above purposes. This research has been conducted as part of the project PADGETS ('Policy Gadgets Mashing Underlying Group Knowledge in Web 2.0 Media – www.padgets.eu), which is supported by the 'ICT for Governance and Policy Modelling' research initiative of the European Commission. In particular, we have examined the most widely use Modelling and Simulation approaches: Discrete Event Modelling and Simulation, Monte Carlo Simulation, System Dynamics, Dynamic Systems, Cellular Automata and Agent-Based Modelling and Simulation. It has been concluded that System Dynamics seems to be the most promising for the above purposes, followed by Agent-Based Modelling and Simulation, and both can contribute significantly to the technocratic enhancement of participative policy making.

The conclusions of our study have interesting implications for management and research. Public sector management should combine the use of the Internet for increasing public participation in public policy making, with the exploitation of the wide range of capabilities provided by the various existing modelling and simulation approaches for analysing the numerous citizens' proposals as to their impact along several dimensions of critical importance for the particular policy area (e.g. unemployment, poverty, education, adoption of a new technology, administrative cost reduction, etc.). The recent public debt crisis in many countries of the world (e.g. USA, European South) necessitates that the limited government financial resources are spent in the most effective manner so that the 'value for money generated' is maximized. Therefore it is important to analyze systematically the rich variety of proposals coming from various groups of the society through public participation, using advanced modelling and simulation approaches, in order to identify the most effective ones on which governments should focus their limited financial resources. The outcomes of this analysis should be presented to the citizens (in a simplified manner), so that they gradually get a feeling of the impact of the submitted proposals, so that their 'participation maturity' increases. This will allow the first generation technocratic approach to public policy making to be combined with the more recent second generation participative approach. Also, future research should be directed towards the development of specific modelling and simulation approaches (e.g. particular methods to be used, data required, outputs, etc.) for the assessment of the impact of specific representative types of citizens' proposals along various dimensions in each policy area. Further research is in progress by the authors as part of the above PADGETS project concerning the use of System Dynamics Modelling and Simulation for exploiting for the above purposes user interactions (e.g. views, ratings, comments and opinions, etc.) with policy-related content published in several Web 2.0 social media from a central platform.

References

Anderson J, Chaturvedi A, Cibulskis M. (2007). 'Simulation tools for developing policies for complex systems: modeling the health and safety of refugee communities'. Health Care Management Science, December 2007, 10(4):331-9.

Antunes, L., A. Respício, Balsa, J. (2008). 'Policy Decision Support through Social Simulation'. Encyclopedia of Decision Making and Decision Support Technologies. F. Adam and P. Humphreys, IGI Global: 716-723.

Bonabeau, E. (2002). 'Agent-based modeling: Methods and techniques for simulating human systems'. Proceedings of the National Academy of Sciences, 99(3): 7280-7287.

Borshchev, A. and A. Filippov (2004). 'From system dynamics and discrete event to practical agent based modeling: Reasons, techniques, tools'. Proceedings of the 22nd international conference of the system dynamics society. Oxford, England.

Casti, L. J. (1997). 'Would-be worlds: how simulation is changing the frontiers of science'. John Wiley & Sons, Inc.

Cayirli, T., Veral, E. (2003). 'Outpatient scheduling in health care: a review of literature'. Production and Operations Management, 12(4): 519-549.

Charalabidis, Y., Gionis, G., Ferro, E., Loukis, E. (2010a). 'Towards a Systematic Exploitation of Web 2.0 and Simulation Modeling Tools in Public Policy Process'. IFIP Second International Conference on e-Participation - ePart 2010, August 29 - September 2, 2010, Lausanne, Switzerland.

Charalabidis, Y., Gionis, G., Loukis, E. (2010b). 'Policy Processes Support through Interoperability with Social Media'. 5th Mediterranean Conference on Information Systems 2010 (MCIS 2010), 25-27 September, 2010, Haifa, Israel.

Clemen, R. T., Reilly, T. (1999). 'Making Hard Decisions with Decisiontools Suite'. Duxbury Press.

Conte, R., N. Gilbert, et al. (1998). MAS and Social Simulation: A Suitable Commitment. Multi-Agent Systems and Agent-Based Simulation, Springer Berlin / Heidelberg. 1534: 1-9.

Chopard, B. and Droz, M. (1998). 'Cellular Automata Modeling of Physical Systems'. Cambridge University Press, ISBN 0-521-46168-5

Cruickshank, P., Edelmann, N., Smith, C. (2010). 'Signing an e-Petition as a Transition from Lurking to Particiption'. in Tambouris E., Macintosh A., Glassey O. (Eds.) Second IFIP International Conference on Electronic Participation – ePart 2010, Lausanne, Switzerland.

Davis, J., K. Eisenhardt, et al. (2007). 'Developing theory through simulation methods'. Academy of Management Review 32(2): 480-499.

