Future research directions in Governance and Policy Making under the UE prism of ICT for Governance and Policy Modelling.

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ABSTRACT

The role of Government has evolved over the last thirty years and while its role in service provision has diminished, its regulation activity is growing. The world has become increasingly interconnected, complex, and fast-evolving and the effects of individual behavior and policy choices are not predictable. The paradox is that while the amount of data available to governments has increased exponentially, yet policymakers clearly struggle to make sense of it so that during the last years, the European Commission has decided to invest heavily in research on this issue. In this paper, the authors report about their experience in the CROSSROAD Project, whose main goal was to build a roadmap in order to provide strategic directions for future research in the domain of "ICT for Governance and Policy Modelling". The roadmap, recently approved by European Commission, intends to be the basis for developing a shared vision, inspire collaborative and interdisciplinary research between academia, business, civil society and government, and provide support and orientation to policy-modeling also after the project end. In this context, the paper analyzes the Model-based Governance issue as the part of the roadmap that suggests the development of advanced tools for an efficient and effective decision-making process.

KEYWORDS

Governance Analysis and Evaluation, Public Policy, Applications and Impact in Governance, Policy Making, Modelling and Simulation, System Dynamics, Decision Support System, ICT Tools, Information Systems

1. INTRODUCTION

In a rapidly changing world, anticipation and timely decision-making are necessary to ensure positive outcomes, stability and safety. Anticipating future events, promptly detecting emergencies and evaluating the impact of different policy choices before they are implemented are necessary features of good governance. On the other hand, the increased complexity of society and economic trends calls for models that at the same time reflect this complexity while making it simpler and addressable.

In recent years, tools available to government to anticipate trends and policy impacts have been rapidly developing. In particular, the anticipation of future trends and impacts of different policies through impact assessment tools have become a standard activity for the most relevant policy decisions, such as fundamental regulatory initiatives in economic and environmental domains. Yet, complex human systems are difficult to predict while understanding the limits of predictability is necessary to avoid judgment errors. The biggest mistake is to presume that we know more than we know.

Most of the current practice for policy modelling and simulation is still centered on traditional analytical mathematical models and/or linear econometric tools, which suffer from a number of shortcomings when applied in the public policy context (Moss 2010). They are traditionally short-term and not effective in elucidating the variety of human behaviour, especially taking into account non-rational forces, tipping points (Schelling, 1969) and non-linear processes. These socio-economic models begin with unrealistic simplified assumptions in order to produce formally correct, consistent and tractable models (Gilbert 2004). The underlying assumption is that the economy can be understood by reference to a single so-called 'representative agent', who takes decisions to maximise his/her utility over an infinite time horizon, thereby ignoring the variety of individual reactions which are the key variable in determining the impact of policies. For example, the failure to anticipate the most recent (or any previous) financial crisis showed the limitations of top-down linear forecasting. Furthermore, those models are highly resource-intensive and purpose-specific, which limits its application to major policy decisions.

While abstract mathematical models tend to result in high-level predictive outputs, computational agent-based models offer higher degrees of granularity. Yet, there is a wide gap between macro and micro models approaches. Still, micro-simulation models are powerful means to predict both the short-term and long-term effects of policies as well as micro effects of demographic processes. Moreover, they are well suited for distributed and uncertain environments and account for individual behaviour and interrelation between behaviours, including imitation.

The use of software agents in simulation models for behavioural and social simulation allows for a more descriptive representation of the behaviour of actors, than the mathematical or statistical models offer. Originally developed for natural sciences, they proved to be particularly suitable in the context of social sciences to explain human behaviour. The software agents are now being applied in the public policy science, especially in areas of strategic regulatory importance such as tax and transfer policy, energy, transport, disaster recovery and water management. Because of their systemic approach, they are also beneficial in terms of integration across government departments, to overcome silos effect and highlight interdependencies between sector-specific government policies.

On the downside, the major drawbacks associated with using agent simulation are the complexity of the resulting control system that needs to be debugged, the lack of facilities to adequately represent/trace knowledge contained by each agent and the selection of tactics used by the agents. Social modelling and simulation tools, in general, suffer from lack of scalability to the macro level, being built ad-hoc for specific purposes. These tools require high level of technical competence, and are therefore struggling to capture the knowledge and the opinion of domain specialists. Models and simulation too often are perceived as black boxes, unintelligible to the user: this is a particular challenge in the field of public policy, where decisions have to be taken on the basis of transparent information. The recent controversies over climate change predictions and models showed the risks of this lack of transparency when dealing with highly complex issues. Furthermore, computational scientists do not adopt timely the most advanced software engineering tools, so that advances in computing power have not been matched by advances in software development techniques, and time-to-solution in many cases is increasing, rather than decreasing. Finally, there is a tendency to reinvent and develop "own" models and simulation tools, and very few policy-oriented modelling software solutions are available, so that adoption of a policy modelling approach still demands a lot of resources.

The present paper presents directions for future research in model-based governance in order to achieve evidence-based policy making and address the current aforementioned problems in policy modeling.

The structure of the paper is as following: Section 2 outlines the context paving the way towards collaborative policy modeling, leading to Section 3 that identifies the role of modelling and dynamic simulation in policy making. Section 4 concludes the paper by recognizing the benefits of research towards the proposed directions.

2. CONTEXT: THE EU 7th RESEARCH FRAMEWORK PROGRAMME (FP7) AND THE "CROSSROAD" PROJECT

As mentioned in the introduction, during the last years, activities related to ICT for Governance and Policy Modelling have been initiated by the European Commission in order to consolidate and advance research in a new, yet multi-disciplinary and fragmented domain. With the ultimate goal to build constituency and outline a concrete roadmap for future research, the CROSSROAD Project ("A Participative Roadmap for ICT Research in Electronic Governance and Policy Modelling") has extensively investigated the underlying state of play in one of its deliverables (Lampathaki, et al., 2010). Based on this work, CROSSROAD[1] aimed at evidencing how a mapping of this domain has been conducted and summarised for the first time, at defining which is the current state of play in research, practice and policy, and at understanding which conclusions can be drawn and what trends are recognised.

CROSSROAD is a Support Action project (FP7-ICT-2009-4, No. 248484), funded by the European Commission under the Objective 7.3 ICT for Governance and Policy Modelling. It aims to deliver a Research Roadmap on ICT for Governance and Policy

[1] See CROSSROAD white paper at the following URL: http://crossroad.epu.ntua.gr/files/2010/02/CROSSROAD-State_of_the_Art_Analysis-White_Paper-v1.00.pdf

Modelling, which will be supported by the contribution of the results deriving from other FP7 projects in this domain and by the involvement of the research community
The CROSSROAD project aimed at answering a clear set of key questions:

1. What is the present state of the art in the field of governance and policy modelling? Which are the most advanced implementation initiatives in this field, and the challenges encountered? What are the present issues to be addressed?
2. Taking into account possible future scenarios, what are the future needs for ICT tools for governance and policy modelling?
3. Comparing present status and future needs, as they also derive from the possible results of other FP7 projects, are there any specific gaps and grand challenges in the domain that can be identified?
4. Between the challenges emerging from present needs and future scenarios, which are related to research, rather than implementation?
5. Which logical relationships (such as originality, redundancy or complementarity) are there between on-going research and also with other application domains? In particular, which of the application fields of governance and policy modelling is likely to be at the frontier of technological innovation, compared to the other application fields?
6. For those research challenges identified, what kind of research support measures should be adopted by the UE or other financing institutions?

As it is possible to appreciate, answering such questions in the order in which they were enumerated, implicitly defines an analysis procedure, and thus a methodology.

Technology RoadMapping (TRM) is a strategic planning approach to identify the actions and funding decisions needed to boost technological development and innovation. It has become a widely used tool for individual companies, entire industries and governmental policy makers in the past decades. The use of the term "roadmap" conveys the main purpose of this approach, namely to chart an overall direction for technology development or usage. In the most traditional sense, TRM aims at supporting the development of new products by establishing causal or temporal relations between the technological possibilities and choices and the business objectives thereby highlighting the necessary steps to reach the market with the right products at the right time. Indeed roadmapping is gradually developing into a new discipline as numerous studies have been devoted to the theory and methodology of roadmapping (Da Costa, Boden, & Friedewald, 2003; Da Costa, Boden, Punie, & Zappacosta, 2003; Willyard & McGlees, 1986).
A standard definition of the science and technology roadmapping approach does not exist, and an examination of roadmaps that have been created indicates that there is considerable diversity among practitioners as to what constitutes a roadmap and which are the roadmapping techniques employed. Amidst this plurality of methodologies, previous projects such as eGovRTD2020 (2006-2007) and PHS2020 (2009) adopted a policy-oriented approach including a foresight element by combining roadmapping with scenario building techniques. This is considered more appropriate for holistic roadmaps focused on highly complex multi-layered and multi-players domains.
The potential of roadmapping has been considered as significant in the domain of ICT for governance and policy modelling as it can constitute an important input in the selection of future research priorities by highlighting the emerging themes and key

technological applications (ICT tools) likely to impact on policy in the coming years. In a recent benchmarking study, roadmapping was highlighted as one of the "recommended best practices" for the selection of priorities in R&D programmes since it does not only identify the bottlenecks that need to be addressed within a realistic time frame, but it can also lead to a high degree of consensus if potential beneficiaries are involved in the agenda-setting process (De Laat, 2004).
In sum, science & technology roadmapping for policy intelligence has a longer time horizon, must integrate roadmapping and scenario building techniques and start from a main societal challenge in order to look beyond technology development at scientific research and at socio-economic factors.

