Decision Support Framework Approach

Towards a Decision Support System (DSS) for Public Policymaking

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List of Abbreviations

<Abbreviation>	<Explanation>
CBA	Cost-Benefit Analysis
CSM	Comprehensive Situational Mapping
DSS	Decision Support System
DGMS	Dialog Generation and Management System
DBMS	Database Management System
DoW	Description of Work
DSS	Decision Support System
EC	European Commission
ES	Expert System
GDSS	Group Decision Support System
GUI	Graphical User Interface
ICT	Information and Communication Technology
IDSS	Individual Decision Support System
KBMS	Knowledge Base Management System
MAS	Multi-Agent System
MBMS	Model Based Management System
MCDA	Multi-Criteria Decision Analysis
NSS	Negotiation Support System
OR	Operations Research
PSM	Problem Structuring Method
RDM	Robust Decision-making
Sense4us	Data insights for policy makers and citizens (this project)
SODA	Strategic Options Development and Analysis
SCA	Strategic Choice Approach
SDM	System Dynamics Modelling
SSM	Soft Systems Methodology
VSM	Viable Systems Model
WP	Work Package

Executive Summary

The overall objective of the 'Decision Support' work package (WP6) is to create Information and Communication Technology (ICT) tools for policy makers that assist public decision processes through simulation of policy consequences and possible future scenarios for risk assessment and policy decision evaluation. This leads to the two major objectives of WP6: (Sense4us DoW).

O1. Development of ICT tool for Game theoretic simulation of policy consequences and possible future scenarios. The simulator will visualize and demonstrate to policy makers (actors) what their decisions on certain issues might result in terms of societal impacts.

O2. Development of ICT tool for Decision evaluation of policy options taking into account multiple objectives, multiple stakeholders with differing preferences.

The deliverable (D6.1) presents an integrated approach for public policy modelling, simulation and decision analysis through a Decision Support Framework that provides a set of interrelated policy analysis activities by mapping Operations Research (OR) methods, modelling and simulation techniques to the activities or tasks involved in public policy development (*formulation*[1]):

1. Policy problem structuring and modelling.
2. Design of policy options and Impact assessment.
3. Multi-criteria evaluation of policy options leading to a policy decision.

The Decision Support framework enables policy analysis with respect to generating and comparing policy options. It will result in the implementation of modelling and simulation techniques to design a Decision Support System (DSS) that provides a web-based user-friendly interface, visualization and report generation. The DSS will design qualitative policy models, quantitative simulation models, criteria models and data formats for policy appraisal based on: Group Decision Support, Problem Structuring (Soft OR technique), Game Theory, Negotiation Analysis, Scenario Planning, Sensitivity analysis, Stakeholder analysis, Multi-Criteria Decision Analysis (MCDA) and Preference Elicitation.

The DSS will be developed using modern software technologies to be integrated to the Sense4us demonstration system of the '*Integration of Proof of Concept*' work package (WP7) in the form of two main software modules:

Policy modelling and simulation: A prototype for a web-based modelling and simulation tool. It provides a user-friendly interface that allow users to: (i) edit, store, load, analyze and share policy models; (ii) simulate possible future scenarios and alternative courses of action as scenarios of change and assess the consequences over time; (iii) collect the simulation runs in the DSS database and analyze them to determine which policy-relevant statements can be supported (i.e., determine the considered policy options); (iv) produce visualizations of policy impacts; (v) calculate a relative ranking of all actors (players) involved in a game theoretic decision-making situation based on their utility preferences in the possible outcomes; (vi) engage in a structured goal negotiation for actors involved in a co-decision situation or considering joining a coalition.

[1] Formulation, in general, is a systemized process of standardizing according to a prescribed manner. Policy formulation is the process of standardizing, or rating, the proposed policy as a viable, practical, relevant solution to the identified problem. The draft of legislation is usually considered as the second activity of policy formulation but still out of the study focus.

Policy Evaluation: A web based MCDA tool prototype for decision evaluation of policy options. It provides a structured procedure to define a Common Policy appraisal format and provides a Preference Elicitation method to collect preferential information from the decision-makers and stakeholders about the relative importance of evaluation criteria and their positive/negative preferences of policy options.

The policy consequence assessments and policy appraisal are to be based upon the integration of several methods, exploiting both simulation runs and knowledge discovery in large data sources to gain insight into citizen groups and their preferences, concerns, and opinions. The structuring and modelling of the policy problem is based on the information search results from various online sources using the tools developed within the '*Semantic Search & Consolidation of Linked Open Data*' work package (WP4) and '*Analysis models and tools*' work package (WP5).

This deliverable covers the work done in WP6 during the first 12 months of the project: (i) the adoption of a Policymaking process model and positioning our decision support endeavors within the process; (ii) the selection of OR methods and modelling and simulation techniques for the decision support framework; (iii) the proposed DSS architecture; (iv) Initial prototype development for the simulation tool; and (v) the integration to other work packages.

Detailed explanations and user pilots for the software modules will come in following deliverables, (D6.2 and D6.5 for the *Policy modelling and simulation tool* – D6.3 and D6.4 for the *Decision evaluation tool*).

Introduction

The study of public policy is a systematic, methodological, approach to improving the policymaking process (Dye, 1972; Easton, 1965; Lasswell, 1951, 1956; Nagel, 1990, 1998). Commitment to an evidence-based policy making approach aims to enable well informed policy decisions by putting the best available evidence from scientific research and experts' knowledge at the heart of public policy development and implementation, this attempt extends the idea of governing based on facts (Davies 2004).

The literature responded to the definition of public policy with a number of different definitions. For example, public policy was described as a "purposive course of action followed by an actor or set of actors in dealing with a problem or matter of concern" (Anderson, 1975, p. 3). It was also the "outcome of political compromise among policy makers" (Lindblom, 1968, p. 4). For the purpose of this study, public policy is defined as a purposeful, goal-oriented action that is taken by government to deal with societal problems or to improve societal conditions for the well-being of its population. It results from the interactions, both official and unofficial, among a number of influential actors on the local and national levels forming what is called the "policy network".

Public policy decision-making occurs in a natural context, where the decision-maker is challenged with the process of arriving at a determination of an action (policy) after consideration of alternatives, amongst competing agendas and priorities. The process has some distinguishing features, see (Bero and Jadad 1997): (i) a population-level decision-making context; (ii) explicit justification is required, as policies are formally and informally evaluated by government agencies, by outside consultants, by interest groups, by the mass media, and by the public; (iii) effect of the existing political ideology and governance; and (iv) evidence of systematic reviews, evaluations and performance measurements on public policies and programs is hard to come by.

"*Public policy issues normally are complex, occur in rapidly changing and turbulent environments characterised by uncertainty, and involve conflicts among different interests. Thus, those responsible for creating, implementing, and enforcing policies must be able to reach decisions about ill-defined problem situations*" (Mitchell, 2009). Further, Mitchell (2009) points out that public policy are developed by officials within institutions of government to address public issues through the political process. When it comes to creating public policy, policymakers are faced with two distinct situations. The first situation, and the ideal one, is for policymakers to jointly identify a desirable future condition, and then create policies and take actions to move toward that desired future state, monitoring progress to allow for necessary adjustments. The alternative, and less desirable, situation occurs when policymakers are unable to reach a consensus regarding a desirable future condition. In this later instance, policymakers try instead to move away from present situations judged as undesirable, even though no consensus exists about the preferred alternative.

The aim of supporting public policy decision-making is to develop ways of facilitating policymaking, which create policies that are consistent with the preferences of policy-makers and stakeholders (such as an increase in economic growth, the reduction of social inequalities, and improvements to the environment), and at the same time based on the available knowledge, evidence and information. The availability of new technologies, open governmental data and large-scale data processing techniques provide a huge potential to advance public decision-making processes and information provision for development of pertinent and acceptable courses of action dealing with public problems.

This deliverable provides a theoretical point-of-departures for model-based decision support within policy analysis and the models selected for implementation in the Sense4us project. The approach supports the analysis of both qualitative[2] and quantitative[3] data available for the policy issue, in order to facilitate the modelling process. The research contributes to the use of problem structuring methods based on cognitive maps[4] to model complex strategic decision-making problems in a graphical representation and integrating such maps with modern decision evaluation methods

In order to develop a comprehensive decision support framework for public policymaking, we needed to gain a better understanding of the "how" of the process and the key factors influencing the public policy decision-making processes. This study is guided by a review of the public policymaking process and strategic theory literature. As well as, a review of OR methods and model-based decision support techniques for policy analysis, which revealed a number of research gaps or research problems, to be addressed, in relation to the concept and application of modelling and simulation techniques.

The research question for this study can be formulated as follows:

How to support public policy decision-making processes on the different EU levels in order to create policies that are both evidence-based and consistent with the preferences of policy makers and stakeholders?

This entails three sub-questions:
How to formulate a policy maker's (or a group of policy makers') understanding of a public policy problem situation using an evidence-based approach?
How to design and evaluate alternative policy options?
How to consider decision-makers' and stakeholders' preferences?

Research Methodology:

This research takes a Design Science approach to developing an Integrated Public Policymaking Decision Support System (DSS). "The design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artefacts (constructs, models, methods, processes and systems. In the design-science paradigm, knowledge and understanding of a problem domain and its solution are achieved in the building and application of the designed artefact". The design science methodology is based on the following main activities: (i) Explicate the problem; (ii) Outline artifact and define requirements; (iii) Design and develop artefact; (iv) Demonstrate artefact; and (v) Evaluate artefact (Johannesson, P. & Perjons, E. 2012).

Design Science is a problem-solving paradigm that addresses what are called 'Wicked problems' in information systems research, are characterized by the following properties: (i) a definitive formulation of the problem does not exist; unstable requirements and constraints; (ii) complex interactions occur between the problem and solution domains; (iii) there exists an inherent

[2] The qualitative data refer to text based information on the policy issue, which is simply either a recording of information from the mental database of policy decision-makers, stakeholders and domain experts, or concepts and abstractions that interpret scientific evidence and facts from other information sources.

[3] The quantitative data for the purpose of this study includes statistical data sets for the different variables of the policy problem, in addition to numerical data for linking parameters like associated costs or benefits.

[4] Cognitive maps: these mental models are often referred to, variously, as mental maps, scripts, schemata, and frames of reference. Cognitive maps have been studied in various fields, such as psychology, education, archaeology, planning, geography, cartography, architecture, landscape architecture, urban planning, management and history http://en.wikipedia.org/wiki/Cognitive_map.

flexibility to change design processes and artefacts; (iv) the solution is critically dependent upon human cognitive ability and human social abilities, e.g., collaboration). (Hevner et al., 2004).

Being taking place in the contexts of an EU research project, this research entails collaboration between the researchers and the practitioners and follows a structured and iterative procedure to address an increasingly complex set of problems and scenarios, culminating in a DSS for public policy modelling, simulation and decision analysis.

The following challenges were identified and addressed in the proposed decision support framework:

- The needed level of knowledge about the Policymaking mechanisms, actual processes and contexts on the EU, National and Local levels;
- Contemporary policy domains are very complex, high-dimensional and include a large dose of uncertainty. This complexity requires assessment of existing methodologies and case studies, in order to be able to define a systematic approach to structure policy decision-making problem situation, design policy options and finally evaluate the considered options leading to a policy decision.
- The needed level of Information and evidence to model the policy problem allowing for further analyses.
- The need to exploit Open Data and Big Data sources, find the most relevant data for structuring and modelling of the problem.
- Considering policymakers and stakeholders' preferences, in addition to data mined from social media and online public discussions on policy issues.
- Cumulative learning in digital environments, potentials in policy context, challenges and limitations.
- Interaction of domain expertise with digital processing technologies; dealing with imperfect/uncertain data.

This deliverable is structured as follows:

Chapter 1 reviews the schools of thought on the policymaking process, discusses policy decision-making contexts and presents the adopted policymaking process model.

Chapter 2 surveys the decision support methods for policy analysis, in order to identify the research gaps and areas were further research is needed.

Chapter 3 presents our decision support framework for the public policy making and the selection of OR and decision support techniques.

Chapter 4 provides a background on DSS technologies and presents the proposed DSS structure.

Chapter 5 provides a discussion of the approach. It starts with the role of the model in the policymaking process, then the link to end-users' requirements and the benefits of the approach for Policymakers.

Chapter 6, presents the concluding remarks.

Appendix I provides an illustrative example for structuring of policy problem on the EU level.

This deliverable is an update of D6.1, aimed at addressing the review comments:

1. "WP6 seems to be isolated and not considered in the development of the SENSE4US system."
2. "Work on policy modelling and simulations should demonstrate the value of the various models in the pilots and provide clear explanations to end-users of how these models are constructed and how they work."

3. "Finally, the DOW states that game theoretic studies will be performed, but these have not been mentioned in the deliverables or during the review meeting."

To address point (1) above, section 3 describes the policy modelling in the context of the other WPs in the project. In a nutshell, the information determined by WPs 4 and 5 of the project (social media analysis and open data searching respectively) can provide information to a user when they are constructing a policy model. In addition, the modelling aspect described in this deliverable is a means of organising the information gathered by a user who uses the tools from WPs 4 and 5.

To address point (2) above, Section 5.3 describes the benefit to end users. The key benefit is that the approach advocated in this deliverable allows the user to construct models that may be simulated to evaluate "policy options" – different pieces of proposed legislation aiming to achieve an objective and their impact on different elements and stakeholders. An example of an objective could be to reduce CO_2 emissions in a town, and a policy option to achieve this could be to subsidise bus tickets, intending to reduce traffic density and therefore emissions. D6.2 also contains a description of the operation of the policy modelling tool.

