

# Decision Support Framework Approach

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Towards a Decision Support System (DSS) for Public Policy Making

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## List of Abbreviations

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<b>&lt;Abbreviation&gt;</b>	<b>&lt;Explanation&gt;</b>
CBA	Cost-Benefit Analysis
CSM	Comprehensive Situational Mapping
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
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

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The overall objective of this work package (WP6) is to create 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.

*“The ultimate objective of the Sense4us project is to advance policy modelling and simulation, providing economic and social benefits at all governmental levels across Europe”, (see Sense4us DoW).*

This deliverable presents our decision support approach for public policy making through a decision support framework and a decision support system (DSS) design, to be integrated to Sense4us tools for Linked open data search and social media discussion dynamics offered by WP4 and WP5.

The Decision Support framework enables policy analysis with respect to generating and comparing policy options and assessing policy consequences. The consequence/impact assessments will utilize the results from WP4 and WP5, and will result in the implementation of the simulation and decision analysis methods in two different software modules using modern software technologies compatible with the demonstration system of WP7.

The framework maps decision support methods and techniques to the activities (tasks) involved in public policy development, and include a set of interrelated policy analysis activities:

1. Policy problem structuring and modelling.
2. Design of policy options through simulating policy consequences and possible future scenarios.
3. Policy decision after multiple criteria evaluation of policy options.

The ultimate objective of studying, modelling and analyzing policy problems is to incorporate the newest management technologies into public policy decision-making in a meaningful and practically feasible way that adds significant value to the process. 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 integrate explicit multiple decision-makers' cognitive understanding of the problem in a causal semantic network or causal map; design alternative options; and provide foresight or forward looking impact assessment in terms of economic, social, environmental and other impacts.

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.

The DSS will design quantitative models and algorithms based upon the following decision support methodologies:

- Problem structuring, for facilitating understanding and communication of a complex policy problem.
- System dynamics, for simulation of policy consequences.
- Multi-criteria decision analysis, for decision evaluation of alternative policy options.
- Stakeholder and negotiation analysis, for supporting structured negotiation between stakeholders and facilitate understanding of how differing policy views and controversies may be incorporated in public policy making.



## Introduction

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“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)

Making and implementing policy at any level of government is fraught with difficulty. The impact of decisions made is not always obvious at the time the policy is formulated or enacted, and any short-comings of the policy become known too late to change it. This is not due to a lack of information; it is due to the difficulty of finding and aggregating the right data out of the sea of information which characterises our modern world.

Supporting better-informed policy decisions requires an understanding of how these decisions are made and the actual process of decision-making. To be effective, policies must holistically address the complexity of the situation rather than propose solutions to single problems. Formulating and understanding the situation and its complex dynamics, therefore, is a key to finding holistic solutions. In order to develop a comprehensive decision support framework for public policy decision-making, we needed to gain a better understanding of the "how" of the process and the key factors influencing the process of decision-making regarding public policy decisions, so that decision-makers can anticipate short-term constraints and long-term opportunities for change.

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<sup>1</sup> and quantitative<sup>2</sup> data available for the policy issue, in order to facilitate the system modelling process. This work is a contribution to the use of cognitive maps<sup>3</sup> to develop simulations for framing or structuring a problem.

A decision support framework approach is outlined, enabling for focused work on its elements:

- Simulation engine and graphical user interface (GUI) for change scenario simulation.
- A common policy appraisal format for multi-criteria decision evaluation of policy options.

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<sup>1</sup> In this study, 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.

<sup>2</sup> The quantitative data for the purpose of this study includes historical data sets for the different variables of the policy problem, in addition to numerical data for linking parameters like associated costs or benefits.

<sup>3</sup> 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](http://en.wikipedia.org/wiki/Cognitive_map).



The structure of the deliverable is as follows:

Chapter 1 provides a background on decision support systems technologies and a background on the decision-making processes in Policy-making problem situations and elaborates on the public policy-making contexts;

Chapter 2 discusses the research motivations and the significance of the study for policy-makers, the decision support research community and the public.