The adopted CROSSROAD approach is summarized in the following figure.

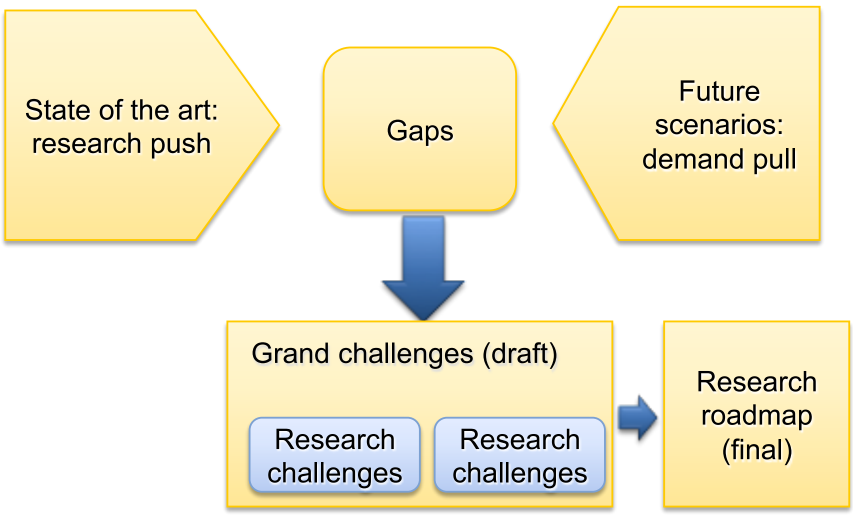

Figure 1: The CROSSROAD Approach

Step I: State of Play
In fact, the first activity, "**State of Play**", provided a substantial and wide review of the State of the Art[2], which gave a consistent definition of the research domains affected (Lampathaki, F., Charalabidis, Y., Passas, S., Osimo, D., Wimmer, M., Askounis, D. - 2010). In an effort to reach consensus on the diverse domains of ICT for Governance and Policy Modelling, a Research Areas Taxonomy has been created on the basis of a concrete quantitative methodology. This taxonomy brought for the first time under a common structure disparate research fields such as agent-based modelling, online deliberation or visual analytics. For each research area, an analysis of the current status of research policy and practice was provided. This provided a snapshot of the future research directions, in continuity with current research. In other words, it delivered a research-push insight on the element that would constitute the roadmap.
The taxonomy, which consists of 5 Research Themes (RTs) as broad thematic categories that contain and classify a number of research areas at lower levels, has been discussed and validated by a large number of experts from the various domains and

[2] D1.2 "State of the Art Analysis" available at http://crossroad.epu.ntua.gr/files/2010/04/CROSSROAD-D1.2-State-of-the-Art-Analysis-v1.00.pdf

disciplines. In particular, the 5 Research Themes depicted in the following figure can be summarized as:

RT.1: Open Government Information & Intelligence for Transparency
RT.2: Social Networks, Citizen Engagement and Inclusion
RT.3: Policy Making
RT.4: Identity Management and Trust in Governance
RT.5: Future Internet for Collaborative Governance

In particular, the CROSSROAD Research Areas taxonomy actually brings together 17 Research Areas that contain more than 80 Research Sub-Areas. In each research theme and its research areas, the research-oriented approaches, the practice-driven implementations and the policy positions have been identified in an effort to elaborate on their current uptake and future perspectives in terms of research potential, practice demand and market penetration.

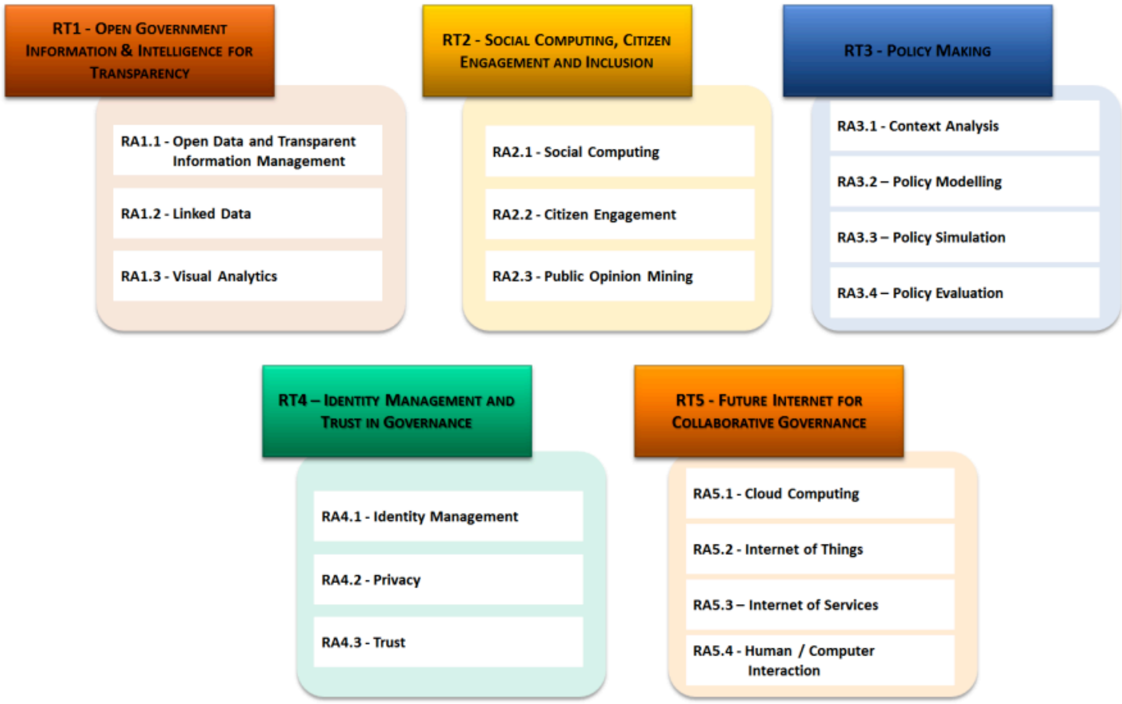

Figure 2: The CROSSROAD Taxonomy (as in the gov2pedia wiki, www.gov2pedia.com)

Step II: Visionary Scenarios

“**Visionary Scenarios Building**”, the second step of our methodology, resulted in more open-ended scenarios on the future of governance and policy modelling, and the deriving technological needs in order to grasp the opportunities and avoid possible difficult challenges. In short, the Visionary Scenarios depicted for the future of governance and policy modelling of Digital Europe at the 2030 horizon (Open Governance, Leviathan Governance, Privatised Governance, Self-Service Governance - see Misuraca, et al., 2010), presented the general societal trends and a deeper analysis of policy trends, which are considered central for understanding and mapping ICT research for governance and policy modelling in future perspective, within the context of the evolving European public sector.

This activity ultimately offered an overview of the opportunities and risks linked to various scenarios, in order to support identifying the key future research challenges in ICT for governance and policy modelling and how these could help drive the European society to achieve the proposed vision for a digital Europe in 2030. In this way, the future needs were identified through the demand-side.

Step III: Gap Analysis

From the integrated analysis of the State of the Art and the Future scenarios, the third step of "**Gap Analysis**" identified an exhaustive list of specific gaps, where the on-going research activities are not going to meet the long-term needs outlined by the future scenarios. These gaps were assessed according to their relevance and impact for achieving the five principles of *Good Governance* (Openness, Participation, Accountability, Effectiveness, and Coherence).

Step IV: Research Roadmap

Afterwards, the identified gaps were "bundled" in a limited number of Grand Challenges. These Grand Challenges were conceived in such a way to be based on the following principles:

1. Be understandable, visual and inspire research ideas.
2. Be bold and disruptive but strongly rooted in the State of the Art and addressable by 2020.
3. Contain significant critical mass of research.
4. Address gaps across multiple Research Themes.