To address point (3) above, section 2.2 contains a discussion of how game theory can contribute to the simulations for evaluating policy options. The game theoretic simulation is a natural extension to causal map simulation. Problem structuring with causal maps acknowledge that different actors can control different variables. A simple scenario is that in a single-user setting of the tool which is the default setting for Sense4us, given that we have more than one actor in the model, and that a second actor has a different goal than the initial one, this actor's response to the first actor can be "emulated" given that the second actor's is profiled and that the goal(s) of the second actor is predicted. Thus, the goal here is to enhance problem understanding and reveal areas of agreement and disagreement among multiple actors who engage in the problem structuring using causal maps. An elaboration of this approach will also be presented in D6.2 and subsequent deliverables.

1 The Policymaking Process

1.1 Schools of thought on the study of public policy

This section communicates the schools of thought on the public policymaking process. Specifically, it informs on the systems and stage heuristics of the policymaking process and reviews the major frameworks for the study of public policymaking.

Easton (1965) envisioned the 'Systems approach' to the study of public policymaking as a framework and model to address the central problem of empirical political study. Easton's Systems approach argues that public policy is the product of a system and that system is a compilation of both intra-societal components (abstract such as: values, issues, theories, models, problems and politics; and concrete components such as stakeholders, policymakers, structures of government, and funds) and extra-societal components and actors within an environment. The compilation of components and actors within the environment, along with the interjected demands, form inputs to the political system (decision-making processes) – which in turn generate outputs (public policy). The effectiveness of the outputs, as measured by feedback, form new inputs that are acted upon by the system.

The Systems approach Easton presented the public policymaking process as continuous, fully integrated, bounded, open, and organic life cycle, when addressing the variety of activities in that life cycle. Easton's system approach provided a method for examining the complex public policymaking life cycle in the fullness of its complexity (role of the framework) and in the narrows of its unique components (role of the model). In order to assess the impact of a policy or an environmental change on the system, we need to reduce the enormous variety of influences into a relatively few, and manageable number of indicators using a model. Several vital considerations are implicit in this interpretation and it is essential that we become aware of them: (Easton, 1965, 17-18)

(1) Such a framework assumes that political interactions in a society constitute a system;
(2) The system must be seen as surrounded by physical, biological, social, and psychological environments;
(3) What makes the identification of the environments useful and necessary is the further presupposition that political life forms an open system;
(4) Systems must have the capacity to respond to disturbances and thereby to adapt to the conditions under which they find themselves.

In Easton's systems approach, the five tenants of a framework are:

(1) Actors; Legislative (organized in parties or committees), Executive (Chief Executive, Staff/Officials, Agencies, Bureaucrats and Civil Servants) and Unofficial (Interest Groups, Political Parties, Think Tanks and News Media). The systems approach, therefore, recognizes the complexity of the involvement of actors, and at the same time establishes a method to analyze the involvement.
(2) Variables; for Easton, the core variables are the inputs, the processes, the outputs, and the feedback. These variables are general categories of the system "that structure, constrain, guide, and influence actions taken by actors.
(3) Units of analysis; the broad unit of analysis in Easton's framework is the whole environment and can also be narrowed to either the intra- or extra-societal components, the abstract or concrete components, the actors, or other specific parts of the environment.
(4) Levels of analysis; the focus of the study on either the "daily activities," "collective-choice," or "constitutional-choice" of the policymaking process.

(5) Scope. For example: In a study, an institution can be a scope, institutions within a state, an entire state system … Also, is affected by the level of analysis.

Anderson (1975) conceptualized policy-making as a series of events occurring in distinct stages and labels these stages 'categories'. This sequential approach helps capture the flow of action in the policy process and defines a 'dynamic' rather than a static system that is highly flexible and open for change. Anderson does not ignore the dynamics of the human interaction in the policymaking process instead; the stages allow the analyst to narrow the focus of study to a certain step in the process. Anderson's framework is not 'culture-bounded', can be utilized for policy analysis in different policymaking systems.

Anderson presented his five stages of policymaking in his book Public Policymaking (1975). Anderson's stages provide grounding for the scientific and the "relevant" approach to the study of the public policymaking process (Anderson, 1975, p. 9). These five categories include: (1) problem identification and agenda formation; (2) policy formulation; (3) policy implementation; (4) policy adoption; and (5) policy evaluation (Anderson, 1975). Finally, Anderson asks the policy analyst to consider new demands for change; does a new problem exist or is the problem solved?

The first framework for the study of public policymaking, the 'Rational-Comprehensive Behavioralist' framework, sought the most logical, rational, and optimal choice for solving a problem from amongst an unlimited set of solutions. The rational-comprehensive framework defined the actors as those involved in the decision-making process. This includes the policymakers, the stakeholders, the policy scientist/analyst, and the public writ large. However, the primary actor is the decision maker. The framework defined the primary variables as the problems facing the decision maker, the entire realm of solutions (which they left unbounded) and their environment. The framework defined the unit of analysis as the arena in which decision-making occurred and the level of analysis as the outcome of the decision maker, who it was assumed used a rational decision-making process and was therefore predictable (Dye, 1972; Easton, 1965; Lasswell, 1951). The scope was also unbounded which led to later developments specifically addressing the scope.

Another framework, the 'Case study', sought to add a more 'realistic' and human component to the decision making process that some early policy scientists thought the Rational-comprehensive Behavioralist framework lacked. It sought to explain the public policymaking process in more broad and general terms because the process itself was not actually rational; the process of public policymaking did not always select the optimal solution, nor did it consider the full option of solutions. Case study maintained the same definitions of actors, variables, units and levels of analysis as the rational-comprehensive behavioralist framework but had a different definition of scope. The scope for the case study was limited to the actors immediately involved in the research, or the variables of interest. (Gall, Borg, & Gall, 1996; Majchrzak, 1984; Weber, 1985).

Lindblom — Incrementalism or Bounded Rationality

Another early and persistent heuristic for studying public policymaking was Lindblom's counter to the rational-comprehensive behavioralist framework termed "Bounded Rationality" known as Incrementalism. Lindblom offers Incrementalism as a decision-making model in which policy change occurs though incremental decisions and not through a rational system. The treatment of the model derived from Lindblom's framework is then described as an adherent to the systems approach of policy analysis. The two core tenants are: (1) policymakers and decision makers disagree on values and policy objectives, and (2) the difficulty of gathering and processing sufficient information to make the "limited comparisons" (Lindblom, 1968).

Kingdon -Multiple Streams – revised Garbage Can model

Kingdon looked at two major pre-decision processes: agenda setting and alternative selection. Kingdon relies on the earlier work of Cohen, March, and Olsen and their development of the Garbage Can model to establish his idea of Multiple Streams. The Garbage Can model describes the decision-making process in organized anarchies[5] with three elements or streams: problems, solutions, and participants (Cohen, March, & Olsen, 1972, p. 16). Kingdon simplifies the public policymaking process to include (1) the setting of the agenda, (2) the specification of alternatives, (3) an authoritative choice among those specified alternatives, and (4) implementation of the decision. Kingdon's Multiple Streams idea, like the Garbage Can model, describes three separate streams (problems, politics, and policy) as flowing separately and when coupled in a policy window[6] forming policy agendas and alternatives for selection. The first two streams listed (problems and politics) go to agenda setting and the latter stream (policy) goes to alternative selections. (Kingdon, 1995)

Lovell's Three-Tier Taxonomy

The Three-Tier Taxonomy, in brief presents three distinct yet related steps to ensure good higher education public policy. These three steps are: (1) A need for the involvement of all stakeholders in the production of higher education public policy; (2) A need for congruence between the proposed higher education public policy and the values of the institutions or systems affected by the higher education public policy; (3) A need for legislative ascription at an appropriate level of administration or management for the higher education public policy to enhance its outcome—void of micromanagement (careful implementation).

The policymaking literature reflects a lack of research involving the quantitative, empirical testing of models exists in the study of public policy. This lack of research is due in large part to the unfinished work of Policy sciences; which are concerned with the contributions of systematic knowledge, structured rationality and organized creativity to better policymaking by testing its frameworks, theories, and models for rigor (Almond, 1966; Blum, 1992; Easton, 1965; Lasswell 1951; Lindblom, 1968).

1.2 Public policy Decision-making

Harris (2012) provides two definitions of decision-making: "decision-making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker"; and "decision making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made from among them". According to Harris (2012), decision-making is a nonlinear, recursive process, that is, most decisions are made by moving back and forth between the choice of criteria (the characteristics we want our choice to meet) and the identification of alternatives (the possibilities we can choose from). The alternatives available influence the criteria we apply to them, and similarly the criteria we establish influence the alternatives we will consider.

Decision theory scholar Herbert Simon defines the decision-making process as having the steps of; intelligence, design, and choice (Simon 1965). At the intelligence step, group members can exchange relevant information. The design stage is the development of potential options or decision alternatives. The choice involves the process of selecting the option determined to be the best. Simon distinguishes two types of rationality in decision-making: substantive rationality (what to choose) and procedural rationality (how to choose), see (Simon

[5] An organized anarchy is an organization which does not meet the conditions for more classical models of decision making

[6] The policy window is an opportunity for advocates of proposals to push their pet solutions, or to push attention to the special problems" (i.e., an opportunity for action). (Kingdon, 1995, p. 165)

1988). From the application point of view, supporting policy planning is in the area of procedural rationality rather than substantive rationality. This is sometimes termed "prescriptive modeling". Furthermore, any policy planning will in theory, at best, lead to a satisficing solution (March 1988), which is a solution path acceptable but not optimal for almost all parties concerned. Public decision making is characterised by conflicting objectives representing the values of different participants with no 'optimal' solution (March 1988).

A similar view on strategic planning for business organisations was developed by Mintzberg (1994). In Mintzberg's framework: during the identification phase, decision makers become aware of the fact that there is a problem, order and combine the information related to the problem. That leads to the development phase which results in one or more solutions to the problem. The design of a long-term policy is a complex and iterative process, which would normally result in one or two solutions for the short term (up to 5 years), and a limited number of options for the long-term (25 years). The next phase is the selection phase, in which all information is coupled and evaluated (Mintzberg 1994).

In order to gain further insight into decision-making processes, it was important to understand the context(s) in which decisions are made. A decision-making context includes all factors within an environment where a decision is made, and is characterised by its complexity. Figure 2 depicts the factors influencing the public policy decision-making:

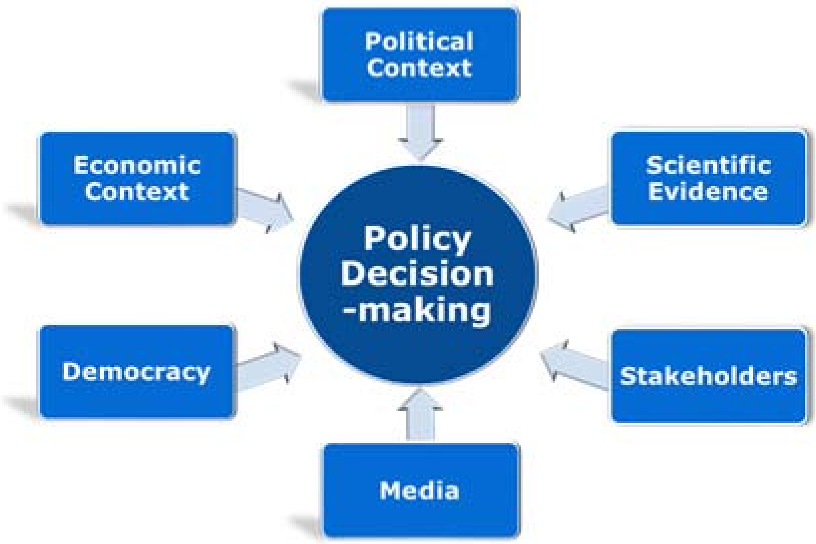


Figure 1 : Policy decision-making context

Jiwani (2010) discussed two distinct decision-making processes that may be worth considering if we are to gain a better understanding of the "how" of policy decision-making at senior levels of government:

(i) The thinking process of decision-making: The process the decision-maker is engaged in when arriving at a determination of an action (policy) after consideration of alternatives. Six themes were identified in the decision-makers' thinking processes: (i) Vision: having a vision and being clear about what the decision-maker is trying to achieve; (ii) Political Astuteness: understanding the political context and linking up policy initiatives (solutions to be processed) to align with the broader government goals and objectives; (iii) Being Tactical: by spotting and seizing opportunities to make change and to move the policy agenda forward in a deliberate and purposeful manner; (iv) Being Strategic: being able to combine policy and strategy to create long-term solutions to challenges, while still meeting the short-term expressed needs; (v) Due Diligence: giving the best advice to the political decision-makers (elected officials), for informed

policy decisions, to make sure that the political leaders clearly understood the implications for the proposed policies, and are fully informed of the anticipated outcomes and the risks involved in moving forward with any policy decision; and (vi) Risk Management: anticipating and managing risks during the policy formulation stage.

(ii) The ethical process of decision-making: The process of arriving at a determination of an action (policy) after consideration of personal values and beliefs and all perspectives to select an option. Themes identified in the ethical process, include: (i) Respect for diverse opinions; (ii) Integrity and Trust: are two extremely important values for senior decision-makers, their team, advisors and others; (iii) Democracy: respecting democracy and the role of democratically elected officials in policy decision-making; (iv) Impact of Policies: Being mindful of the potential impacts (positive and negative) of policy decisions on various stakeholders; (v) Passion for Public Service: Having a passion for public service that allows the decision-maker to make positive changes; and (vi) Intuition about doing the right thing.