Chapter 3 reviews the decision support and OR methods that support policy analyses whether it is prescriptive or evaluative, discusses public policy analysis and presents a policy-making process model.

Chapter 4 presents our decision support framework for the public policy making.

Chapter 5 discusses the requirements for a public policy decision support system and presents our DSS framework.

Appendix I holds a case application of structuring and modelling of a public policy problem to provide decision support by the framework components.

# 1 Background

## 1.1 Decision Support System Technologies

Decision support systems (DSSs) 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.

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).

*Typical Attributes of DSS's are:* (i) Eased Access (to raw distributed data; often updated in near-real time); (ii) Facilitated Analysis (of data often through use of automated intelligence); and (iii) Rich Communication (of results and new ideas in a meaningful and practical form, often augmented by sophisticated graphical depictions). *Common Targeted Benefits of DSS's:* (i) Elevated Strategic Advantage; (ii) Reduced Lead-Time to complete work; (iii) Smarter Response (to changes / failures); (iv) Greater Consistency; (v) Worker Empowerment; (vi) Reduced Cost; (vii) Increased Innovation; and (viii) Higher Retention. (Bendoly 2008)

There are different opinions in terms of the structure of the DSS. The typical DSS consists of such three subsystems as the data management, model management, and user interface. The DSS is configured with the 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 tasks. Therefore it can be concluded that such composition of the DSS is the most rational (Fig. 1). (Turban et al. 2005)

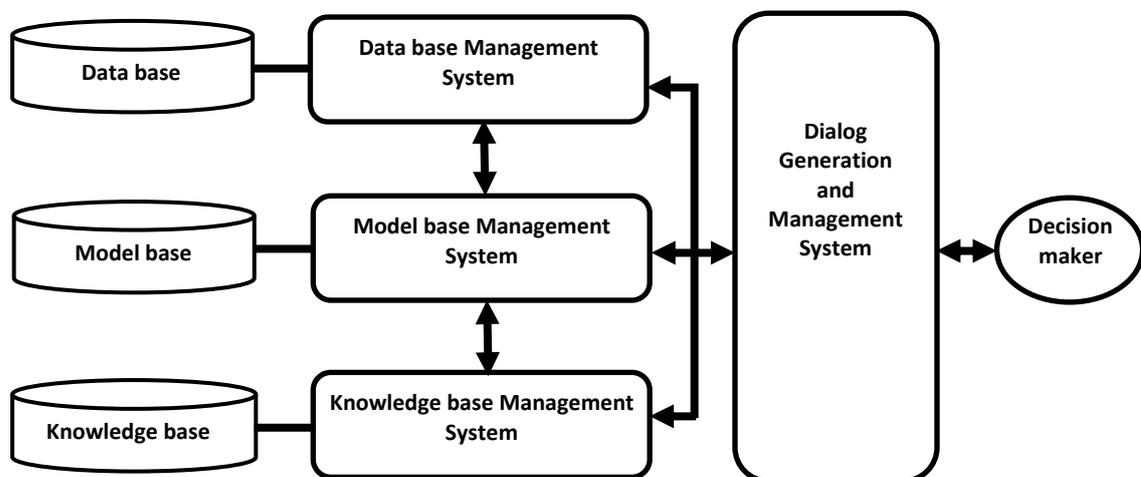


Figure 1 : Standard DSS structure (Source: Turban et al. 2005)



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.

In order to choose the suitable model it is rational to use the knowledge and experience of which the user of the DSS or expert system possesses. The KBMS is the necessary component of the effective DSS. It allows generating, collecting, managing, disseminating and using knowledge needed to solve problems.

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. A significant element of conceptual structure of the DSS is the decision-maker usually understood as an analyst who analyses the situation, takes into account the rules, however, makes his own conclusions. According to the results of structuring the DSS the application of the standard composition DSS is an important condition for effective provision of strategic planning decisions.

Summarizing DSSs presented in special literature, the most rational list of DSSs from the standpoint of intelligent support specification consists of the: 1) individual decision support system (IDSS); 2) group decision support system (GDSS); 3) negotiation support system (NSS); 4) expert system (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).