The four grand challenges that have to be met, composed of several research challenges, which were identified in the collaborative and peer-reviewed process, are the following:

1. **Model-based collaborative governance**: How to assist policy makers in taking evidence-based decisions in our complex, unpredictable world? Existing econometric models are unable to account for human behaviour and unexpected events. New policy modelling and simulation are fragmented, single-purposed and work at micro-level. There is a need for robust, intuitive, reusable collaborative modelling tools that can be integrated into daily decision-making processes.
2. **Data-powered collective intelligence and action**: How can we make sure that increased transparency translates into actual more open and more effective policy-making? Current tools require high involvement and attention, therefore engaging only the very committed people. They are designed to facilitate conversations, rather than action. There is a clear need for more intuitive collaborative tools that are able to engage also less interested people, maximizing the impact of short attention span and low-engagement, as well as for ICT based feedback mechanism that are able to encourage real action and behavioural change.
3. **Government Service Utility**: How to provide high-impact services to citizens, businesses and administrations in a way that allows for co-design, public-private collaboration, citizen interaction and service co-generation that allows for 1-stop, 1-second service delivery at very low cost and administrative burden and for completely new services, through mash-up and interoperability-by-design?

4. **Scientific base of ICT-enabled governance**: How to make ICT-enabled governance a rigorous scientific domain, by providing formal methods and tools? The systematic classification of problems and solutions and description through formal languages, in an effort to make diagnosis and prescription of solutions a scientific process that will allow building on top of existing knowledge.

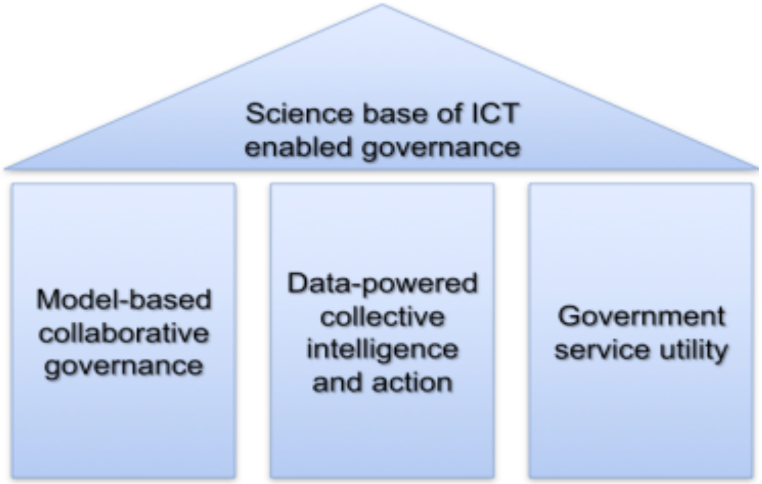

Figure 3: The CROSSROAD Grand Challenges

For each Grand Challenge, a subset of specific Research Challenges have been identified and analysed in detail, and they ultimately constitute the core of the roadmap. Methodologically speaking, the first draft of the roadmap presenting the initial description of Grand Challenges and the related Research Challenges was then followed by a collaborative deliberation process, which went first through a consultation phase (both offline and online) and then through a validation by the Experts Scientific Committee.

In particular, the GC1 Model-based Collaborative Governance deals with the development of advanced tools and methodologies, following the vision of a radically different context for policy modelling and simulation, where standardisation and reusability of models and tools, system thinking and modelling applied to policy impact assessment has to become pervasive throughout government activities. This will be the main focus of the next sections as it actually constitutes a core challenge in research and development on new ICT tools concerned with policy making and governance assessment for the next years to come.

3. THE ROLE OF MODELLING AND DYNAMIC SIMULATION IN THE POLICY MAKING FRAMEWORK

Our rapidly changing and complex society requires an efficient and effective decision-making process, able to anticipate future events, promptly detecting emergencies and evaluating the impact of different policy choices, reflecting the real-life complexity while making it simpler and addressable. The GC1 Model-based Collaborative Governance deals with the development of advanced tools and methodologies in order to pursue these goals, following the vision of a radically different context for policy modelling and simulation, where standardisation and reusability of models and tools,

system thinking and modelling applied to policy impact assessment has become pervasive throughout government activities. GC1 aims at enabling the engagement of all stakeholders (even without expert skills) in a collaborative policy model building, simulation and evaluation process. This implies a great effort to improve state-of-the-art ICT tools and methodologies, in order to guarantee the efficiency of the policy modelling process, in terms of usability and consequently time and cost consumption, and its effectiveness, in terms of reliability and knowledge of both models and policies.
In this context, the research challenges that should be addressed with a long-term perspective include:

- **RC1.1: Integrated, composable and re-usable models** to create more comprehensive and complex models by using smaller building blocks or existing objects/models. This implies both model interoperability and the definition / identification of proper modelling standards, procedures and methodologies.
- **RC1.2: Collaborative modelling** encompassing participation of all stakeholders in policy-making process through the implementation of Internet-based easy-to-use tools for all the levels of skills.
- **RC1.3: Easy access to information and knowledge creation** with a particular focus on elicitation of information which, in turn, during the overall model building and use processes will help decision makers to learn how a certain system works and ultimately to gain insights and understanding in order to successfully implement a desired policy.
- **RC1.4: Model validation** in order to guarantee the reliability of models and, consequently, of policies that are crucial for policy makers who need and use information that results from the simulations to develop more effective policies.
- **RC1.5: Interactive simulation** concentrating on the fact that larger is the model in terms of size and complexity, the larger is the resulting amount of data to analyse and visualize. In particular, this RC refers to the issue of integration of visualisation techniques within an integrated simulation environment, in order to dramatically increase the efficiency and effectiveness of the modelling and simulation process, allowing the inclusion and automation of some phases (e.g. output and feedback analysis) that were not to this point managed in a structured way.
- **RC1.6: Output analysis and knowledge synthesis** refers to output analysis of a policy model and, at the same time, to feedback analysis in order to incrementally increase and synthesise the knowledge of the model (and consequently of the policy).

In particular, **RC1.1** relates to the modelling process, which follows the decision of assessing a certain policy and the assumptions that underline it. The modelling process can be conducted by creating a scalable model from the very beginning (at different organisational levels) as well as by aggregating/re-using and then integrating already existing models or parts of the model under construction. It is by all means important for the modelling process to be carried out in a collaborative way (**RC1.2**), allowing the involvement of different stakeholders (from government to citizens), in different organisations or at different levels of the same organisations. The modelling process is also strictly connected to the availability of data (**RC1.3**), which is needed in order to populate the model and give correct values to the variables included in the model itself.

Moreover, the availability of historical time-series allows for a validation (**RC1.4**) of the model itself. A validation is needed in order to assess the formal "rightness" of the model, before assessing a policy's assumptions. Once the model has been validated, simulations may begin. These simulations conducted interactively by changing decisions (data value) during the course of the simulations themselves (**RC1.5**), may in consequence produce new data or modify existing data over time. This data needs to be analysed (**RC1.6**) in order to assess the validity of the simulations and eventually, provide a feedback either on the simulation process or in some cases on the modelling process. When, ultimately, a satisfying result has been achieved or when a complete understanding (due to feedbacks on RC1.1/RC1.2, RC1.3, RC1.4 and RC1.5) of the system has been gained, the knowledge synthesis allow for updating the data sources (RC1.4) in order to ultimately produce/create knowledge about the system. In results, on a basis of the outcome, the decision whether the certain policy that had been tested should be eventually implemented can be taken.

Here follows an extensive description of the identified sub-research challenges that build up the Grand Challenge of Model-based Governance.

RC1.1: Integrated, composable and re-usable models
This research challenge seeks to find the way to model a system by using already existing models or composing more comprehensive models by using smaller building blocks (sometimes also called "molecules" - which are models themselves) either by reusing existing objects/models or by generating/building them from the very beginning. Therefore, the most important issue is the definition/identification of proper (or most apt) modelling standards, procedures and methodologies by using existing ones or by defining new ones. Further to that, the present sub-challenge calls for establishing the formal mechanisms by which models might be integrated in order to build bigger models or to simply exchange data and valuable information between the models. Finally, the issue of model interoperability as well as the availability of interoperable modelling environments should be tackled.
The current practice in composing and re-using models is still not sufficiently widespread. In relation to Model Reuse, this is mainly due to the fact that little to any repository actually exists. Moreover, the publicly available models are not "open" to modification or re-use. Some modelling environments (or modelling suites) provide some examples and small libraries of ready-to-use models, but in most cases, they are not completely open nor any explanation is provided on how to reproduce them (their structure, parameters, etc.). The Model Composition horizon is even more clouded as the potential advantages resulting from the possibility of composing bigger models from smaller ones have been shown only recently. It is essentially due to the problem of interoperability and integration of different vendors' (thus proprietary) model formats and to the lack of standards allowing to perform composition tasks. Another problem stems from the fact that many models are still too dependent on their implementation methodology. For example, it is quite difficult to compose a model by using an Agent-based model developed in a certain environment or suite with a Discrete-Event model or/and with a System Dynamics one developed in completely different environment/suite. Moreover, model integration is at present almost non-existing. Very few modelling environments/suites provide the import/export functionalities and a standard language for model interoperability is not currently available. Most of the

current practice for data communication or information transfer is performed by means of third party solutions (e.g.: interoperability in most cases is achieved by transferring data via electronic spreadsheets or, only in rare cases, by using Database Management Systems (DBMS) or Enterprise Resource Planning (ERP) systems.