1.3 Adopted Policymaking Process Model

In order to position our decision support within the policymaking life cycle, we will introduce a process model for policy-making, which is based on Anderson's stages heuristic and defines the following three stages: the problem identification stage, the policy formulation stage and the policy implementation stage which combines policy adoption, implementation and evaluation of Anderson's model.

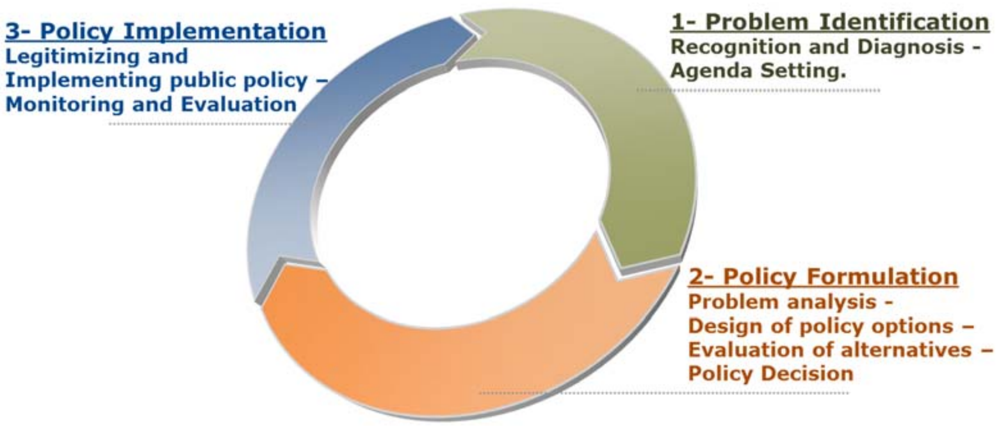


Figure 2 : Policy-making Process Model

1- Problem Identification

i. Recognition and diagnosis

Recognition is the process in which decision makers become aware of the fact that there is a problem and diagnosis is required to order and combine the information related to that problem.

ii. Agenda Setting

Focusing attention, involving interest groups, setting targets, defining and documenting the long-view and/or the short-view of the policy.

2- Policy Formulation (Focus of the Decision Support Framework)

i. Problem analysis

- Identify elements of policy problem: actors, stakeholders, decision variables, parameters, links, goals, risks, limitations and associated technologies.
- Identify problem environment: conflicting goals, inter- and intra-group negotiations.
- Specify decision dynamics: interrupts, feedback loops, delays, and speedups.

- Policy coordination structure: policy formulation for complex problems can be factored into a set of related design sub-problems, each has a 'champion' or 'most interested party'.

ii. Design of policy options/alternatives
Formulate policy proposals through political channels by policy-planning organisations, interest groups and government bureaucracies. Identify the feasible options that will or might lead to desired policy consequences, conduct impact assessments of different policy options.

iii. Multi-criteria evaluation of policy options/alternatives
Compare the feasible options using multi-criteria decision evaluation, since conflicting goals are likely to exist as well as differing acceptance levels for different stakeholders. Capture (or elicit) the preferences of decision makers and stakeholders and frame these and the impact assessments in a common policy appraisal format enabling for use of multi-criteria decision methods in order to gain insights into what options should be preferred or discarded.

iv. Policy Decision
Decide upon policy after evaluation of the options encompassing different viewpoints and perspectives, multiple objectives, and multiple stakeholders using integrated assessments.

3- Policy Implementation

i. Legitimizing and implementing a public policy
Policy is legitimized as a result of the public statements or actions of government officials at all levels. This includes: executive orders, rules, regulations, laws, budgets, appropriations, decisions and interpretations that have the effect of setting policy direction. Policy is implemented through the activities of public bureaucracies and the expenditure of public funds.

ii. Monitoring & Evaluation
Record and control of the implementation. Analysis, evaluation and feedback of the results of implementation.

The model is a systems model in that it is organic, open, bounded and responds to the tenants defined in Easton's Systems approach. The model fits in both the Rational-Comprehensive framework and the Incremental or Bounded- Rationality framework? First, it is an example of the rational-comprehensive framework because it relies on rational discourse and assumes, relating to decision-making, a rational method of selecting the optimal proposal will occur. Second, it is an example of the Rational-Comprehensive model in that the continuous nature of the model allows for a complete discovery of all possible solutions. The model is an example of the Incremental framework in that the identification and development of problems relies on the status quo level of the system and acknowledges the continuous nature of the process, indicating that policy-making is an ongoing, continuous process that requires continuous assessment, evaluation, and reaction.

We can highlight two main types of policy analysis occurring within Policymaking life cycle:

1- Prospective and Prescriptive analysis: ex ante impact assessments and evaluations carried out at the early stages of policy development, in order to answer forward-looking questions concerning policy consequences, and provide prescriptions about policy proposals under consideration. In this activity, scientific knowledge is a central influencing variable in the shaping of ideas, applicable particularly in complex policy problems which incorporate a high level of (scientific) uncertainty.

2- Retrospective analysis, ex post evaluations used in the assessment performance measurement of policies and programs that are already in place.

2 Model-based Decision Support for Policymaking

2.1 OR Methods for policy analysis

In the late 1960s the British central government implemented an OR group with the intention of promoting the use of OR in decision and policy making (Kirby 2000). Common tools for prescriptive analysis in this field are net present value assessments of costs and benefits of potential public policies, as well as cost-benefit analysis (CBA) (Munger 2000). CBA remains the best known method for evaluating public policies among practitioners, despite some recent criticisms (Ackerman and Heinzerling 2004; Adler and Posner 2006; French et al. 2005; Dunn 2012). The criticism focus on how to properly monetize all costs and benefits and on the objective claim CBA approaches tend to have.

Some limitations of traditional OR methods such as linear programming and goal programming include problems with overreliance on quantitative data and the use of an expert mode of analysis, led to the development of problem structuring methods (PSM's) (Franco and Montibeller 2010). See (Rosenhead and Mingers 2001) for an overview of the characteristics of a wide range of PSM:s including; Strategic options development and analysis (SODA), Soft systems methodology (SSM), Strategic choice approach (SCA), Robustness analysis, Drama theory, Viable systems model (VSM), and Decision conferencing. PSM's deal with unstructured problems characterized by the existence of multiple actors, multiple perspectives, incommensurable and/or conflicting interests, and key uncertainties. These methods rely heavily on participative engagement with decision makers, adopting a facilitative mode of engagement, and simple, often qualitative, models (Franco and Montibeller 2010).

The combined use of qualitative and quantitative modelling enriches the analysis and can provide useful insight. There is a lack of an integrated set of procedures to collect and analyse qualitative data or information to create OR models. This causes a gap between the problem and the resulting model. The application of these procedures with textual data to support the modelling process in one or more case studies could lead to specific recommendations to enrich system analysis practice through the development and testing of reliable formal protocols that can be replicated and generalized (Luna-Reyes et al. 2003).

While decision support scholars have recognised the importance of problem structuring for successful decision analytical support interventions, most of them have relied on ad hoc practices for structuring the problem. Supporting technologies for identifying the key variables and links in a complex problem situation may enhance the possibility of reaching a better problem understanding.

PSM's are now widely acknowledged as part of decision analytic tools and there is a growing but still small body of research and practice on how to integrate such methods with other formal and/or quantitative methods" (Tsoukias et al. 2013). There is a considerable range of practical issues in PSMs field which are currently either under-theorized or un-resolved. Therefore, case studies for practical engagements of PSMs with strategic and actual public policy problems is considered to be of great importance in order to identify challenges on how PSMs can be conducted for modelling and analysis of complex problem situations. (Tsoukias A. et al., 2013)

Another important source of policy analysis support was the development of decision analysis in late 1960s (Raiffa 1968), with the use of expert judgment in defining subjective probabilities of outcomes, and further extensions to decision analysis with multiple objectives in mid 1970s (Keeney and Raiffa 1993). "*The main advantage of using a multicriteria method is the richness of results it provides. It generates not only a ranking of decision options, but also the relative global performance of each alternative*", (Montibeller G. and Belton V. 2006).

Multi-criteria decision analysis (MCDA) has been extensively used to support a wide variety of complex decision problems as a tool for evaluating options where decisions involve the achievement of multiple objectives.

A major task in structuring an MCDA model is the definition of which decision alternatives will be assessed by the evaluation model. Traditionally, MCDA has taken an alternative-focused thinking perspective, where the set of options was assumed as given and stable (Roy 1996). However, the identification and creation of new alternatives is certainly one of the most important aspects of any MCDA intervention. No matter how careful and sophisticated the evaluation model is; if the decision alternatives under consideration are weak, it will lead to a poor choice (Brown 2005). Thus, support in the generation of feasible alternatives is important for a decision support framework. Most decision problems discussed in the literature consider the set of alternatives on which they apply as “given”, while in practice, policy makers rarely come with established alternatives. There is a lack in operational and/or formal methods for addressing the cognitive activity of designing policy options or alternative actions to be taken. Actually, most of policy making is about designing or constructing alternatives in a process aiming to support forward looking thinking and design of innovation policies (Franco and Montibeller 2011).

Tsoukias A. et al. (2013) introduced a new category of decision analytics labelled ‘’Policy Analytics’’ which aim to support policy makers in a way that is meaningful (in a sense of being relevant and adding value to the process), operational (in a sense of being practically feasible) and legitimating (in the sense of ensuring transparency and accountability). Decision analysts need to draw on a wide range of existing data and knowledge (including factual information, scientific knowledge, and expert knowledge in its many forms) and to combine this with a constructive approach to surfacing, modelling and understanding the opinions, values and judgments of the range of relevant stakeholders. The term ‘’Policy Analytics’’ is therefore used to denote the development and application of such skills, methodologies, methods and technologies, which support relevant stakeholders engaged at any stage of a policy cycle, with the aim of facilitating meaningful and informative hindsight, insight and foresight. (Tsoukias A. et al., 2013)

Public policy problem situations are often ill-structured decision problems with multiple, unclear and/or conflicting objectives. That makes modelling of such problems as optimization models, maximizing or minimizing specific economic objective functions subject to constraints, an oversimplification of the problem. Simulation of the complexities involved may allow evaluation and observation of global behavior and system dynamics that cannot be analytically predicted. Simulation, in comparison to optimization tries to answer questions of the form ”what if?” instead of “what is best?”. If the problem is not accurately understood and stated, it is hard to recommend policy alternatives addressing the underlying problem situation. For that reason, a large part of the decision support activities occurring within a policy cycle is about understanding, formulating and structuring “problems”. The accuracy of the definition of the problem allows identifying appropriate policy alternatives or evaluating the success of an existing policy. Thus, problem structuring is a key element of the public policy analysis process.

Robust decision-making (RDM) methods seem most appropriate for public policy analysis, which is characterized by deep uncertainty, existence of rich set of decision options and sufficient complexity of the decision challenge that decision makers need simulation models to trace the potential consequences of their actions over many plausible scenarios. An RDM analysis typically creates a large database of simulation model results, and then uses this database to identify vulnerabilities of proposed strategies and the tradeoffs among potential responses and represent a multiplicity of plausible futures. Two key items in this toolkit are Exploratory modelling and Scenario discovery (Bankes, S.C. 1993, Bryant and Lempert 2010).

The long-term implications of policy making imply the need to consider the range of possible futures, sometimes characterized by large uncertainties and calling for the development of future scenarios. Scenario planning, a widely employed methodology for supporting strategic decision making, helps decision makers to devise strategic alternatives (policy options) and think about possible future scenarios. "Scenario-driven planning closes the gap between problem framing which depends on qualitative analysis and problem solving which depends on quantitative analysis by blending qualitative and quantitative analytics into a unified methodology" (Georgantzas & Acar, 1995). The analysis of change scenarios allows the design of strategies to take place in spite of the messiness of the situation (Schoemaker, 2002). Further research on how scenarios are constructed and how to address issues of robustness in scenario planning is needed.

2.2 The 'Game theory' foundations and application in policymaking

Game theory is a method of decision-making that ranks the relative utilities of the available courses of actions by quantifying possible outcomes, from which participants are able to choose an optimum course of action. Further, game theory allows for a relative ranking of all the players involved. The basic premise of game theory is that each player has utility preferences in the possible outcomes. Analysis of these utilities helps predict which course of action each competitor is likely to choose—assuming that each player is rational and hence likely to choose the course of action providing the greatest utility.

Roth and Erev (1998) said, "Game theory has traditionally been developed as a theory of strategic interaction among players who are perfectly rational, and who (consequently) exhibit equilibrium behavior" (p. 1).

The basic game theory, as stated by Von Neumann (1944), is the zero-sum game. This game is a two-person game in which each player competes directly against the other for payoffs established in advance of the contest. Each player determines the payoffs from his choice of strategies and tries to maximize his or her gain. What each player gains results in a corresponding loss for the other participant. In this basic game, the net gain does not increase; the "pie" remains the same size. The Nobel Prize winning economist, Nash (1951) theorized and proved that these games reach equilibrium; each player utilizing a dominant strategy to reach his maximum or maximizing his minimum gain. He introduced the idea of a "Nash equilibrium"—a situation in a multiplayer game in which each player's position is optimized with respect to the others'.

Obviously, the real world is seldom comprised of issues that (a) involve only two parties and (b) are zero-sum games. Most issues involve multiple players and the payoffs are usually determined to some extent by what action the players take. Zagare (1984) called the two man zero-sum game a "degenerate case along the continuum of conflict" (p. 40). More realistically, competitors face many different entities and do cooperate occasionally. Therefore, to better approximate real life, theorists advanced to the non-zero-sum games. Non-zero-sum games assume that value is created. The inclusion of more players greatly increases the difficulty of evaluating expected utilities. Von Neumann and Morgenstern addressed this difficulty by developing "a characteristic function" (Von Neumann & Morgenstern, 1944, p. 241) to simplify representation in n+ person games and address coalition building. The characteristic function extracts the essence of the game (the core), the factors or conditions germane to coalition forming.