Dooley, K. (2002). 'Simulation research methods'. Companion to Organizations. J. Baum, London: Blackwell: 829-848.

Epstein, J. M. (1999). 'Agent-based computational models and generative social science'. Complexity 4(5): 41-60.

Ferro, E., Caroleo, B., Cantamessa M. and Leo, M. (2010). 'ICT Diffusion in an Aging Society: A Scenario Analysis'. Electronic Government, Springer Berlin / Heidelberg. 6228: 263-274.

Fishkin, J. S. (1997). 'The Voice of the People - Public Opinion and Democracy'. New Haven and London, Yale University Press, 1997.

Forrester, J. (1961). 'Industrial Dynamics'. Cambridge, MA: Productivity Press.

Hegselmann, R. (1996). 'Modelling social dynamics by cellular automata'. Social Sience Microsimulation: 41-54.

Held, D. (1987). 'Models of Participation'. Cambridge, Polity Press, 1987.

Jarkko, K. (1999). 'On the circuit depth of structurally reversible cellular automata'. Fundamenta Informaticae, 38: 93–107.

Lave, C. A. and J. G. March (1975). 'An introduction to models in the social sciences'. University Press of America.

Law, A. M. and W. D. Kelton (2000). 'Simulation modeling and analysis'. McGraw-Hill.

Loukis, D. (2010). 'Analysis of methodologies of modelling and prediction of complex behavior social systems with applications in Public Administration & E-Government using Information Technology'. Department of Information and Communication Systems Engineering, University of Aegean.

Loukis, E., Xenakis, A., Charalabidis, Y. (2010). 'An Evaluation Framework for e-Participation in Parliaments'. International Journal of Electronic Governance, 3(1): 25 – 45.
Luna-Reyes, L. F. and J. R. Gil-García (2009). 'Using Institutional Theory and Dynamic Simulation to Understand Complex E-Government Phenomena'. Proceedings of the 27th International Conference of the System Dynamics Society. Albuquerque, New Mexico, USA.
Mergel, I. A., Schweik, C. M. and Fountain, J. E. (2009). 'The Transformational Effect of Web 2.0 Technologies on Government'. Available at SSRN: http://ssrn.com/ abstract=1412796
Nikolai, C. and Madey, G. (2009). 'Tools of the Trade: A Survey of Various Agent Based Modeling Platforms'. Journal of Artificial Societies and Social Simulation 12(2):2.
O' Reilly, T. E. (2005). 'What is Web 2.0'. 2005, retrieved online at: http://www. oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html
Osimo, D. (2008). 'Web 2.0 in Government: Why and How?'. JRC Scientific and Technical Reports. European Commission, Joint Research Centre, Institute for Prospective Technological Studies.
Punie, Y., Misuraca, G. and Osimo, D. (2009). 'Public Services 2.0: The Impact of Social Computing on Public Services'. JRC Scientific and Technical Reports'. European Commission, Joint Research Centre, Institute for Prospective Technological Studies
Railsback, S., Lytinen, S., Jackson, S. (2006). 'Agent-based Simulation Platforms: Review and Development Recommendations'. Simulation 82(9): 609-623.
Rittel, H. W. J., Weber M. M. (1973). 'Dilemmas in a General Theory of Planning'. Policy Sciences, 4: 155-169, 1973.
Rowe, G., Frewer L. J. (2004). 'Evaluating Public-Participation Exercises: A Research Agenda'. Science, Technology & Human Values, 29(4): 512-557, 2004.
Saebo, O., Rose, J., Flak, L. S. (2008). 'The shape of eParticipation: Characterizing an emerging research area' Government Information Quarterly, 25: 400-428.
Santucci, D. (2007). 'Studying e-petitions: State of the art and challenges'. ESF-LIU Conference on Electronic Democracy, Vadstena, Sweden, 2007
Scholl, H. (2001). 'Agent Based and System Dynamics Modeling: A Call for Cross Study and Joint Research'. Proceedings of the 34th Annual Hawaii International Conference on System Sciences (HICSS-34) –Volume 3 – Volume 3, IEEE Computer Society.
Singh, V. (2006). 'Use of Queuing Models in Health Care'. The Selected Works of Vikas Singh
Schwaninger, M., S. Ulli-Beer, et al. (2008). 'Policy Analysis and Design in Local Public Management A System Dynamics Approach'. Handbook of Transdisciplinary Research: 205-221.
Sutner, K. (1991). 'De Bruijn Graphs and Linear Cellular Automata'. Complex Systems, 5: 19–30.
Troitzsch, K. G. (1997). 'Social Science Simulation – Origins, Prospects, Purposes'. Simulating social phenomena: 41-54.
Winston, W. L. (2003). 'Operations Research: Applications and Algorithms'. Duxbury Press.