Current research, as well as previous research, has not yet worked on (with the exception of just a few cases) the problem of different models integration. At present, due to the plethora of different modelling/simulation environments/suites many competing file formats exist. It is possible that vendors perceive the modelling practice as a very small market niche (as the users stem mainly from Academia and to a very small extent from private companies where a Decision Support Systems is used, what is more the Public Administration share is negligible) and therefore are reluctant to introduce interoperable features.

Also, current research, as well as previous research, has only recently begun to explore the following issues:

· *Open-source modelling and simulation environments* (there are open environments that are rising in importance in the research community, albeit in most cases they only provide the possibility to implement and simulate a model according to the modelling methodology they refer to).

· *Communication of data among models* developed in different proprietary (or open) environments by depending on third party solutions (e.g.: interoperability is in most cases only achieved by transferring data by means of electronic spreadsheets or, only in rare cases, by using a DBMS or an organisation's ERP).

· *Open visualisation of results* stemming from model simulation (e.g.: online visualisation of simulation results in a browser by interfacing - only in a few cases - the simulation engines, or - as it is more often the case - by connecting to a third party mean, as described in the previous bullet point).

Future research should therefore focus on:

· Definition of standard procedures for model composition/decomposition, e.g. how to deductively pass from a macro-description of models to the fine definition of its building-blocks or molecules (top-down approach), how to inductively conceive a progressive composition of bigger models by aggregating new parts as soon as they are needed (bottom-up approach) or by expanding already existing objects.

· Proposition of a minimum set of archetypical structures, building blocks or molecules that might be used according to the proper level of decomposition of the model (e.g. systemic archetypes, according to the Systems Thinking / System Dynamics approach, might be useful to describe the overall behaviour thanks to the main variables in the system to be modelled at a macro-to-middle level). The procedures to implement, validate and redistribute any further improvement of these "minimal" objects should be investigated.

· Definition of open modelling standards, as the basis for interoperability, that is defining common file formats and templates (i.e.: by means of XML) which would allow the models described by means of these XML files to be opened, accessed and integrated into every (compliant) model-design and simulation environment.

· Interoperability, also intended in terms of Service Oriented Architectures (e.g.: certain stand-alone and always operative models might expose some "services" in order to make available either their endogenous data or bits of information, or some peculiar function or structural part, while some other may request to use those services when needed. In consequence, it creates a need for a definition of model repositories, a list of operative models and the functionalities that they might expose which finally, entails the definition of a SOA among interoperable models).

· Definition and implementation of model repositories (and procedures to add new objects to them), even if they are restricted to hosting models developed according to a specific methodology (Agent Based, System Dynamics, Event Oriented, Stochastic, etc...)

· Definition and implementation of new relationships that are created when two models are integrated. All possible important relationships resulting from a model integration/composition should be identified and eventually included in the new deriving integrated model.

· Input / Output definition / re-definition: the integration of modelling techniques is a pertinent issue in the scope of this challenge. The multi-modelling tools should be, in future, available not only to experts but also to lay users. Moreover, at present, only a few of the actually available modelling/simulation suites are able to provide the possibility to build a model by referring to a different modelling methodology.

Model composition and model reuse are inherent aspects of modelling. Thus, this sub-challenge is related to virtually any research field that needs modelling and simulation.
According to the general need for policy assessment and evaluation, there are some specific issues stemming from the Models Reuse, which are strongly related to governance:

· The public software and / or public data reuse policies: the concept of data and software reuse should be further extended to models reuse. The ones belonging to Governmental Bodies should be freely redistributed inside the Public Administration or made freely available to those PAs that might request their use (redistributing in turn, any eventual modification/upgrade/update).

· The entire shape of the given public policy might not be completely clear to a decision-maker from the start, thus a progressive model description might be necessary. In consequence, decision-makers might find helpful to have at hand several different libraries of building blocks to build their policy from.

Model Integration becomes also an inherent part of the modelling and simulation. There are several aspects of this research challenge that are strongly linked to Governance:

· Different public administrations might have developed different models (different here is understood as a difference in the used modelling methodology or a difference in the level of description of the models) which may be later integrated to build a completely new model;

· Different entities may decide, for manageability purposes in the modelling process, to subdivide very complex and complicated models into smaller and more tractable sub-models, which might be later integrated to build up the originally designed one;

· Also, different institutional levels might find it useful to develop their own perspective of the model (at the level of detail proper to their institutional level), so that it would be easy afterwards to integrate the various “niveaux” into a scalable model

· Cloud computing

RC1.2: Collaborative modelling

This research challenge is related to the process of collaboratively defining and implementing a model, with a particular reference to the public policy modelling. It is, thus, connected with the public aspect of every citizen's life, from a decision maker to an average citizen. Collaborative modelling calls for the definition of the citizen's role in the public policy modelling process (e.g.: the mass participation issues and processes have been already researched in depth by the e-Participation research programs). In order to guarantee participation there are some prerequisites that should be fulfilled:

- All citizens who access ICT services in order to participate should represent the views of communities affected by the given policy.
- All citizens are able to take part in the modelling process via intuitive IT systems that enable them an effective and efficient contribution.
- All citizens possess proper skills (or are assisted) to purposely follow a process of group model-building in order to avoid/abate wrong mental models and thus ultimately reach a shared vision of the problem.

In current practice, collaborative modelling is mainly performed offline; still the rules and guidelines for session processes are not yet sufficiently widespread. In fact, the abatement of wrong mental models and the creation of knowledge from information usually imply the dialogue of people with different views of the problem as well as the need for critical skills. Further to that, the information that occurred in a discussion has to be grounded and definitively transferred to the formal model. Thus, e-Participation might be of help in achieving a critical mass of data and information exchange online but in itself does not solve the problem of mass cooperation and collaboration in a formal modelling process. Even more, the participation in this process entails, at present, a thorough knowledge on modelling processes or tools that an average citizen does not have. Therefore, there is an urgent need for Intuitive Interfaces, Modelling Wizards and guided simplified approaches to modelling.

According to current research, the following issues are being explored:

- Group model building and systems thinking
- Web 2.0 tools for collaboration

As far as future research is concerned, it should thus be focused on:

- Collaborative Internet-based modelling tools, allowing more than one modeller to cooperate, at the same time, on a single model.
- Definition of frameworks allowing even "low-skilled" citizens to provide their contribution (even if in a discursive way) to the modelling process
- Design of more intuitive and accessible Human-Computer Interfaces

This research challenge is connected to the research on Web 2.0 and the next generation web. As far as the Policy Modelling in Governance is concerned, this research challenge bridges the gap between citizens and decision makers. It permits an early stage evaluation of the decision maker mental models by opening a dialogue with citizens and allows for an exchange of perspectives. It finally enables the collaboration in the public policy modelling process with the use of a rigorous and formal scientific process.

RC1.3: Easy access to information and knowledge creation

According to a cybernetic view of intelligent organisations (Sargent, 2008) knowledge supersedes 1. the facts, 2. data (statements about facts) and 3. meaningful information (what changes us), the last also defined as “the difference that makes the difference”. Knowledge most often defined as “whatever is known, the body of truth, information and principles acquired” by a subject on a certain topic. Therefore knowledge is always embodied in someone. It implies insight, which, in turn, enables orientation, and thus may be also use as a potential for action (when we are able to use information in a certain environment, then we start to learn, which is the process that helps developing and grounding knowledge). Two more concepts come after knowledge on the same scale (Schwaninger, 2009), and are Understanding and Wisdom. Understanding is the ability to transform knowledge into effective action, i.e. in-depth knowledge, involving both deep insights into patterns of relationships that generate the behaviour of a system and the possibility to convey knowledge to others, whereby wisdom is a higher quality of knowledge and understanding the ethical and aesthetic dimensions.