Brandenburger and Nalebuff (1995) provided a useful tool for identifying the various courses of action leaders have available. They advocated using the acronym PARTS (Players, Added values, Rules, Tactics, and Scope).

Players. In a political environment, players include involved parties that have strategic interests involved.
Added values. “Added values are what each player brings to the game”. There are ways to make yourself a more valuable player; one-way to raise value is to make an opponent uncertain how much the other party will fight over an issue.
Rules define how the game is played. Rules give structure to the game. Rules might arise from law, custom, practicality, or contracts.
Tactics are moves used to shape the way players perceive the game and hence how they play. Sometimes, tactics are designed to reduce misperceptions; at other times, they are designed to create or maintain uncertainty.
Scope describes the boundaries of the game. It is possible for players to expand or shrink those boundaries. (Brandenburger & Nalebuff , 1995, p. 57).

With respect to the kind of decision support system outlined herein, a “game” is considered to be a rule-based interaction between actors, which is a common way of exploiting game theory in distributed artificial intelligence or multi-agent systems. Given that the outcome of a policy option is dependent on more than one actor, and that these actors may not share interests or is at least not willing to “pay” more than needed, game theoretic concepts can be used when simulating in a causal map where different actors is in control of different variables.

3 The Proposed Decision Support Framework

Figure 3 presents the decision support framework with the steps of the policy formulation stage of the adopted policymaking process model, as the tasks to be performed by WP6, the framework shows the assignment of tasks to the 'Policy modelling & simulation' and the 'Policy Evaluation' software modules, also the decision support methods or technologies used for each task. Finally the results from WP4 and WP5 are incorporated into the framework as inputs to support structuring and modelling of policy problem and multi-criteria evaluation of policy options.

In Figure 3 the main activities are described along with the underlying methods and the tools to be developed for the Sense4us toolset.

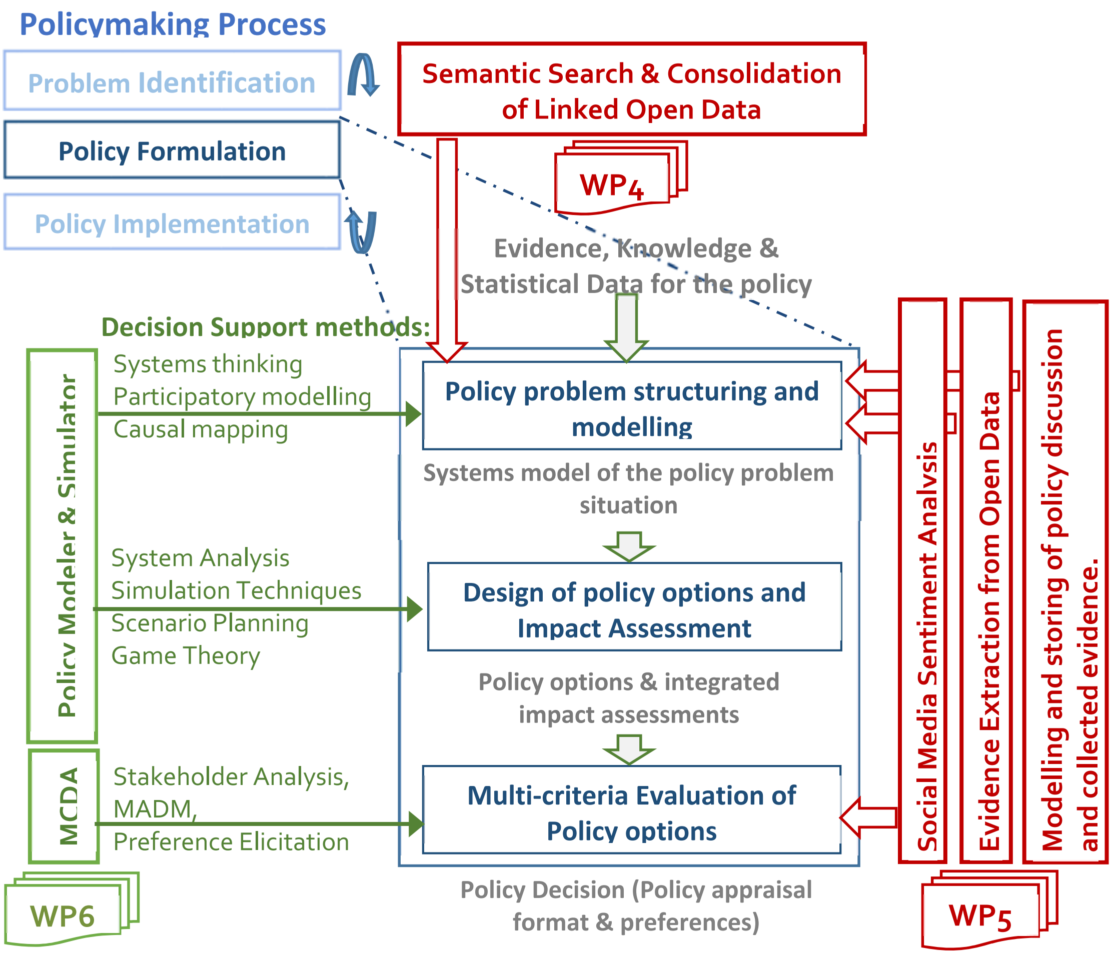


Figure 3 : Sense4us, WP6 Decision Support Framework

The framework contains a set of interrelated policy analysis activities, listed below, with the decision support methods and techniques to be employed in each activity:

(1) Policy problem structuring and modelling – Systems thinking and systems dynamics, Problem structuring using Causal maps (Based on Acar's causal mapping method – soft OR modelling), and participatory modelling.

(2) Design of policy options and Impact assessment – Dynamic simulation based on the analytical capabilities of the causal mapping method, Scenario Planning, Game theory and Negotiation analysis.

(3) Evaluation of policy options and policy decision– using MCDA, Stakeholder analysis and preference elicitation methods.

Furthermore, channels conveying data or objects are related to activities. Two types of channels are: Input/output (double arrow): describes what knowledge or object is input/output of an activity; and Resources (single arrow): describes what techniques and tools are used to support an activity.

It is worth noting that the framework does not prescribe a sequential way of working per se, but instead presented as logical grouping of the work done. Thus, the arrows in Figure 3 should not be interpreted as temporal ordering but as input-output relationships. Indeed, the policy analysis process is recursive. It is common in practice and methodologically possible to return to previous performed activities and iterate them in order to elaborate on policy analysis considering all relevant variables and all possible solutions.

The integration to WP4 is to support the policy problem structuring and modelling by identifying relevant model components (actors, policy instruments or policy impacts) from concepts resulting of linked open data search, investigating the interlinking between two concepts and exploiting open and big data to find the most relevant data sources. This integration allows modelling of the linked open data search results.

The integration to WP5 tools supports the problem structuring and the definition of a criteria model for policy decision evaluation with evidence extracted from the online public discussions about policy in social media and from the vast amounts of open data from WP4 that will be made available to WP5 data analysis mechanisms and prediction models. This will help to engage citizens in sharing knowledge and expertise by showing them where their input has had an effect on policy decision-making. The sentiment analysis provides insights into the public opinion regarding the impact of the policy with respect to specific criteria.

3.1 Policy Problem Structuring and Modelling

Problem Structuring aims to enable a better understanding of unstructured problems characterized by the existence of multiple actors, multiple perspectives, in-commensurable and/or conflicting interests, intangibles and key uncertainties.

The use of cognitive or causal maps is among the early approaches to enable for problem understanding, originally intended for representing social science knowledge, see (Axelrod 1976). A causal map is a directed graph where nodes represents societal concepts or variables (such as: public funding, economic growth rate, emission rates…etc.) and links represent causal connections. Two nodes (e.g., car traffic and emissions) and a link from the former to the latter would then mean that there is a cause-effect relationship, negative or positive. Multiple perspectives of the problem from different actors can be represented and debated for improving the policy-makers' understanding of the problem situation and sharing it with associates. Several "dialects" of cognitive maps have emerged, which share focus on the qualitative aspects of problem structuring, see, e.g., (Acar and Druckenmiller 2006).

Belton and Stewart (2010) identified the main phases of the process of applying problem structuring in a MCDA context using a number of case studies. They emphasized that Causal mapping was applied extensively for the representation of issues, jointly or separately for different stakeholders. Such maps can be analysed in order to identify, inter alia:

- Nodes which have outgoing influence or causal arcs, but no incoming arcs: these suggest driving forces which may be external constraints or action alternatives.
- Nodes which have incoming influence or causal arcs, but no outgoing arcs: these suggest extrinsic goals or consequences, which may be associated with ultimate performance measures or criteria of evaluation.

- Closed loops of cause–effect relationships (arcs): action may need to be taken to break such loops, especially of “vicious” rather than “virtuous” cycles. (Belton and Stewart, 2010).

In this section, we will outline how knowledge of experts can be represented as causal maps, and how the graphical structure of causal maps can be quantified and used for simulation.

In the selected approach, problems are seen as deviations from a goal or a standard, those deviations originate in a change that propagates itself through causal connections, while a policy option is seen as a purposeful action for change that can affect these deviations.

The “Causal mapping and situation formulation”, method developed by Acar, W. (1983) is the method used for problem structuring and modelling. The method is an adequate vehicle for capturing and representing the main elements of a social system and tackling it analytically. The primitive elements used in the causal mapping method are: Independent variables (sources of change), dependent variables (middle and outcome variables), change transmission channels (causal links), change transfer coefficients, time lags, minimum thresholds , status-quo level of the system (initial values for the problem’s key variables with zero initial relative changes) and the current state of the system. Actors are represented as coupled with the variables representing the system components. Goals for different actors of the problem can be defined, in terms of a goal vector (one-dimensional or multi-dimensional) showing the targeted change(s) in outcome variable(s) relative to their status-quo values, it can be, in order to facilitate group decision making and negotiation analysis.

The design conditions satisfied by the Causal mapping method include:

(i) capturing the problematic situation which provides the problem contexts;

(ii) identifying key variables, distinguishing between controllable (decision) variables and uncontrollable variables, acknowledgement of existence of key actors and tracking their objectives;

(iii) clarifying implicit assumptions about casual relationships among large tangles of interacting elements (objectives, variables, qualitative factors and constraints);

(iv) using a graphical support (representation), to be a dialectical process for analysing assumptions and scenario implications;

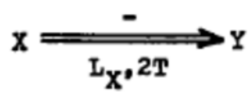
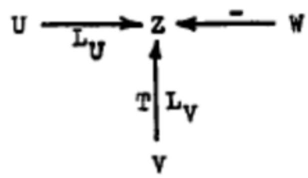
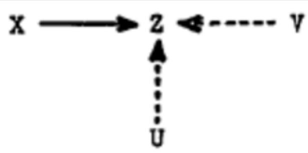
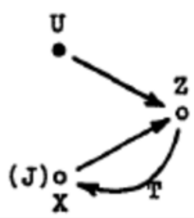
(v) being simple, robust, easy to control, adaptive, easy to communicate with and as complete as possible;

(vi) hosting and relating concepts of strategic consulting, such as: positioning, vulnerability, competitiveness, strategy, tactic … etc; and

(vii) conceptualization: employing OR concepts such as notions of “feasibility”, “probability”, “cardinal utility”, “optimality” and “linearity assumptions”. (Acar, 1983)

Table 1 shows a step-by-step procedure for graphing a problem situation manually, with the right most column providing examples and illustrations. For more details, see (Acar, 1983).

Level 0 – Surveying – Checklist model		
Stage 1: Elements	1- The social system under consideration and its boundaries.	**City AB**
	2- Actors: Persons, groups, or schools of thought involved in the system as single entities.	Decision maker, Governor Local Elected officials Business representatives
	3- Variables or factors characterizing the situation.	Examples: Public Facilities - Energy cost

Stage 2: Distinction	1- Independent variables (origins - sources of change / Middle and outcome nodes (dependent variables).	Example: Investing on improving city physical image
	2- Controlled or decision variables / Uncontrolled variables or unforeseen changes.	Controlled: involvement of business Uncontrolled: Weather
	3- Variables (quantitative or meaningful to be increased-decreased). 4- Restrictions (qualitative factors).	Restriction Example: Tax returns greater that expenditures on business services
Level 1 – Structuring – Qualitative model		
Stage 1: Protocol (Operational definitions**)**	1- Identify origins under your control (your decision variables)	
	2- Identify origins under other actors' control (decision variables of other actors)	
	3- Identify the uncontrolled origins.	
	4- Factor sheet: short names of all variables and factors.	
Stage 2: Structure (Change transmission channels and restrictions**)**	1- Full channel: double arrow from upstream variable X to downstream variable Y, if X is sufficient to induce change in Y. Place a "-" sign next to the arrow if changes in these variables are not in the same direction. If a minimum change in X is required to be transmitted to Y indicate that by a threshold level L_X If the change transmission is not instantaneous, indicate the time lag of change transfer in terms of number of time periods T.	
	2- Half channel: single arrow from variables U,V,… to variable Z if change in any of these variables is necessary but not sufficient to induce change in variable Z. Indicate sign, min. threshold and time lag as above.	
	3- Restrictions: dotted arrow to a variable indicates a qualitative constraint on the transmission of change from any link to that variable.	
	4- Complete the network: represent all quantified variable or factors by nodes, blacken all uncontrolled origins, if an origin is a decision variable of some actor J label it with (J).	