### 1.2 Decision-Making Processes in Public Policy

As early as 1968, Lindblom spoke about policy in terms of analysis determining policy, whereby an investigation of the merits of various possible actions has disclosed reasons for choosing one policy over others. However, studying how these merits are considered by the decision-makers, that is which key factors, influences, or determinants are weighed, and how these are weighed by the decision-maker in the selection of policies, has not been well documented (Lindblom 1968).

Schneider and Ingram (1993) have theorized that the “social construction of target populations” shapes both the policy agenda and the actual design of policy:

“Public officials find it to their advantage to provide beneficial policy to the advantaged groups who are both powerful and positively constructed as ‘deserving’ because not only will the group itself respond favourably but others will approve of the beneficial policy being conferred on deserving people. Similarly, public officials commonly inflict punishment on negatively constructed groups who have little or no power, because they need fear no electoral retaliation from the group itself and the general public approves of punishment for groups that it has constructed negatively” (Schneider and Ingram 1993).

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.

Mitchell (2009) points out that: Public policies 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.

It may be worthwhile to examine what is the 'thinking' behind making policy decisions, and whether personal values, beliefs and intuition play any role in the decision-makers' final selection of policies. Jiwani G. (2010) discusses 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:

(1) 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.

(2) 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.

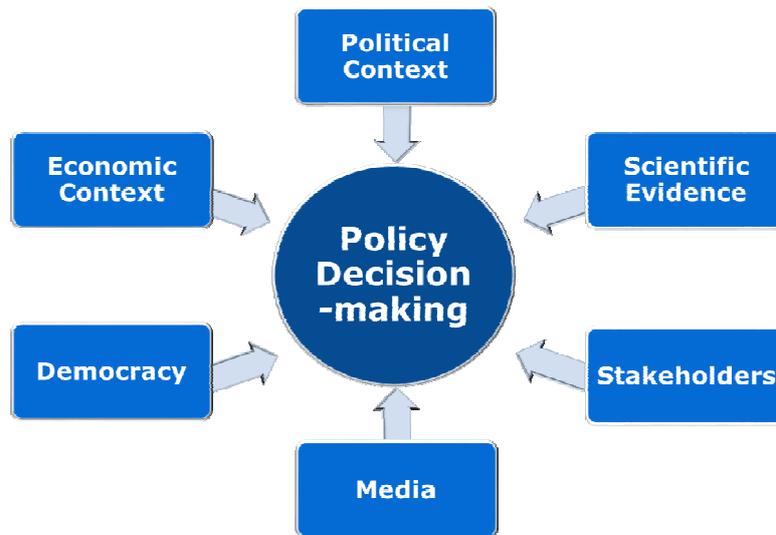
Simon (1988) distinguishes two types of rationality in decision-making: substantive rationality (what to choose) and procedural rationality (how to choose), see (Simon 1988).

From the application point of view, support of policy planning is in the area of procedural rationality rather than substantive rationality. This support, which leads to better decisions, is sometimes termed prescriptive modelling. Furthermore, any policy planning will, at best, lead to a satisficing solution (March 1988), which is a solution path acceptable (not optimal) for almost all parties concerned. In the normative view, it is assumed that decision problems can be generalised and solved in an objective and rational manner. A problem can be translated into a mathematical model, future preferences are exogenous, stable and known with adequate precision, and an objective function can be formulated. Under these conditions an optimal solution can be derived. March argues, that public decision making is characterised by conflicting objectives representing the values of different participants with no 'optimal' solution (March 1988).

Simon (1965) defines the decision-making process as having the following steps: intelligence, design, and choice. In 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. 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).

### 1.3 Public Policy-Making Contexts

In order to gain further insight into decision-making processes, it is important to understand the context(s) in which decisions are made. Although literature and practices acknowledge that there are a multitude of variables that affect policy decisions to a greater or lesser extent, individually and collectively, there is little systematic documentation about factors and influences considered by senior decision-makers in government in making policies and about the actual process of decision-making (Jiwani 2010). 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 2 : Policy-making contexts*

**Democracy:**

We will focus on the most common form of democracy, "representative democracy", in which citizens elect officials to make political decisions, formulate laws, and administer programs for the public good. In a democracy, government is only one element coexisting in a social fabric of many institutions, political parties, organisations, and associations. Attributes of democracy: (i) the conduct within a country of free and fair elections; (ii) the existence of a well-organized and competitive party system; (iii) a delineation of, respect for, and protection of basic civil liberties and human rights within the society; and (iv) the encouragement, support of, and active participation of a vigorous civil society and, in particular, strong interest groups.