The research challenge is related to the elicitation of information which, in turn, during the overall model building and use processes will help decision makers to learn how a certain system works and ultimately to gain insights (knowledge) and understanding (apply the extracted knowledge from those processes) in order to successfully implement a desired policy. It is important to note that other research fields (in particular, ICT disciplines) tend to misuse the word “knowledge” and invert it with ”information”. As already discussed, there is a current misuse of the concepts of knowledge and information.

In current practice, information is drawn from data stored in different types of media (mainly DBMS/ERPs). Web 2.0 has further transformed the way we create data and elicit information from data. Data availability ceased to pose problems as a result of:

- The Internet growth and its uptake
- User Generated Content in Social Networks
- Cooperation of IT systems from different organisations thanks to the Service-Oriented Architectures (even among old legacy systems), which resulted also in private data availability
- Public Administration Transparency and Public Data use/reuse

The knowledge is still mostly created and passed on by formal methods of teaching, even though the advents of the e-Learning field allow for an increased possibility to perform Distance Learning on the Web.

But, since knowledge is developed and grounded by the learning process through action in the environment, the learning in real life comes from committing mistakes. In the field of real life governance, it entails implementing a wrong policy and observing the positive and negative consequences that this policy generates (for example due to a system’s “policy resistance”). At present, thanks to the increasing data availability, information elicitation process is much easier, either by tacitly bringing users (data generators) to provide data in a guided way (according to a pre-set framework for data input) or with a help of a specific process (e.g.: consultations in e-Participation tools).

According to current research, the main focus is put on the Knowledge Management field or also (more properly, as in our case) to the Knowledge Elicitation field. The latter basically encompasses the following steps:

· Data retrieval and extraction

· Data analysis and interpretation (which usually produces information)

· Data/information adaptation and integration (this is particularly the case where information needs to be used in a model)

However, there is still a large field to be explored – the methods of extraction of meaningful information from unstructured sources of data, e.g. when analysing free texts, which applies to all sources of User-Generated Content (forums, wikis, social networks, etc.), where the semantic dimension is essential to derive meaningful information rather than just quantitatively analysing the syntax of text. In general, a lot of data is generated by citizens and particularly by their behaviour online, so that the available aggregated data sets contains information on what a citizen does, what s/he likes, how s/he behaves in certain environments, and so on. This data is considered very valuable both for private and public organisations (even though under privacy restrictions which have to be properly addressed). Also, according to the knowledge creation and development of understanding (regarding a specific system), there is some research currently carried out on how to improve the learning process via the use of e-Learning systems. Yet, what is still missing is the availability of micro-worlds, i.e. complex virtual environments where reality is somehow reproduced and where a decision maker is trained in order to implement his/her strategies and hypothesis and perform what-if analysis without the need to necessarily learn from mistakes in real life.

Future research will thus have to focus on the following issues:

· Information elicitation by analysing and interpreting data, also taking into account the semantic point of view.

· Creation of proper micro-worlds (or ILEs, Interactive Learning Environments), where the acquired information on a certain system is used (by means of actions), and knowledge is developed by observation of the outcomes of the actions. Also, ILEs will have to be integrated into LMS (Learning Management Systems) in order to extend the potential of distance learning practices, eventually also in a cooperative way (mass learning).

· Interoperability of data sources in order to integrate/aggregate different types of data and be able to automatically infer information from more meaningful datasets.

· In view of the "Internet of Things", the provision of "portable" models/tools for citizens in order to gather valuable data based on citizens'' real behaviours. Moreover, these models and tools would enable citizens to check the results of their actions by analysing in real-time the response of the model to the information they are contributing to generate, and thus evaluating the eventual benefits they are receiving from their virtuous behaviour or harm they are creating either to their environment or to themselves (e-Cognocracy).

Proper information acquisition and knowledge development are the key aspect in all research fields, so this RC has a horizontal importance for research in general. According to the general need for policy assessment and evaluation, there are some specific issues stemming from this research challenge, which are strongly related to governance:

· Public data use and thus public information elicitation (by citizens)
· Citizens' behavioural data which are gradually becoming essential for any policy assessment process
· Interoperability of public IT systems
· Creation of a common understanding on a certain system's behaviour (by means of learning) in order to develop a shared vision on the problems that a certain policy might want to overcome

RC1.4: Model validation

Policy makers need and use information stemming from simulations in order to develop more effective policies. As citizens, public administration and other stakeholders are affected by decisions based on these models, the reliability of applied models is crucial. Model validation can be defined as "substantiation that a computerised model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" (Schlesinger, 1979). Therefore, a policy model should be developed for a specific purpose (or context) and its validity determined with respect to that purpose (or context). If the purpose of such a model is to answer a variety of questions, the validity of the model needs to be determined with respect to each question. A model is considered valid for a set of experimental conditions if the model's accuracy is within its acceptable range, which is the amount of accuracy required for the model's intended purpose. The substantiation that a model is valid is generally considered to be a process and is usually part of the (total) policy model development process (Sargent, 2008). For this purpose, specific and integrated techniques and ICT tools are required to be developed for policy modelling.

Model validation is composed of two main phases:

· *Conceptual model validation*, i.e. determining that theories and assumptions underlying the conceptual model are correct and that the model's representation of the problem entity and the model's structure, logic, and mathematical and causal relationships are "reasonable" for the intended purpose of the model.
· *Computerised model verification* ensures that computer programming and implementation of the conceptual model are correct, as well as states that the overall behaviour of the model is in line with the available historical data.

In current practice, the most frequently used is a subjective decision of the development team based on the results of the various tests and evaluations conducted as part of the model development process. Another approach is to engage users in the validation process. When developing large-scale simulation models, the validation of a model can be carried by an independent third-party. Needless to say, that the third party needs to have a thorough understanding of the intended purpose of the simulation model. Finally, the scoring model can be used for testing the model's validity (e.g. see Balci, 1989; Gass, 1983; Gass & Joel, 1987). Scores (or weights) are determined subjectively when conducting various aspects of the validation process and then combined to determine category scores and an overall score for the simulation model. A simulation model is considered valid if its overall and category scores are greater than some passing score.

Typically all above-mentioned approaches are applied after the simulation model has been developed. Performing a complete validation effort after the simulation model has been finalised requires both time and money. However, conducting model validation concurrently with the development of the simulation model enables the model development team to receive inputs earlier on each stage of model developement. Therefore, ICT tools for speeding up, automating and integrating model validation process into policy model development process are necessary to guarantee the validity of models with an effective use of resources.

The scientific corpus of work identifies a large number of subjective and objective validation techniques used for verifying and validating the submodels and the overall model. Sargent (2009) provided a review of the most relevant ones: Animation; Comparison to Other Model; Degenerate Tests; Event Validity; Extreme Condition Tests; Face Validity; Historical Data Validation; Historical Methods; Internal Validity; Multistage Validation; Operational Graphics; Parameter Variability / Sensitivity Analysis; Predictive Validation; Traces; and Turing Tests.
The standard validation generally uses a combination of these techniques.

Future research and practice on Model Validation should explore the following issues:

· In order to speed up and reduce the cost of a model validation process, user-friendly and collaborative statistical software should be developed, possibly combined with expert systems and artificial intelligence.

· Due to the big gap between theory and practice, the considerable opportunity exists for the study and application of rigorous verification and validation techniques. In the current practice, the comparison of the model and system performance measures is typically carried out in an informal manner.

· Complex simulation models are usually either not validated at all or are only subjectively validated; for example, animated output is eyeballed for a short while (see example from Barcelo (2000) of a detailed microscopic traffic simulations). Therefore, complexity issues in model validation may be better addressed through the development of more suitable methodologies and tools.

· Model validation is not a discrete step in the simulation process. It needs to be applied continuously from the formulation of the problem to the implementation of the study findings as a completely validated and verified model does not exist. Validation and verification process of a model is never completed.

· As the model developers are inevitably biased and may be concentrated on positive features of the given model, the third party approach (board of experts) seems to be a better solution in model validation.

· Considering the ranges that simulation studies cover (from small models to very large-scale simulation models), further research is needed to determine with respect to the size and type of simulation study (i) which model validation approach should be used, (ii) how should model validation be managed, (iii) what type of support system software for model validation is needed.

· Validating large-scale simulations that combine different simulation (sub-) models and use different types of computer hardware such as in currently being done in HLA (Higher Level Architecture). A number of these VV&A issues need research, e.g. how does one verify that the simulation clocks and event (message) times (timestamps) have the same representation (floating point, word size, etc.) and validate that events having time ties are handled properly.

Model Validation is connected both to modelling and simulation. According to the general need for policy assessment and evaluation, there are some specific issues stemming from the Model Validation, which are strongly related to governance:

· Reliability of models: policy makers use simulation results to develop effective policies that have an important impact on citizens, public administration and other stakeholders. Model validation is fundamental to guarantee that the output (simulation results) for policy makers is reliable.