Level 2 – Graphing – Quantitative model		
	1- Improve the structure resulted from level 1 by specifying the proportionality ratio of the change transmitted by each channel.	
	2- Goal vector: list all variables in which you have particular interest write the desired percentage of change for each variable.	
	3- Indicate if internal or external problems need to be encountered to achieve your goals.	

Table 1 : Acar's casual mapping: A step-by-step procedure for graphing problem situation

The method supports three classes of analyses, see (Acar 1983) for detailed description:

1- Backward Analyses: Clarifying, testing and reassessing assumptions about the web of cause-effect relationships underlying the situation, to reveal areas of agreement and disagreement among multiple actors. Once negotiated, the set of assumptions becomes the explicit foundation upon which the choice problem is defined. This foundation would enable policy options to be appraised. It can be divided into: (i) Major assumptional analysis (validity of the major aspects of the graph elements and relationships); and (ii) Minor assumptional analysis (validity of detailed qualifications and quantifications of the graph).

2- Structural Analyses: It includes: Graph scope, connectivity analysis, reachability analysis and Goal comparative analysis (qualitative and quantitative).

3- Forward Analyses: Implications of change through generating change scenarios and simulating the transfer of change. It includes:

(i) Scenario simulation: running change scenarios on the graph – transfer of change from origins throughout the network (see section 3.2);

(ii) Goal negotiation analysis: Goal feasibility and compatibility (existence of a scenario to realize a goal or goals jointly); and (iii) Effectiveness and efficiency of a decision option (change scenario) – expression of outcomes in comparison with objectives and relative to change needed at origins.

The following inputs are considered to support constructing a causal diagram for the policy problem situation:

1- Expert or domain knowledge of the policymaker, the policy analyst or a domain expert.
2- Text analysis and Natural Language Processing (NLP) techniques, to identify key variables (entities) and derive inferences about the influences among key variables from verbal descriptions of the problem. Key information sources for a public policy problem include: (i) Public policy documents, evaluations and impact assessment reports from governmental institutions' websites; (ii) Research and Assessment reports from industry, research institutions and NGOs; and (iii) Published literature (mainly from refereed journals).
3- The use of participatory exercises to develop a pool of variables that can be used to model the policy problem, identify multiple users' subjective views representing different vantage points and engage in a synthesis analysis of different views of the links and dependencies, in order to develop a joint model for the problem.
4- Results of the Linked Open data search tools.

5- Evidence extracted from the online public discussions and open data from WP4 that will be made available to WP5 data analysis mechanisms and prediction models.

The use of these cause and effect diagrams is highly valuable to capture and represent explicitly the decision-makers' understanding and subjective view of a public policy problem, and consequently evaluation criteria for the decision options can be identified or derived from concepts of the causal diagram. To deal with the dynamic complexity inherent in social systems and to infer dynamic behaviour, quantitative simulation is required (Senge, 1990; Sterman, 2000). Therefore, and particularly in those situations where it is important to understand the interactions among the variables over time, the value added by Causal/cognitive maps can be significantly increased if they are complemented with simulation modelling.

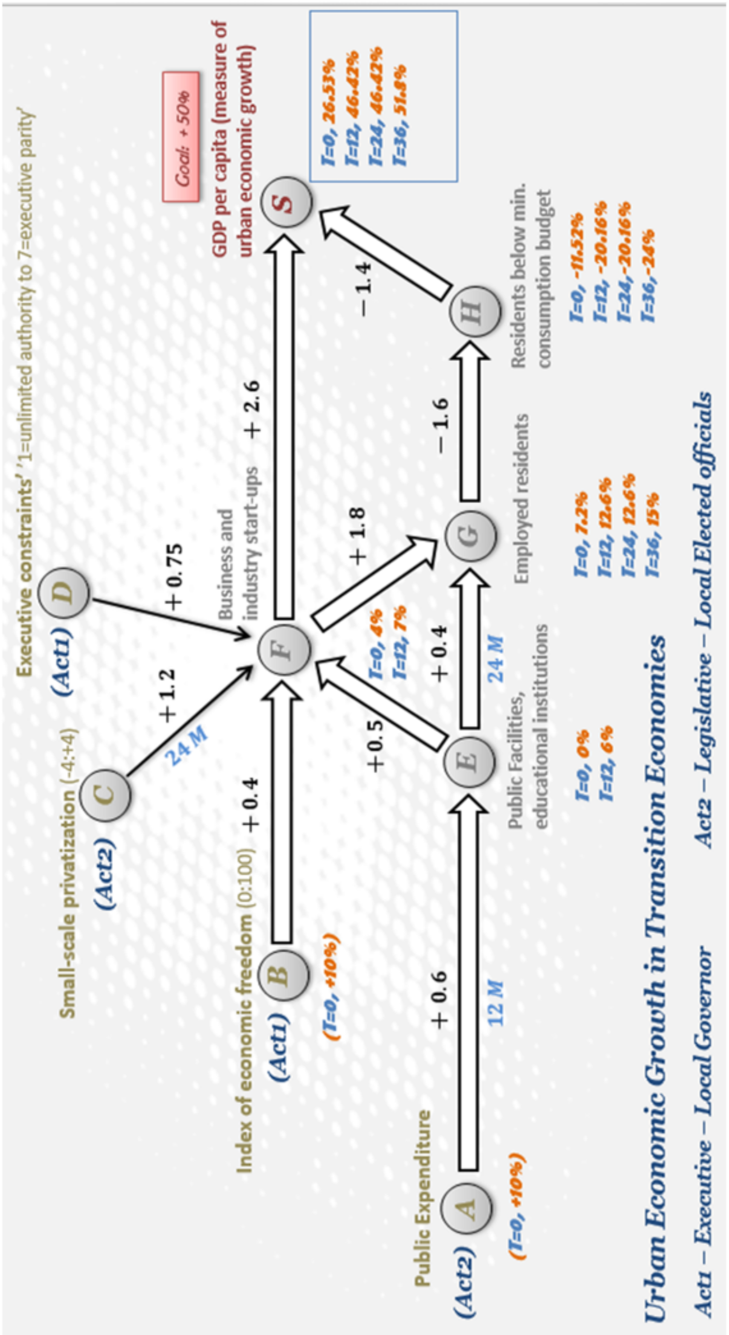


Figure 4 : Example for a Causal mapping representation of a Policy Problem

Figure 4 shows an illustrative example for structuring of a problem in terms of a quantitative causal mapping model, including representation of actors. It also defines a change scenario of an increase 10% in variable A and an increase 10% in variable B and shows the simulation results. It is a hypothetical scenario developed for demonstration purposes.

We need to be careful with the quantification of the model in order to develop a reliable simulation model of the problem (Harris 2012). We suggest the calculation of interval estimations of the regression coefficient for all linked variables to guide the quantification of change transfer coefficients, the calculation is carried out based on time series historical data, using simple or multiple linear regression, according to nature of the link. Also, it is important here to avoid using qualitative (soft) variables, as much as possible, by replacing them with relevant quantitative indicators or indices to minimize the subjectivity associated with defining value scales for such variables.

3.2 Design of Policy Options and Impact Assessment

Dynamic simulation models are mathematical models that consist of equations describing dynamic change. If system state conditions are known at one point in time, the system state at the next point in time can be computed. Therefore, dynamic simulation allows to observe the behaviour of the modelled system and its response to interventions over time.

The "Causal mapping and situation formulation" method is a powerful tool for scenario-driven planning. A base line scenario is defined with initial values for the problem's key variables with zero initial relative changes. A policy proposal (action alternative) is represented by a scenario of change from the status-quo level of the system. The desired state of the system is represented by a goal vector (targeted relative changes in outcome variables compared to the base line scenario). The casual mapping model allows change scenarios to be run on the graph. The method allows triggering change by a 'Pure scenario', a single change at one source, or a 'Mixed scenario', change in several sources all at once or with a time lag (For example: A goal vector with k nonzero components, it would take a mixed scenario of up to k pure scenarios to realize it). In addition, it defines 'Willed scenarios' against 'non-willed' (environmental) scenarios.

The rich computational semantics of Acar's causal mapping support automated modelling and simulation in ways that other varieties of cognitive mapping approaches do not (Druckenmiller and Acar, 2009). The method enhances the causal mapping with rich computational properties by including indications not only of the directions and signs of the presumed causal influences, but also of their intensities, minimum threshold values and the possible time lags. Thus, it results in a mathematical model that identifies influences and trends among a certain set of the problem parameters by building on reliable historical data to produce forecasts.

Graph change analysis allows us to investigate the dynamic consequences of entering a change in one of the graph origins, thus simulating the propagation of change throughout the causal map. The simulation is run upon the policy problem model (causal map) defined at the previous activity, whereas the set of goal variables and their target values are used for impact appraisal, i.e., defining efficiency and effectiveness of a scenario for fulfilling the objectives. Based on the simulation results unsatisfactory scenarios are filtered out, while efficient and "interesting" scenarios are suggested as policy options for further evaluation.

The simulation engine should implement the underlying computational algorithms of causal mapping. Additionally, the visualization component should be extended to display simulation results for a given scenario. The tool for scenario generation should implement particular robustness analysis mechanisms and scenario discovery processes to allow the

identification of vulnerabilities of proposed policy options by specifying some performance metric and applying statistical or data mining algorithms to explore the space of implemented scenarios. The simulation tool should provide visualizations of the scenarios and a way of sorting them according to the impact assessments.

The approach allows for representation of multiple actors involved either in a competitive or a co-decision legislative procedure. Each actor may have control over one or more of the controllable decision variables, allowing him to trigger change in order to achieve the targeted impact. This allows policy makers to shape policies that takes into account their competitors' likely responses when deciding on their own actions, by quantifying and estimating utility each actor has in the alternative courses of action (based on costs and benefits), while accounting for the possible alternative futures.

With respect to *Game theoretic simulation*, problem structuring with causal maps acknowledges that different actors can control different variables. A pure change scenario is analogous to that one actor impose a change on one variable that the actor controls. Given that we have more than one actor in the model, and that a second actor has a different goal than the first one, this actor's response to the first actor can be "emulated" given that the second actor's preferences is profiled and that the goal of the second actor is predicted. Thus, when two or more actors in control of different variables of the map is expected to make conflicting decisions, this is called a "game" and given that we can anticipate how these actors will behave we can conduct game theoretic simulation.

3.3 Multi-criteria Evaluation of Policy options

In the context of policymaking the decision maker is confronted with a huge and complex amount of information, usually of a conflicting nature and reflects multiple interests, consequently the use of MCDA can be very valuable to assist decision makers organize such information in order to identify a preferred course of action. It allows decision-makers to judge the performance of alternative policy options using different measures and from stakeholders' different points of view of what represents a positive or negative policy impact. Furthermore, integrating MCDA to dynamic simulation of policy consequences reveals key uncertainties related to evaluation criteria of policy options to be implemented in the future as well as their importance to stakeholders.

The proposed MCDA approach provides a structured procedure for evaluation of policy options. It will result in designing criteria models and data formats for policy appraisal, based on Multi-attribute decision making (MADM), utility estimation techniques, Stakeholder Analysis and Preference elicitation. A decision analysis toolbox will be designed taking into account the many potential decision-makers and stakeholders with differing powers, interests and preferences.

According to the EC report 2.10.2013 COM (2013), evaluation is a key Smart Regulation tool, helping the governmental body to assess whether actions are actually delivering the expected results. Hence, it is an ex post evaluation tool and in particular it seeks answers to the following:

- *Effectiveness* - Have the objectives been met?
- *Efficiency* - Were the costs involved justified, given the changes which have been achieved?
- *Coherence* - Do the actions complement other actions or are there contradictions?
- *Relevance* - Is the action still necessary?
- *Added value* - Can or could similar changes have been achieved without action, or did the action make a difference?

Developing an explicit evaluation process of policy options involves judging the effectiveness, efficiency and efficacy of alternative courses of action and evaluating policy impacts in terms of economic, social, environmental and other societal impacts. A criteria model for evaluation of policy options can be designed using *Effectiveness, Efficiency, Coherence, Relevance, Added value as the main criteria, then define measurable attributes underlying these criteria.*

Franco L. A. and Montibeller G. (2011) examined the role of problem structuring in MCDA interventions, from defining the problem and the required level of participation to structuring the evaluation model. They introduced a framework for conducting MCDA interventions, in which the role of problem structuring is made explicit. The framework includes three phases, in Phase 1; the analyst structures the problem situation and designs a decision process with the right level of participation. Once completed, the analyst starts Phase 2, the structuring of an MCDA evaluation model, which consists of structuring a value tree, developing attributes and identifying decision alternatives. Finally, the analyst can conduct Phase 3, the evaluation of decision alternatives. The process has a recursive nature as the MCDA model can change the definition of the problem or the scope of stakeholders' participation; similarly, the assessment of alternatives can change either the structure of the MCDA model or the definition of the problem (Franco and Montibeller 2011).

Given that we have identified feasible policy options from scenario generation, according to (Franco and Montibeller 2011), there are two main tasks remaining in structuring MCDA evaluation models; i) representation of objectives in a value tree, and ii) the definition of attributes to measure the achievement of objectives.

Multi-Attribute Decision Making:

Multi-Attribute Decision Making (MADM) techniques can be applied When the decision consists of selecting one out of a finite set of feasible alternatives $A = \{a_1, \ldots, a_k\}$, (Belton and Stewart, 2002).

In MADM techniques, the decision process starts by structuring the problem as an attribute tree hierarchically ordering the decision makers' aims at different abstraction levels. It is generally assumes that each criterion can be operationalised by a set of measurable attributes allowing for assessing the consequences arising from the implementation of any particular alternative. In the next step preferential information is elicited. The relative importance of criteria is captured in weights w_{jl} for each criterion j at each abstraction level l. At the lowest level of the value tree these objectives are translated into attributes, with each one of them evaluating a given characteristic of the decision options (for example, an objective 'efficiency' may be measured by the attribute 'operating cost'). The performance of each decision option against each attribute is determined and weights reflecting acceptable trade-offs of performance among objectives are elicited from the decision-makers. (Comes T., et al. 2011)

When used in conjunction with a causal-map, the structure and content of the map informs the building of the multi-attribute value model, in an ad hoc translation. Similarly, the causal map may be used to elicit attributes and objectives.

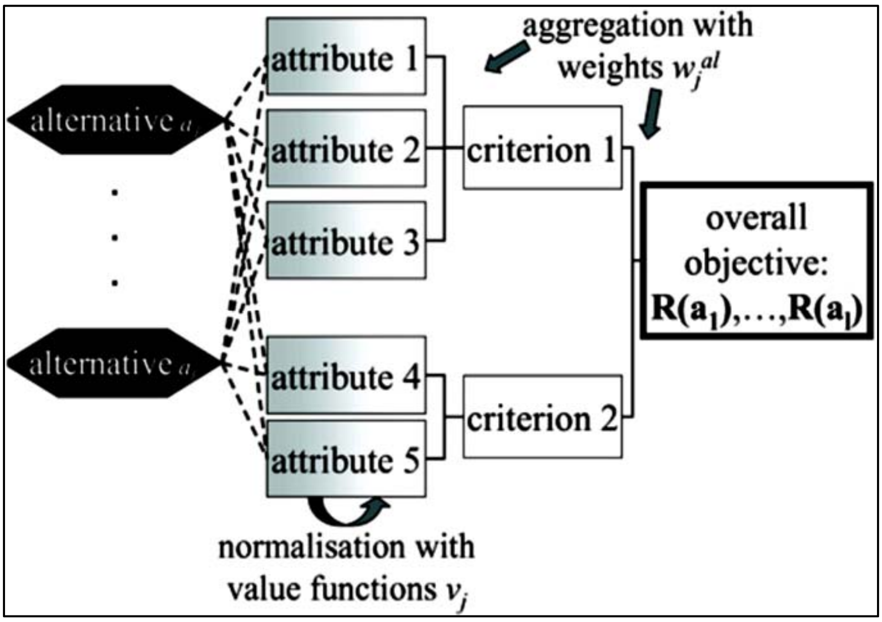


Figure 5 : Attribute tree: measurable attributes in gradient boxes, criteria and overall goal in white boxes. Dependence of attributes on the alternatives (represented as diamonds) is shown by dashed lines. (Comes T., et al. 2011)

Stakeholder Analysis:

Quite often public policy makers have to balance between interests of many different groups of people or individuals who can affect or are affected by the achievement of the policy goals. Thus, attention to the stakeholder configuration and distribution of interests should be a basis for finding implementable and effective solutions to policy issues. Typical policy stakeholder analysis is limited to identification of immediate stakeholders and qualitative description of the latter. While contemporary policy analysis practices are greatly facilitated by advanced quantitative decision and risk analysis techniques, there is evident lack of relevant analytic applications for the issue of policy stakeholders assessment. As a step to operationalize policy stakeholder analysis, this research seeks a format to identify and profile policy stakeholders. The data framed by this format is to be further used as input to formal decision and risk analysis.

Stakeholder analysis is also important to show that the intervention has followed rational, fair and legitimate procedures to satisfy those involved with, or affected by the decision. There are several tools for stakeholder analysis available in the literature. The most widely used techniques include the power-interest grid, star diagram, and stakeholder influence map; and stakeholder-issue interrelation diagram and problem-frame stakeholder maps (Bryson 2004).

Preference elicitation:

It requires that decision-makers either vote in favour of or against an option; or decide for a given option goal path. Preferencing is a voting method, described in Eden and Ackermann (1998) and Bryson et al (2004), which asks decision-makers to indicate their preferences for selected options which feature in the map. Each decision-maker performs a holistic judgment, informed by the map as a whole and their learning from the problem-structuring process. Typically, each decision-maker is provided with a number of votes (in practice these may be physical or electronic 'sticky dots') which they allocate to the options according to their positive and negative preferences. At the end of this process, the total number of positive and negative votes assigned to each option is determined.

As with any model based on decision-makers' preferences, these results should be employed with caution, as preferences are constructed along the process of decision support, rather than simply mirrored by the model (Roy, 1996; Belton and Stewart, 2002).

4 An integrated Policymaking DSS

Strategic decision-making plays only a minor role in research on decision support systems (DSS). In strategy or policy making problems, supporting the decision process is more important than supporting the search for an 'optimal' solution to the problem, especially since for most policy problems a well-defined objective function does not exist. So it is more about a formalized procedure to produce an integrated system of decisions, than the actual choice. The view on a DSS in a policy making context is rather to help in formalizing and improving parts of this procedure through the use of ICT tools.

4.1 DSS Technologies

DSS's symbolize a specific class of information systems designed to help users which rely on knowledge, in a range of decision-making positions to solve the encountered problems. An important point in most common DSS definitions is that DSS's refer to applications that are designed to support, not replace, decision making. DSS's: (i) Cover a wide spectrum of combinations of methodological tools or ideas, with software and hardware; (ii) Allow a decision-maker to translate his subjective world view into explicit models; (iii) Support values of: Rationalism, Intuition and Participation.

Recent analysis on decision support and expert systems has shifted from considering them as solely analytical tools for assessing best decision options to seeing them as a more comprehensive environment for supporting efficient information processing based on a superior understanding of the problem context (Gupta et al. 2006).

State of the art research in decision support for socio-economic areas, include: (i) e-management models that incorporate reliable participatory decision-making practices and quality management indicators; (ii) implementation of digital media to allow well-informed collaborative decision-making; (iii) platforms that support integration and interoperability of many data sources concerning social, financial, and physical aspects of the urban environment; (iv) development of online planning support systems (van Leeuwen and Timmermans 2005).

A conventional DSS with the purpose of delivering intelligence information consists of three subsystems; the data management, the model management, and a user interface.

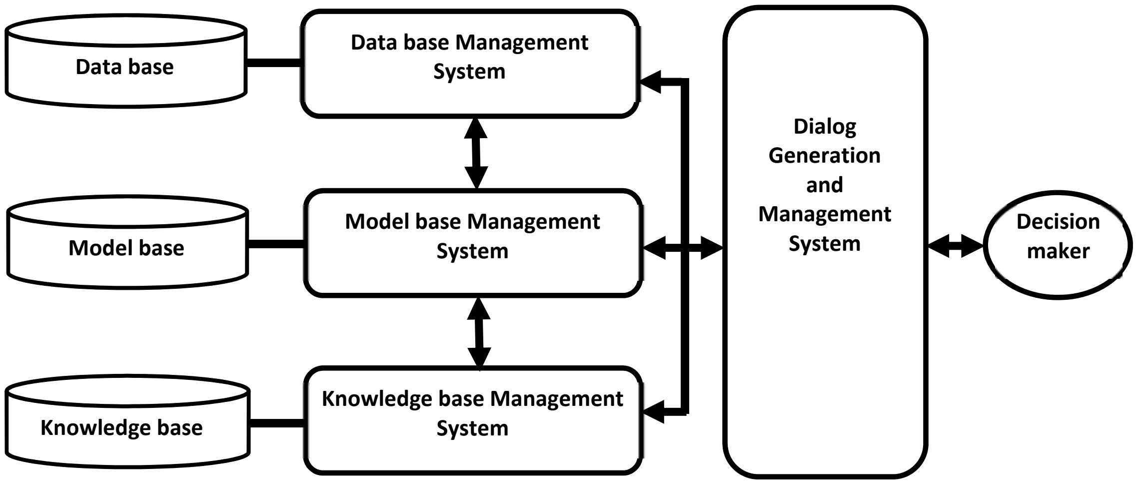


Figure 6 : Standard DSS structure (Source: Turban et al. 2005)

The DSS is configured with four subsystems: 1) the dialog generation and management system (DGMS); 2) the database management system (DBMS); 3) the model base management system

(MBMS); 4) the knowledge base management system (KBMS). A significant component of the DSS is the decision-maker or user and his/her tasks.

The essential function of the DGMS is transforming the input from the user into languages that can be read by the DBMS, MBMS and KBMS and into a form that can be understood by the user. The DGMS supports the dialogue between the user and the other constituents of the DSS. Being the one component of the DSS with which the user directly interacts, the user views the DGMS subsystem as the entire DSS.

The DBMS is defined as a software kit for organizing data in database. The primary tasks of the DBMS are the capture and storage of internal and external data which are needed to make decisions (Turban et al. 2005). In scientific literature a broader approach to the purpose of DBMS is found; the DBMS allows to link data from the different sources to a database that can possess both quantitative and qualitative data which describe the object (Kaklauskas et al. 2007). The primary functions of the MBMS are the creation, storage and update of models that enable the problem solving inside the DSS. According to Kaklauskas et al. (2007), the MBMS performs a similar role with models as well as the database management system with data. The MBMS assists the user to choose a desirable model, to adapt it to the situation.

The above components (DGMS, DBMS, MBMS, KBMS) are considered to constitute the software portion of the DSS. The final part is being the decision-maker himself, usually understood as an analyst who analyses the situation and makes own conclusions.

Summarizing DSSs presented in special literature focusing on so-called “intelligent decision support” which focus more on providing recommendations, problem solving, and analysis than on providing data, we can identify the following categories of systems: 1) individual decision support system (IDSS); 2) group decision support system (GDSS); 3) negotiation support system (NSS); 4) expert systems (ES).

The IDSS essential functions are: 1) capture of data and knowledge from various sources; 2) algorithmic data manipulation; 3) presentation, storage of the information reports necessary to analyse a problem, to make a decision.

The GDSS is an interactive computer-based system which allows a group of decision makers to accept effective decisions of unstructured problems. In special literature the specifics of GDSS is pointed out in terms of the support for: 1) decision process; 2) content of problem (Matsatsinis and Samaras 2001). The GDSS structures the process of problem-decision, in this way helps to concentrate on the important issues, to avoid the irregularities and inefficient actions. In order to systematize the GDSS variety, different features of classification are applied. The most popular is the influence on group's activity.

The NSS is often regarded as a certain specialized variety of GDSS, which is oriented to provide assistance for people involved in the negotiations in order to get the acceptable decision for each. The NSS provides information on opportunities of compromise, which helps to reach mutually acceptable decisions. In such systems, the negotiation component helps to purify the objectives of participants and integrate their vague, subjective priorities and the objective data. The main functions of NSS are: 1) provision of information on actual object necessary to negotiate, 2) support of electronic negotiation. Examples of NSS’s include NEGOPLAN and NegocIAD (Kaklauskas et al. 2007; Butkevičius and Bivainis 2009).

4.2 Proposed DSS Structure

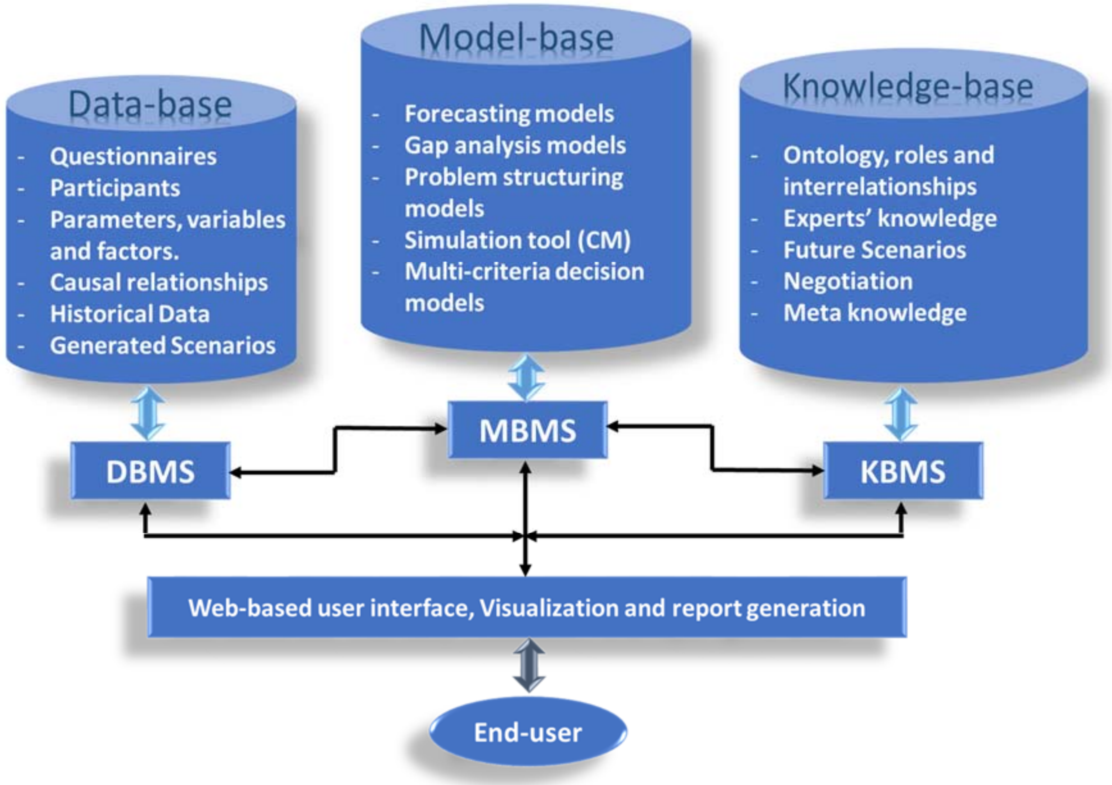


Figure 7 : DSS structure

Figure 5, provides the DSS components and their integration. We consider that the DSS database stores all data related to the models produced for policy problems including problem elements; actors/decision makers, stakeholders, variables/factors, and relations between factors. In addition, data sets for the problem parameters obtained from various data sources may be stored in the database.