· Acceleration of policy modelling process: policy models must be developed in a timely manner and at minimum cost in order to efficiently and effectively support policy makers. Model validation is both cost and time consuming and should be automated and accelerated.

· Composable and re-usable models: a policy model developer deciding to re-use existing models or compose them, stumble across the issue of models' reliability. Model validation can be used for certifying this reliability and creating a database of validated models.

RC1.5: Interactive simulation

As policy models grow in size and complexity, the process of analysing and visualising the resulting large amounts of data becomes an increasingly difficult task. Traditionally, data analysis and visualisation were performed as post-processing steps after a simulation had been completed. As simulations increased in size, this task became increasingly difficult, often requiring significant computation, high-performance machines, high capacity storage, and high bandwidth networks. Computational steering is an emerging technology that addresses this problem by "closing the loop" and providing a mechanism for integrating modelling, simulation, data analysis and visualisation. This integration allows a researcher to interactively control simulations and perform data analysis while avoiding many of the pitfalls associated with the traditional batch / post processing cycle. This research challenge refers to the issue of the integration of visualisation techniques within an integrated simulation environment. This integration plays a crucial role in making the policy modelling process more extensive and, at the same time, comprehensible. In fact, the real aim of interactive simulation is, on the one hand, to allow model developers to easily manage complex models and their integration with data (e.g. real-time data or qualitative data integration) and, on the other hand, to allow the other stakeholders not only to better understand the simulation results, but also to understand the model and, eventually, to be involved in the modelling process. Interactive simulation can dramatically increase the efficiency and effectiveness of the modelling and simulation process, allowing the inclusion and automation of some phases (e.g. output and feedback analysis) that were not managed in a structured way up to this point.

In current practice, data analysis and visualisation, albeit critical for the process, are often performed as a post-processing step after batch jobs are run. For this reason, the errors invalidating the results of the entire simulation may be discovered only during post-processing. What is more, the decoupling of simulation and analysis/visualisation can present serious scientific obstacles to the researcher in interpreting the answers to "what if" questions. Given the limitations of the batch / post processing cycle, it might be advisable to break the cycle and improve the integration of simulation and visualisation. Implementation of an interactive simulation and visualisation environment requires a successful integration of the many aspects of scientific computing, including performance analysis, geometric modelling, numerical analysis, and scientific visualisation. These requirements need to be effectively coordinated within an efficient computing environment. Recently, several tools and environments for computational steering have been developed. They range from tools that modify performance characteristics of running applications, either by automated means or by user interaction, to tools that modify the underlying computational application, thereby allowing application steering of the computational process. However, the development of these tools is still based on model developers needs and therefore a gap still exists between requirements of policy makers and those of developers. In a collaborative modelling environment, interaction is fundamental in order to speed up the process and make ICT tools user-friendly for all the stakeholders involved in the policy model development process.

In the current research, interactive visualisation typically combines two main approaches: providing efficient algorithms for the presentation of data and providing efficient access to the data. The first advance is evident albeit challenging. Even though computers continually get faster, data sizes are growing at an even more rapid rate. Therefore, the total time from data to picture is not decreasing for many of the problem domains. Alternative algorithms, such as ray tracing (Nakayama, 2002) and view dependent algorithms (Lessig, 2009) can restore a degree of interactivity for very large datasets. Each of those algorithms has its trade-offs and is suitable for a different scenario. The second advance is less evident but very powerful. Through the integration of visualisation tools with simulation codes, a scientist can achieve a new degree of interactivity through the direct visualisation and even manipulation of the data. The scientist does not necessarily wait for the computation to finish before interacting with the data, but can interact with a running simulation. While conceptually simple, this approach poses numerous technical challenges.

With regard to future research, interactive simulation plays a crucial role in a collaborative modelling environment. The trade-off between the possibility of enlarging models and including several kinds of data, and the number of people that can understand and modify the model should be deeply analysed. For this purpose, some fundamental issues must be approached:

- Systems should be modular and easy to extend within the existing codes.
- Users of the systems should be able to add new capabilities easily without being experts in systems programming.
- Input / output systems should be easily integrated.
- Steering systems should be adaptable to hardware ranging from the largest of supercomputing systems to low-end workstations and PCs.

Interactive simulation is a particular aspect of simulation. As far as the Policy Assessment in Governance is concerned, this challenge may:

· Accelerate the simulation process: policy makers would be able to analyse simulation results, eventually run new scenarios and make decisions as soon as possible and at the minimum cost.
· Collaborative environment: the bigger is the number of stakeholders involved in policy modelling and simulation process, the greater is the necessity of an interactive simulation environment that allows non-experts to use the model and understand results as well as permit experts to easily understand new requirements and consequent modification.
· Citizen engagement: interactive simulation tools help to engage citizens in policy-making process and to display to them in a simple way the results.
· Data integration: interactive simulation tools allow better managing of a large number and different types of data and information, both for input and output/feedback analysis.

RC1.6: Output analysis and knowledge synthesis
Inputs driving a simulation are often random variables. For example, in a simulation of a manufacturing system, the processing times required at a station may have random variations or the arrival times of new tasks may not be known in advance. In a bank, customers arrive at random times and the amount of time spent at the counter is not known beforehand. In financial simulations, future returns are unknown. Because of the randomness in the components driving simulations, the output from a simulation is also random, so statistical techniques must be used to analyse the results. However, output is obviously related with the input, according to the assumption that it is basically the structure of a system to drive its behavior. In particular, the output processes are often non-stationary and auto-correlated and classical statistical techniques based on independent identically distributed observations are not directly applicable. In addition, by observing a simulation output, it is possible to infer the general structure of a system, so ultimately gaining insights on that system and being able to synthesise knowledge on it. There is also the possibility to review the initial assumptions by observing the outcome and by comparing it to the expected response of a system, i.e. performing a modelling feedback on the initial model. Finally, one of the most important uses of simulation output analysis is the comparison of competing systems or alternative system configurations.
Visualisation tools are essentials for the correct execution of this iterative step. The present research challenge deals with the issue of output analysis of a policy model and, at the same time, of feedback analysis in order to incrementally increase and synthesise the knowledge of the system.

In the current practice a large amount of time and financial resources are spent on model development and programming, but little effort is allocated to analyse the simulation output data in an appropriate manner. As a matter of fact, a very common way of operating is to make a single simulation of somewhat arbitrary length run and then treat the resulting simulation estimates as being the "true" characteristics of the model. Since random samples from probability distributions are typically used to drive a simulation model through time, these estimates are realisations of random variables that may have large variances. As a result, these estimates could, in a particular simulation run, differ greatly from the corresponding true answers for the model. The net effect is that there may be a significant probability of making erroneous inferences about the system under study. Historically, there are several reasons why output data analysis was not conducted in an appropriate manner. First, users often have the unfortunate impression that simulation is just an exercise in computer programming. Consequently, many simulation studies begun with heuristic model building and computer coding, and end with a single run of the program to produce "the answers." In fact, however, a simulation is a computer-based statistical sampling experiment. Thus, if the results of a simulation study are to have any meaning, appropriate statistical techniques must be used to design and analyse the simulation experiments and ICT tools must be developed to make the process more effective and efficient. In addition, there are some important issues of output analysis that are not strictly connected to statistics. In particular, an evident gap in literature regards the analysis and integration of feedbacks in modelling and simulation process. Actually, stakeholders are involved, in a post-processing phase, in order to analysis the results (more often only the elaboration of them) and understand something about the policy. Sometimes they are able to give a feedback on the difference between their expectations and the result but the process is not structured and effective tools are lacking. The development of tools for analysing and integrating feedbacks should be explored in order to enlarge the number of stakeholders involved and, at the same time, to allow efficient and effective modification at each phase of the process, incrementally increasing the knowledge of the model and, consequently, of the given policy.

In current research, main references are Law (1983), Nakayama (2002) , Alexopoulos & Kim (2002), Goldsman & Tokol (2000), Kelton (1997), Alexopoulos & Seila (1998), Goldsman & Nelson (1998), Law (2006).
For output analysis, there are two types of simulations:

- *Finite-horizon simulations*. In this case, the simulation starts in a specific moment and runs until a terminating event occurs. The output process is not expected to achieve steady-state behavior and any parameter estimated from the output will be transient in a sense that its value will depend upon the initial conditions (e.g. a simulation of a vehicle storage and distribution facility in a week time).
- *Steady-state simulations*. The purpose of a steady-state simulation is the study of the long-run behavior of the system of interest. A performance measure of a system is called a steady-state parameter if it is a characteristic of the equilibrium distribution of an output stochastic process (e.g. simulation of a continuously operating communication system where the objective is the computation of the mean delay of a data packet).