The model base of the DSS integrates different quantitative models, which enable the DSS to support decision-making for public policy formulation (design). The DSS knowledge base will contain the formal ontologies of the different policy domains, definition of the roles, relationships and interactions among participants (analysts, experts, and decision makers), questionnaires, future scenarios and meta-knowledge (justification/explanation).

The aim of such setup is to allow a user to interact with databases, quantitative models, qualitative knowledge and other users within the system; and to keep track of the current status of relevant parameters and variables subject to be part of a model.

5 Discussion

5.1 Mathematical modelling and Role of the model in Policymaking

"A model is a set of assumptions often referring to a highly idealized situation, from which assumptions about the relations to be observed are derived' to be compared with observations. Agreement with observations corroborates the model" (Rapoport, 1958, p. 976). A mathematical model is a deliberate act of representing a problem we are concerned with in a "scientific form". The usefulness of mathematical models lies in the fact that they allow us to test real world behaviour in an artificial setting, thus being easy and inexpensive to perform in repetition. With ever-increasing computer power we are able to deal with increasingly large and complex data sets.

Models of social and policy sciences do not match with the models of natural or physical science in the predictive abilities, due primarily to the complexity of the actors involved in public policymaking. Although forecasting in such complex settings of public policy problems is notoriously difficult and turns out to be wrong most of the time, it remains a necessary management tool. It is used to define a path and to align resources along a certain objective, even if this objective needs to be constantly re-evaluated to take unforeseen events into account. Even if it is not possible to predict accurately policy consequences of future policies, it is at least possible to measure the impact of current and past policies and make this knowledge available to decision makers.

Dye (1972) discussed the role of the model is to describe, simplify, clarify, identify, communicate, direct inquiry, and provide possible explanations for policy as an outcome of the policymaking process – (Dye, 1972)
- A public policy model should identify the really significant aspects of public policy. It should direct attention away from irrelevant variables or circumstances, and focus upon the 'real' causes and 'significant' consequences of public policy.
- A "model should be operational". That is, a model should refer directly to real world phenomena which can be observed, measured, and verified".
- A public policy model should also communicate something meaningful about the public policymaking. The communication relies on a sense of shared meaning (transparency and understanding) that can only be achieved by engaging the user into the model building process.
- Finally, a model approach should suggest an explanation of public policy. "It should suggest hypotheses about the causes and consequences of public policy—hypotheses which can be tested against real world data". (Dye, 1972)

5.2 Link to user requirements

Primary target end-user group is represented by policy makers operating at different levels, e.g.- mayors, executive officers, heads of administration, elected representatives (members of the regional parliaments etc.), civil servants dealing with policies planning, implementation and evaluation, as well as policy advisors, policy analysts, think tanks, representatives of civic society (NGOs, civic organizations) as well as the research community, which can have multiplication effects on policy makers at all levels. A secondary, broader target group is represented by all stakeholders who can benefit from improved social and societal models to show policy and decision-making consequences, facilitated dialogue and interaction with policy makers and ultimately enhanced relevance of policy-making to their needs.

Simulation and visualization of policy impacts takes place in governments in a black box manner. The approach outlined in this deliverable for policy modelling and simulation provides a visual structure of the policy problem that allows multiple perspectives of the problem to be

represented and analytically debated. This contributes to transparency, openness and customizability of the model, identified as user requirements by WP2.

Bringing facts and abstractions from scientific and experts' knowledge into the modelling process, supports an evidence-based policymaking approach and contributes to satisfaction of user requirements of provenance and trust in the simulation results by building up on reliable information in different formats integrated from multidisciplinary and trusted information sources.

Simulating possible future scenarios and alternative courses of action allows for devising policy options and performing an ex-ante impact assessment. Simulation shows the relations between policy instruments (funds, taxes, subsidies, prohibition, etc.) and societal effects. "If we change this policy instrument, according to what we know, what are the effects (over time) on the factors subject to policy targets? What are the side effects on other factors?"

5.3 Benefits to Policy makers, Stakeholders and Citizens

The proposed decision support approach is expected to provide the following benefits to decision-makers through the use of appropriate theories, methods and tools that support the process of transforming data and information inputs into conceptual and formal models for public policy analysis:

- Providing informed views of the problem situation with representation of the system components by seeking to elicit resolution of the problem through debate and negotiation among the decision makers and stakeholders, rather than from the analyst, using the graphical representation of the problem (Causal map) as a communication tool.
- The method cannot capture all the intricacies of a situation to its minutest details, but can sufficiently map out its principal elements and their relationships. This is also important for the speed and ease of use required in a tool intended to be used by policy makers. (Acar, 1983).
- Identifying the most relevant data for the policy issue through the modelling process, as moving from perceiving a situation 'fuzzily' to 'qualitatively' to 'quantitatively' and understand implications by complementing it to a quantitative simulation, trying out various change scenarios, assessing policy consequences and thus refining the quantitative model.
- Make it clear for the public what were the options on time of taking decision (stakeholders to be better informed about policy alternatives – more transparency to policy making process).
- Evaluation of existing policies and policy proposals to be implemented in the future are both possible through the use of the MCDA software module.
- The Decision Support framework adapts several frameworks, notably Problem Structuring, Scenario Planning, Group Support Systems, Negotiation Analysis, Game theory and MCDA. This new construct gives Policy makers the ability to be more successful in achieving societal goals and dealing with societal problems, through:
    - identifying influences and trends of evolution among the problem parameters by building on reliable data to produce forecasts;
    - representing the social dynamics of the multiple actors involved in the policy context (relationships, interests, powers, goals) and model that as a cooperative or a competitive (game theoretic) situation;
    - capturing the long time delays and systemic effects of policies or actions for change, the fact that cause and effect are often distant in time;

- performing integrated impact assessment of policy proposals in terms of economic, social, environmental and other impacts, by including the relevant problem variables in the model of the problem.

6 Concluding Remarks

The aim of the approach outlined in this deliverable is to apply cognitive strategic thinking and scenario-based planning in a public policy problem situation in order to model the decision-makers' cognitive understanding of the problem, design and simulate decision options. This is done by structuring the problem as a "causal semantic network" or "causal map". This map can be equipped with quantified relationships allowing for foresight or forward looking impact assessment in terms of economic, social, environmental and other impacts. Further, since the number of possible scenarios can rise significantly, algorithms for generation of a smaller set of interesting scenarios can be designed.

The results of this study is significant for policymakers, the decision support research community and the public. The proposed DSS is a complex sociological structure that models human cognition and knowledge of a public problems by clarifying, testing and reassessing assumptions about the web of cause-effect relationships underlying the problem situation. Once negotiated, the model becomes the explicit foundation upon which the choice problem is defined and the policy options are appraised.

The resulting model for the policy problem situation can be integrated to multiple simplified decision models, e.g., optimization models and decision trees, to improve the scenario generation and design of policy options by taking into account costs, benefits, resource constraints and risks associated with natural, socio-economic, and technological systems as well as decision processes, perceptions and values.

One innovative aspect of the work done in WP6 is to implement an approach for public policymaking decision support that integrates the application of problem structuring methods (PSM's), Scenario-based dynamic simulation with a MCDA framework that supports evaluation of policy options taking stakeholders and policy makers' preferences into account.

A second innovative aspect, which may apply for the project as a whole, is the integration between work packages to support problem structuring using inputs from WP4 and WP5. It is of interest to see how the information obtained from those sources (all available within the Sense4us toolkit) contribute to increased problem understanding and investigating what information of importance for model building that is accessible through those means and what information that needs to be obtained elsewhere.

Adopting such decision support approach for public policy analysis will enhance policy modelling and simulation, produce an important body of knowledge (public problems definitions in a structured form) and result in the development of participative, transparent and forward looking decision support tools for public policymaking. It also supports an evidence-based policymaking approach, where policy analysis draws upon factual information, scientific knowledge, and expert knowledge.

Through close interaction with policy makers around Europe the Sense4us project will enable for validation of results in complex policy-making settings and direct the research towards the support of more timely, more effective and well-informed policy creation.

7 References

[1] Acar W., (1983). Toward a Theory of Problem Formulation and the Planning of Change: Causal Mapping and Dialectical Debate in Situation Formulation. Ann Arbor, Michigan: U.M.I.

[2] Acar, W. and Druckenmiller, D. (2006). Endowing cognitive mapping with computational properties for strategic analysis, Futures 38:993-1009.

[3] Ackerman F., Heinzerling L. (2004). Priceless: on knowing the price of everything and the value of nothing. The New Press, USA

[4] Adler M.D., Posner E.D. (2006). New Foundations of Cost Benefit Analysis. Harvard University Press.

[5] Almond, G. A. (Dec., 1966). Political theory and political science. The American Political Science Review, 60, 4, 869-879.

[6] Andersen D., Rohrbaugh J. (1992). Conceptual and Technical Problems in Integrating Models of Judgment with Simulation Models. Systems, Man and Cybernetics 22/1, 21-34.

[7] Anderson, J. E. (1975). Public policy-making. New York: Praeger.

[8] Bankes, S.C. (1993): Exploratory Modeling for Policy Analysis, Operations Research 41 435–449 no. 3

[9] Belton V. and Stewart T. (2002). Multiple Criteria Decision Analysis: An Integrated Approach. Kluwer: Dordrecht.

[10] Belton, V., and Stewart, T. (2010). Problem structuring and multiple criteria decision analysis. In *Trends in multiple criteria decision analysis* (pp. 209-239). Springer US.

[11] Bero L. A. & Jadad A.R. (1997). How consumers and policymakers can use systematic reviews for decision making. Annals of Internal Medicine, 727(1), 37-42.

[12] Blum, D. E. (1992). Public policy, a discipline still evolving, focuses more on preparation of managers. Chronicle of Higher Education, 38, 25, pp. A19-20.

[13] Brandenburger, A. M., & Nalebuff, B. J. (1995). The right game: Use game theory to shape strategy. Harvard Business Review.

[14] Brown R. (2005). Rational Choice and Judgment: Decision Analysis for the Decider. New York: Wiley.

[15] Bryant, Benjamin P., and Robert J. Lempert (2010). "Thinking inside the box: A participatory, computer-assisted approach to scenario discovery." Technological Forecasting and Social Change 77.1: 34-49.

[16] Bryson J.M., (2004). What To Do When Stakeholders Matter: stakeholder identification and analysis techniques. Public Management Review 6(1): p. 21-53.

[17] Bryson J.M., Ackermann F, Eden C and Finn CB (2004). Visible Thinking. Wiley: Chichester.

[18] Butkevičius A., Bivainis J. (2009). Planning of National Budget Expenditure – Nacionalinio biudže- išlaidų planavima. Vilnius: Technika, 2009. 246 p. ISBN 978–9955–28–469–7.

[19] Cohen, M.D., March, J. G., & Olsen, J. P, (Mar, 1972). A garbage can model of organizational choice. Administrative Science Ouarterly, 17, 1,1-25.

[20] Comes T., Hiete M., Wijngaards N., Schultmann F., (2011). Decision maps: A framework for multi-criteria decision support under severe uncertainty. Decision Support Systems 52: 108–118

[21] Davies P., 2004. Is evidence-based government possible? Jerry Lee lecture, 4th Annual Campbell Collaboration Colloquium Washington D.C.

[22] Davis J.P., Hall J.W., (2003). A software-supported process for assembling evidence and handling uncertainty in decision-making, Decision Support Systems 35: 415–433.

[23] Druckenmiller, D. A. and Acar, W. (2009). An agent-based collaborative approach to graphing causal maps for situation formulation, *Journal of the Association for Information Systems* 10(3), article 3.

[24] Dunn W.N. (2012). Public policy analysis, 5th Edn. Pearson.

[25] Dye, T. R (1972). Understanding public policy. Englewood Cliffs, NJ: Prentice-Hall.

[26] Easton, D. (1965). A systems analysis of political life. New York: John- Wiley & Sons.

[27] Eden C. and Ackermann F., (1998). Making Strategy-The Journey of Strategic Management. Sage: London.

[28] European Commission (2013). Communication from the Commission to the European Parliament. Strengthening the foundations of Smart Regulation – improving evaluation, Brussels, 2.10.2013 COM (2013) 686 final.

[29] Forrester J.W. (1992). Policies, decisions and information sources for modelling. Eur J Oper Res 59.1:42–63.

[30] Franco L. A., Montibeller G. (2010). Facilitated modelling in operational research. Eur J Oper Res 205:489–500.

[31] Franco L. A., Montibeller G. (2011). Problem structuring for multicriteria decision analysis interventions. In: Cochran et al. (ed) Wiley encyclopedia of operations research and management science. Wiley, USA.

[32] Georgantzas, N. C. and W. Acar (1995). Scenario-Driven Planning: Learning to Manage Strategic Uncertainty. Westport Connecticut: Quorum Books.

[33] Gupta J., Forgionne G.A., Mora M.T. (2006). Intelligent Decision-making Support Systems. Foundations, Applications and Challenges, Springer-Verlag.

[34] Harris, R. (2012). June 9. Introduction to Decision Making, Part 1. VirtualSalt. Available: http://www.virtualsalt.com/crebook5.htm (retrieved on 10/09/2014)

[35] Hevner et al., 2004. DESIGN SCIENCE IN INFORMATION SYSTEMS RESEARCH, MIS Quarterly, vol. 28, no 1.

[36] Jiwani G.N. (2010). Uncovering the Unknown of Government Policy Decision-making Process at Senior Levels: Multiple Case Study. University of Washington, 2010. http://books.google.se/books?id=nr0AaAEACAAJ

[37] Johannesson, P. and Perjons, E. (2012). “A Design Science Primer”, 1st ed., CreateSpace.

[38] Kaklauskas, A., Zavadskas, E. K., Trinkūnas, V. A. (2007). Multiple criteria decision support online system for construction. Engineering Applications of Artificial Intelligence 20(2), pp. 163−175.

[39] Keeney R.L. and Raiffa H., (1993). Decisions with Multiple Objectives. Preferences and Value Tradeoffs, 2nd edn. Cambridge University Press: New York

[40] Kingdon, J. W. (1995). Agendas, alternatives, and public policies. 2d ed. New York: Longman.

[41] Kirby M. W. (2000). Operations research trajectories: the Anglo–American experience from the 1940s to the 1990s. Oper Res 48:661–670.

[42] Lasswell, H. D. (1951). The policy orientation. In D. Lemer, & H. D. Lasswell (Eds.). The policy sciences (pp. x-y). Stanford: Stanford University Press.

[43] Lindblom, C. E. (1968). The policy-making process. Englewood Cliffs, NJ: Prentice-Hall.

[44] Luna-Reyes, Felipe L. and Andersen D. L. (2003). Collecting and analyzing qualitative data for system dynamics: methods and models. System Dynamics Review 19(4): 271-296.

[45] March J.G. (1988). Bounded rationality, ambiguity, and the engineering of choice, in: Bell D.E., Raiffa H., Tversky A. (Eds.), Decision Making: Descriptive, Normative, and Prescriptive Interactions, Cambridge University Press, Cambridge, UK.

[46] Matsatsinis, N.F., Samaras, A.P. (2001). MCDA and preference disaggregation in group decision support systems. European Journal of Operational Research 130(2), 414-429.

[47] Mintzberg, H. (1994). The Rise and Fall of Strategic Planning, Prentice-Hall, New York.

[48] Mitchell B. (2009). Policy-making process. Available: (retrieved on 10/09/2014) http://www.waterencyclopedia.com/Oc-Po/Policy-Making-Process.html

[49] Montibeller G. and Belton V. (2006). Causal Maps and the Evaluation of Decision Options: A Review. The Journal of the Operational Research Society Vol. 57, No. 7, Special Issue: Problem Structuring Methods, pp. 779-791.

[50] Munger, M.C. (2000). Analyzing policy: choices, conflicts, and practices. WW Norton, New York.

[51] Nagel, S. S., (1990). Policy theory and policy evaluation: Concepts, knowledge, causes, and norms. New York: Greenwood Press.

[52] Nagel, S. S., (1998). Public policy evaluation: Making super-optimum decisions. Brookfield, VT: Ashgate.

[53] Raiffa H., (1968). Decision analysis: introductory lectures on choices under uncertainty. Addison-Wesley England, Oxford.

[54] Raiffa H., (2006). Preferences for multi-attributed alternatives, Journal of Multi-Criteria Decision Analysis 14: 115–157.

[55] Rosenhead, J. and Mingers, J., (2001). Rational analysis for a problematic world revisited: problem structuring methods for complexity, uncertainty and conflict. Wiley, USA.

[56] Rosenhead J. and Mingers J. (2004). Problem Structuring Methods in Action. Eur J Opl Res 152: 530-554.

[57] Roth, A. E., & Erev, I. (1998, September). Predicting how people play games: reinforcement learning in experimental games with unique mixed strategy equilibria. The American Economic Review, 88(4), 848-852.

[58] Roy, B. (1996). Multi-criteria Methodology for Decision Aiding. Dordrecht: Kluwer.

[59] Schoemaker, P. J. H. (2002). Profiting From Uncertainty: Strategies for Succeeding No Matter What the Future Brings. New York: Free Press.

[60] Senge P.M. (1990). The Fifth Discipline: The Art and Practice of the Learning Organization. New York: Doubleday Currency.

[61] Simon H. A. (1965). Administrative Behavior: A Study of Decision Processes in Administrative Organisation, 2nd edn. New York: Free Press.

[62] Simon H. A. (1988). Rationality as process and as product of thought, in: Bell D.E., Raiffa H., Tversky A. (Eds.), Decision Making: Descriptive, Normative, and Prescriptive Interactions, Cambridge University Press, Cambridge, UK, 1988.

[63] Sterman J. D. (2000). Business Dynamics: Systems Thinking and Modelling for a Complex World. Irwin/McGraw-Hill: Boston.

[64] Stewart T.J., (1992). A critical survey on the status of multiple criteria decision making theory and practice, Omega 20: 569–586.

[65] Tsoukias A., Montibeller G., Lucertini G., Belton V. (2013). Policy analytics: an agenda for research and practice, EURO J Decis Process 1:115–134.

[66] Turban, E., Aronson, J., Liang, T-P. (2005). “Decision Support Systems and Intelligent Systems” 7th Edition. Pearson Prentice Hall.

[67] van Leeuwen, J.P., Timmermans, H. (2005). Introduction in Recent Advances in Design and Decision Support Systems in Architecture and Urban Planning, 2005 Springer Science + Business Media, Inc.

[68] Von Neumann, J., & Morgenstern, O. (1944). Theory of games and economic behavior. Princeton, NJ: Princeton University Press.

[69] Zagare, F. C. (1984). Game theory: Concepts and applications. Beverly Hills, CA: Sage University Publications.

APPENDIX I

Case Study - the EU 2030 Climate and Energy Framework

There is an ongoing debate on what should be the EU's climate and energy targets in 2030. At present, the EU's climate and energy targets by 2020 are approved, how-ever by 2020, the EU strive to reduce climate change-causing emissions by 20% compared to 1990 levels and to ensure that renewable energy sources would make at least 20 percent of all energy. The need to move ambitious and binding climate and energy targets for 2030 has to go in line with scientific findings on climate change. It is estimated that in order to avoid the most severe consequences of the greenhouse, gas emissions have to be reduced by 80-95% compared to 1990 levels by 2050. In practice, this means learning how to live without fossil fuels, even if it was enough for centuries and that is possible even to existing technologies, and is not more expensive than retrofitting an outdated with fossil fuel -related infrastructure. (ROADMAP 2050)

With respect to the case herein, the EU 2030 Climate and Energy targets, it is a case for policy legislation on the EU level with multiple and interrelated economic, environmental and social impacts. The main characteristics of the policy making on the EU level are: (i) the question of whether we are committed to evidence-based policy making, or not; (ii) the co-decision legislative procedure of the three main institutions involved in policy making on the EU level: the EU Commission (EC), the European Parliament (EP), and the Council of EU; and (iii) the influence of external factors such as media coverage and the lobbying effect of interest groups and non-governmental organisations.

The identified policy issues are:

(i) new targets for renewables share in EU energy sector, (i.e. 30 % proposed by the EP), considering the main energy sectors: Transport, Buildings (electricity/heating/cooling), and Industry;

(ii) commercial interest and fuel market competition (renewables vs. fossil fuels and vs. nuclear energy sector);

(iii) issues of land use and environmental impact to the land/soil; and

(iv) environmental advantages – less pollutants, less CO_2 etc.

The Figure A1 below shows a causal diagram for the problem that map out key variables and their causal dependencies. This qualitative causal map is derived using text analysis of verbal descriptions of the problem. The textual data analyzed is obtained from 'Fifth Assessment Report: Climate Change 2013, Summary for policy-makers, the Intergovernmental Panel on Climate Change' (IPCC AR5) and a sample research paper that presents facts and scientific knowledge about the problem. The applied text analysis algorithm was published in two conference papers[7]. The algorithm can be summarized with the following steps:

[7] "Text Analysis to Support Structuring and Modelling a Public Policy Problem-Outline of an Algorithm to Extract Inferences from Textual Data". Ehrentraut, C., Ibrahim, O., Dalianis, H.. World Academy of Science, Engineering and Technology, International Science Index, Humanities and Social Sciences, 1(6), 736, (2015).

"A Causal Mapping Simulation for Scenario Planning and Impact Assessment in Public Policy Problems: The Case of EU 2030 Climate and Energy Framework", Osama Ibrahim, Aron Larsson, David Sundgren. Proceedings of the 5th. World Congress on Social Simulation, WCSS2014, E. MacKerrow, T. Terano, F. Squazzoni, J. S. Sichman (Eds.): pp. 284-295, 2014.

Step 1. Decomposing text into a series of inferences.

– The text is browsed searching simultaneously for trigger words from one of the following categories. Read in sentence by sentence and extract sentences which contain a word from at least one, two or all the three following categories:

- Inference indicating words: because, thus, then, however, mean, compare … etc.
- Modal words: will, would, can, could, must, may … etc.
- Influence indicating words: result, impact, influence, relate, cause, affect, increase, rise, decrease, reduce, hinder, improve, support, benefit, important … etc.

– Put chosen inference sentences and attached reference into desired format.

– GUI that displays all inferences with references. (User engagement)

Step 2. Inferences are scanned for nouns, adjective-noun combinations to identify variables and entities.

Step 3. The initial set of variables (entities) is processed and refined by the user to identify synonyms, group and rank entities in order to reach to the final set of key variables.

Step 4. An adjacency matrix $A = [a_{ij}]$, is constructed with the identified key variables to indicate interdependencies, where $a_{ij} = 0$ if a variable x_i is not related to variable x_j; $a_{ij} = 1$ if x_i is related to x_j and changes are in the same direction; $a_{ij} = -1$ if x_i is related to x_j and changes are in opposite directions.

Step 5. Translate the matrix into a causal diagram with directed polarized relationships.

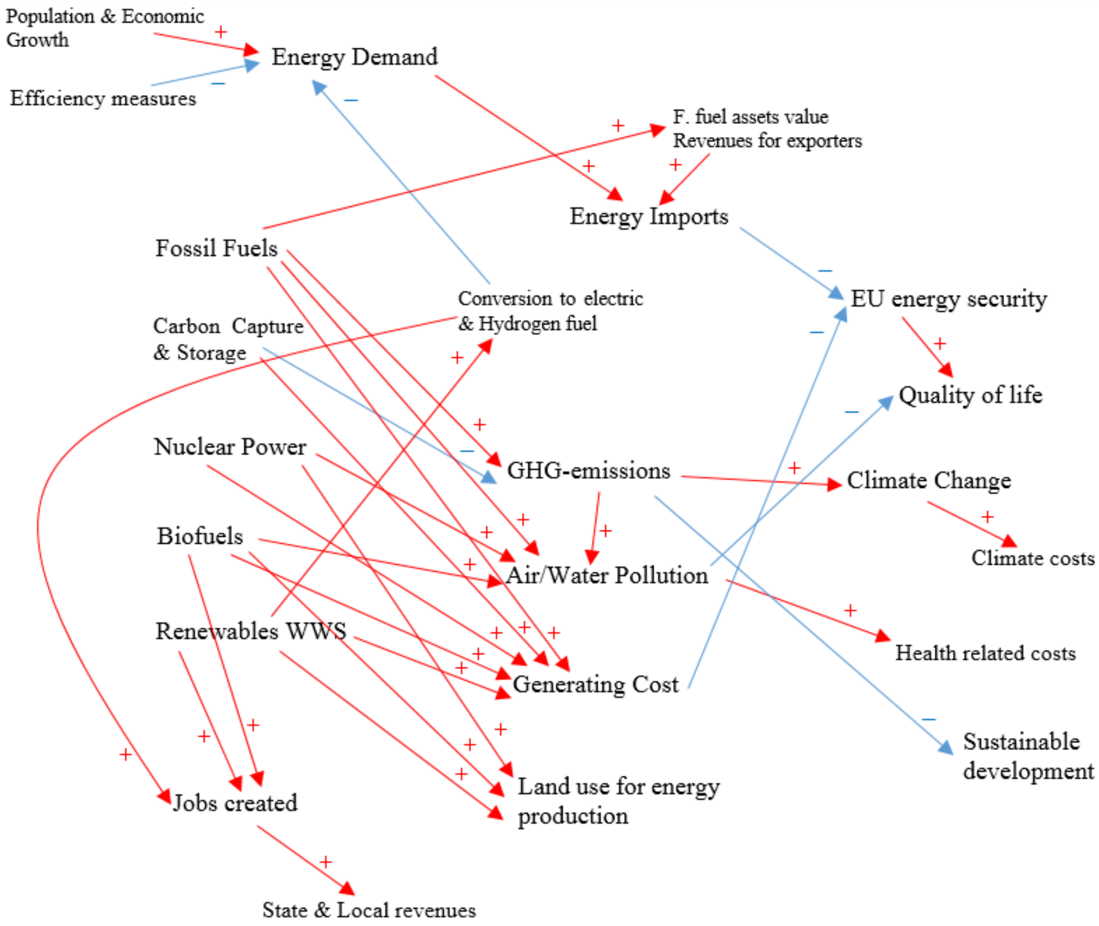


Figure A1 : A qualitative causal diagram of the problem

References:

ROADMAP 2050: A Practical guide to a Prosperous, Low-Carbon Europe. The European Climate Foundation (ECF), retrieved from: http://www.roadmap2050.eu

The Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report: Climate Change 2013 (AR5), Summary for policy-makers, retrieved on 22-05-2014: http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

Jacobson MZ, Howarth RW, Delucchi MA, et al. (2013), "Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using wind, water, and sunlight". Energy Policy 57(June): 585-601.