A fundamental issue for statistical analysis is that the output processes of virtually all simulations are non-stationary (the distributions of the successive observations change over time) and auto correlated (the observations in the process are correlated with each other). Thus, classical statistical techniques based on independent identically distributed observations are not directly applicable. At present, there are still several output-analysis problems for which there is no commonly accepted solution, and the solutions that are available are often too complicated to apply. Another impediment to obtaining accurate estimates of a model's true parameters or characteristics is the cost of the computer time needed to collect the necessary amount of simulation output data. Indeed, there are situations where an appropriate statistical procedure is available, but the cost of collecting the amount of data dictated by the procedure is prohibitive.

Referring to previous cited works and in particular to Goldsman (2010), future research should further explore following issues:

· ICT tools for supporting or automating output/feedback analysis
· Allowing an incremental understanding of the model (knowledge synthesis)
· Adapting Design Of Experiment (DOE) for policy model simulation
· Use and integration of more-sophisticated variance estimators
· Better ranking and selection techniques

Output analysis is a specific aspect of simulation. According to the general need for policy assessment and evaluation, there are some specific issues stemming from the output analysis, which are strongly related to governance:

· Acceleration of policy assessment process: automated output analysis tools would help policy makers to efficiently and effectively analyse the impacts of a policy even if the large number of simulation data must be taken into account
· Citizen engagement: user-friendly automated tools for output analysis can be offered to citizens in order to share the simulation results and better engage them in policy-making process.

4. CONCLUSIONS: CLOSING THE LOOP ON POLICY MAKING

Contrary to common wisdom, the size of government has not decreased in the course of the 20th century. It has increased continuously until the 70s, and remained stable all through the next 30 years, despite privatisation. We have seen a move from a service provision role towards a regulatory one, often in new areas such as environment, telecom and technology (OECD, 2005). As such, the role of government today is much more about "steering" than about "rowing". The policy-maker's job has become more difficult because of new challenges. First, today's society and economy is more than ever interconnected, unstable, and unpredictable. As Taleb (Taleb, 2008) puts it, we live in the age of "extremistan", a world of "tipping points" and "power laws" where extreme events are "the new normal". There are many indications of this extreme instability, not only in negative episodes such as the financial crisis but also in positive development, such as the continuous emergence of new players on the market epitomised by Google.

The current tools available for policy design, implementation and evaluation are ill-suited for capturing this complex and interconnected nature. Policy models oversimplify reality through a reductionist approach, and work mostly under the assumption of linear developments, predictability and general equilibrium in the long run. Alternative tools, built in the realm of complexity science and enabled by the explosion in data availability, are used only at micro level and for niche areas.

Secondly, the policy issues of today can only be met through the collaboration of all the components of the society, including the private sector, individual citizens and the civil society. Climate change, low carbon economy, respecting consumable resources, sustainability of the health system, all require the proactive involvement and action of all stakeholders, and changes in the daily behavior of citizens. Low carbon can only be achieved if everyone changes the small daily choices on things such as energy consumptions. Preventing sky-rocketing health costs can only be achieved by more healthy behavior by everyone, day by day (some researchers talk about the need for an "empathic civilisation" (Reddy et al. 2007). Top-down policies are unlikely to generate effective impact. As the UK Prime Minister puts it, "the success of the Big Society will depend on the daily decisions of millions of people".

Furthermore, citizens are increasingly expecting to have a voice in complex policy decision-making. Current decision support tools work under the assumption that government have the data, analyses it and then takes a decision. To change this, the emergence of the "Gov 2.0 paradigm" has offered interesting opportunities for citizens to enter into data production, analysis and decision-making, but its impact is far from striking. Too often, gov2.0 collaboration ends in conversations on social networks, blog and twitter but real impact has only been achieved in specific, highly advertised cases which led to high mobilisation. Furthermore, participation in collaborative activities remains limited to those very highly motivated in policy issues.
Finally, the problems we are facing are rooted in the short-term nature of human nature and our difficulty to take due account of long-term impact of our choices. Short-term impacts are more predictable and more visible, but in an increasingly interconnected world the actual long-term impact of the choice can be unintended and opposite to the expectations. In summary, traditional policy making tools are limited insofar as they assume an abstract and unrealistic human being: rational (utility maximizing), average (not heterogeneous), atomised (not connected), wise (thinking long-term) and politically committed. We see now the opportunities for an ICT-enabled policy-making model that takes full account of human nature.

Faced with these challenges, the CROSSROAD project has identified a set of emerging innovative solutions, which will have to constitute the building blocks for the next generation policy-making approach, and Grand Challenge 1 is the core of these blocks. None of these blocks is already mature, but each of them is developing at high pace. The combination of these accelerating trends is likely to achieve an impact far bigger than the sum of its part, if properly integrated and addressed in a strategic perspective.

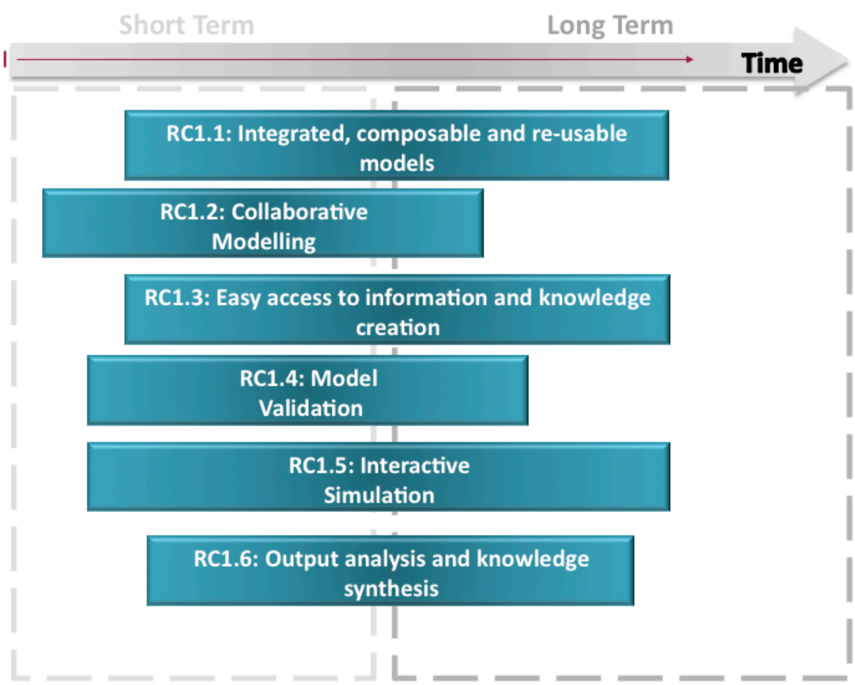

Figure 4: Grand Challenge 1 - timeline

In the vision of GC1, Model-based collaborative governance will be extremely beneficial to all key stakeholders in terms of:

- Implementing more comprehensive and complex models by reusing consolidated basic building blocks, existing models and knowledge on modelling.
- Allowing any stakeholder to contribute to the policy-making process without requiring expert skills.
- Propagating "culture" of modelling towards the ultimate goal of decisions assessment.
- Using already existing knowledge from every level of population and from every stakeholder.
- Describing policy models with a level of detail comparable to the institutional level at which the model itself gets described, allowing to proceed in a process of further detailing by scaling down the various institutional levels of an organisation.
- Providing tools with different levels of usability and difficulty adapted to different users' skills.
- Retrieving information related to user behaviors, thus helping the way in which also soft variables might affect a model.
- Allowing the various stakeholders to access and inspect data from different sources.
- Making the policy modelling process more efficient through the development of interactive decision support systems, which would reduce costs and time consumption.
- Making the policy modelling process more effective, certifying the reliability of simulation results and their usefulness for policy-making process, through the continuous application of model validation at each step of the process, from the formulation of the problem to the implementation of the study findings.
- Making the policy modelling process more effective trough development of ease-to-use and automated tools for feedback analysis and integration.
- Engaging citizens through the development of user-friendly tools for better understanding policies.
- Improving the understanding of models and, consequently, of policies

But what are the advantages of using ICT modeling and simulation tools to support policy making and governance? Or better, why we should urge governments and public administration to widely adopt those tools?
The challenges the governments must face in the modern society are complex. They are characterised by many interactions between different actors, each one having different (and often contrasting) interests. Taking decisions in such a scenario is difficult. Taking the "right" decision is even harder. Example of such complex decisions is the response to the current financial crisis or the management of air traffic during the recent volcanic ash cloud. But we can also consider less disruptive situations: the impact of changes in demographic population on pension systems as well as the impact of the change of the pension system on future generations or, internationally, the impact of development policies on poverty distribution. And finally, the global decisions on environmental policies aimed at reducing the climate change. There are also "ordinary", every day decisions, the public administration take to ensure the better life for their citizens: budgeting projects and initiatives, urban development planning and designing territorial policies. Also those daily decisions may be improved.

In sum, there is an increasing need for a higher quality of the public decision-making. The decisions should be based on better forecast and more accurate evaluation of the impact they have on the different facets of the society. More information and facts are needed in support of those decisions.
What is more, those decisions are today thoroughly scrutinized by different stakeholders (citizens, business, third sector organisations) external to the traditional decision-making apparatus, and this process has steadily increased in the recent years. Nowadays, decision-makers have to face challenges concerning the acceptance of their decisions by those "external" actors, which are more and more informed, knowledgeable, and determined to have their voices heard.
In this view, it is clear that we need better and more transparent decisions, in shorter time, and duly accompanied by sufficiently strong evidences.

But how can governments satisfy the need to have a higher quality of the decision making process, in the complex scenario described above?
In the recent years, the ICT-based tools and practices have emerged in both the Collaborative Governance (citizens' engagement, mass conversation, and collaboration tools enabled by the availability of open data) and Policy Modelling (forecasting, systems thinking, formal modelling, simulation and visualisation) domains. Such tools aim at the common goal of improving public decision-making in the age of complexity; at making the policy-making and governance more effective and more intelligent. They help us through:

- Releasing public data, linking them and producing visual representations able to reveal unanticipated insights.
- Using social computing to promote engagement and citizens' inclusion in policy decision, and exploit the power of ICT in mining and understanding the opinions they express.
- Analysing policies and producing models that can be visualised and run to produce simulations able to show the effects and impacts from different perspectives such as political, economic, social, technological, environmental and legal facets.

Even if a long-term assessment of the benefits that ICT for governance and policy modelling could bring is not yet possible (being the majority of use cases still young, and the general adoption still in its infancy), to look at some of the current practices can significantly shed light on those benefits.
However, as stated above, the number of practices and the state of the technology development which we considered in the domain are not sufficient to draw final conclusions about the benefits of adopting those ICT tools in policy-making process. And no easy "recipes" can be provided.
Nevertheless, looking at the practices and considering the wider online discussion[3] that emerged during the project duration, we can identify **three kinds of potential benefits deriving from a wider usage of ICT for governance and policy modelling**:

1. ***Quality of policy-making***: Using tools for wider engagement of non-governmental actors in the process can radically improve the quality of policy-

[3] on LinkedIn: http://www.linkedin.com/groups?mostPopular=&gid=2594136

making. It allows a wider evaluation of all the interest at stake and reduces the risk of missing some, sometimes crucial, aspects or consequences of the decision. Collective thinking stimulates creativity and generates original solutions of the given issue and provides a suitable environment for rapid evaluation of those alternatives and their feasibility. Last but not least, involving all the interested actors in the decision process allows for a smoother implementation process.

2. ***Speed of policy-making***: More information, especially in visual form can favour a faster decision-making process. Evidence, especially when supported by advanced visualisation has the power to eliminate ambiguity and prejudices related to the decision that should be taken. It allows for concentrating on real issues and provides a better understanding of those issues. Wider consultations can be carried out more easily (and timely) by using ICT-supported platforms. All this contributes to reducing significantly the amount of time needed for the decisions-making process.
3. ***Evidence-based policy decision***: Tools for scenario design, simulation and forecasting allows a better understanding of the effects and consequences of policy decisions, especially when policy models are designed to capture different effects. They enable timely evaluation of alternatives (especially when assisted by models and visualisation techniques). The availability of evidences is important for the daily decisions that constitute the core of government activities, but is particularly relevant for a number of global issues (global warming, financial crisis, epidemiological emergencies), where the importance of the decision is strongly connected to the complexity of the problem at hand (for which, in fact traditional modelling approaches are not anymore adequate, and methodologies based on the "science of complexity" are under development).

To conclude, albeit from an academic/research perspective the advantages of those technologies are quite evident, their adoption in the public policy decision-making process and organisational processes has to be carefully introduced in order to make the changeover as smooth as possible, avoiding friction with the current practices. Also, even though the advantages of such tools seems to be easily understandable, all efforts have to be made to translate them in a form of easy "graspable" from the perspective of policy makers (that not always coincides with the one of the academia/research community).

When involving external actors in the decision process, with the intention of gaining the above-identified benefits, this involvement process has to be carefully designed. Citizens have to feel that they are devoting their time and energy to contribute into decision-making process that is relevant for them ("to strike a chord with the everyday lives of citizens within the community", an expression used in the online discussion). The absence of a strategy may frustrate the participants and produce a counterproductive effect on quality and effectiveness of policy-making.

Finally, the use of those technologies can support long-term planning, beyond the traditional focus on short-term benefits that policy-makers (but also citizens) often chase and respond to. System dynamics tools, simulation, serious gaming can help users to understand, visualise and be accountable for the long-term impact of their action. This is very important in the view of the strong need for long-term reflection and impact evaluation to address the grand societal challenges such as ageing, climate change, poverty reduction, diseases' effect.

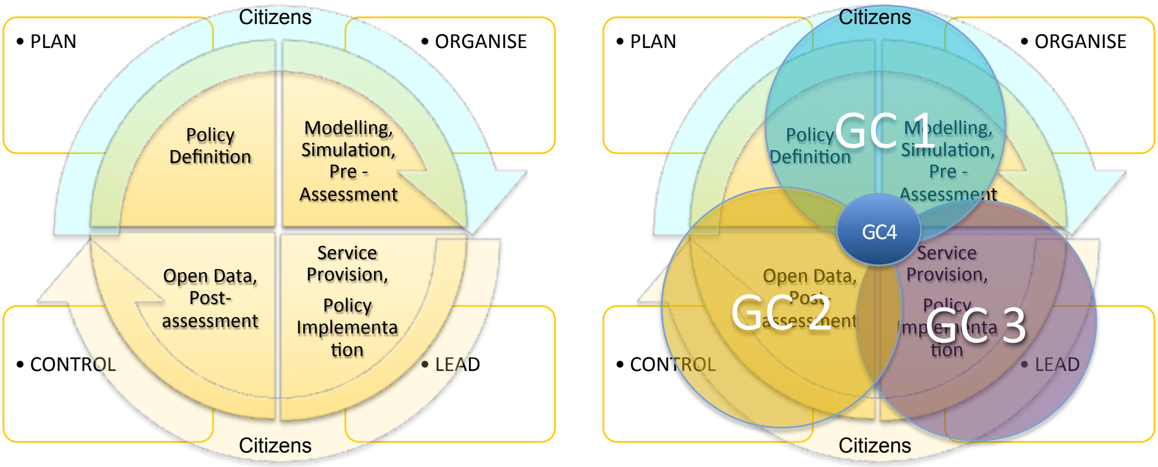

Figure 5: Citizens involvement

Thus not only Grand Challenge 1 "Model-based Collaborative Governance", brings together in a collaboration mode the following actors:

- *Government officials* at all levels that would participate in the model-based collaborative governance, providing crucial data and information and eventually directly being involved in the policy-making process.
- *Policy-makers* that would extend their control on the policy-making process, actively participating in modelling and simulation phases (not just as modellers' customers but as a modellers themselves).
- *Industry*, in particular the ICT sector that would collaborate with Academia in order to develop tools for model-based collaborative governance.
- *Academia and Researchers* that would collaborate with Industry, providing and improving state-of-art methodologies and techniques in order to develop tools for model-based collaborative governance. This would involve researchers from Computer Science, Mathematics and Operations Research, Statistics, Economics and Social Sciences.
- *Citizens and enterprises* that, as the main beneficiaries of developed policies, would be able to actively participate in model-based collaborative governance trough Internet-based collaborative tools.

In summary, our vision for 2030 embodies a radically different context for policy modelling and simulation. Thanks to standardisation and reusability of models and tools, system thinking and modelling applied to policy impact assessment has become pervasive throughout government activities, and is no longer limited to high-profile regulation. Model building and simulation is carried out directly by the responsible civil servants, collaborating with different domain experts and colleagues from other departments. Visual dynamic interfaces allow users to directly manipulate the simulation parameters and the underlying model.
Policy modelling software becomes productized and engineered, and is delivered as-a-service, through the cloud, bundled with added-value services and multidisciplinary

support including mathematical, physics, economic, social, policy and domain-specific scientific support.
Cloud-based interoperability standards ensure full reusability and composability of models across platforms and software.
System policy models are dynamically built, validated and adjusted taking into account massive dataset of heterogeneous data with different degrees of validity, including sensor-based structured data and citizens-generated unstructured opinions and comments. By integrating top-down and bottom-up agent based approaches, the models are able to better explain human behaviour and to anticipate possible tipping points and domino effects.

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