**Economic Context:**

One of the key factors for a government is the prevailing economic context it is faced with when making policy decisions, specifically the availability of resources, the economic growth, the economic climate with its potential impact on consequent generations or reduction of revenues, debt and expenditures (current and future commitments). Hence policy decision-making by governments clearly takes into account the financial impact of various policy alternatives when making decisions.



**Political context:** (Elected officials – Political ideology– Government objectives)

The political context must be considered when addressing policy decisions that are being undertaken at government levels. The political ideology of the government of the day, the preferences and demands of politicians, and the overall mandate of government and strategic priorities of the government department must all be taken into account when studying government policy decision-making. Therefore, the decision-makers need to understand as fully as possible the potential political ramifications and risks associated with policy decisions they make.

**Scientific Evidence:**

Science or scientific evidence (both quantitative and qualitative) has a place in policy decision-making. Gray (1997) points out that the decision analysis approach is the most systematic approach to incorporate evidence into the decision-making process since it does not only describe the evidence that must be taken into account but also requires estimates of the impact of taking any of the various options (Gray 1997).

**Stakeholders:**

Stakeholders, interest groups, or advocates, also known in some instances as lobbyists, have been known to attempt to identify the necessity and potential efficacy of selecting certain policy options that would benefit populations at large, resolution of which could earn governments' considerable approval from its constituencies.

Stakeholders also bring to the attention of policy-makers areas that government is "failing to intervene" to address societal needs.

Stakeholder influence and advocacy are seen as powerful influences, in lobbying governments to act. Stakeholders may also threaten the political survival of governments by withdrawing their support or lobbying efforts aimed at punishing the politicians for decisions that impose costs or take away existing benefits from them.

**Media:**

There are media claims that government prioritises certain policy actions based on media reporting, raising awareness amongst policy-makers on various topics of interest to the public, such as "public inquiry" into issues, or creating the awareness amongst decision-makers of the need to create new policies, or review and possibly amend existing government policies. Public opinion and opinion polls can exert political pressure on senior decision-makers in governments to respond.



## 2 Motivations

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 Information and Communication Technology (ICT) tools.

More attention should be paid to problem structuring and modelling, than to how we solve the available problem definitions, which are sometimes: poor, very scientific, so complicated or even not useful.

Public policy makers need to be open to more effective ways, new learnings and research ideas in order to ensure due diligence and affect change (Jiwani 2010). To influence the well-being of populations and to ensure the privilege afforded to them by the public and senior government officials (political leaders) is not abused.

The aim of supporting public policy decision-making is to develop ways of facilitating policy-making which create policies consistent with the preferences of policy-makers, such as an increase in economic growth, the reduction of social inequalities, and improvements to the environment. For instance, diverse populations are at significant risk of being disproportionately affected by government policies due to the compounded effects of cumulative vulnerabilities these populations experience during their lifetimes, such as poverty, stigma and discrimination, and lack of access to health and social resources such as information.

A large body of public policy analysis is devoted to retrospective analysis (evaluation), which tries to understand the causes and consequences of policies after they have been implemented (Tsoukias et al. 2013). Evaluation plays an important part in organisational learning, identifying and sharing different practices. Thorough evaluation also identifies unintended and unexpected consequences, which also need to be taken into account. It provides an opportunity to receive stakeholders' feedback and requests for change. Good evaluations should be based on sufficient data and opinions of stakeholders and actors who are (directly and indirectly) affected by public policies on the EU, National or local levels.

According to the EC report 2.10.2013 COM (2013), "Evaluation is a key *Smart Regulation* tool, helping the European Commission to assess whether EU actions are actually delivering the expected results". It seeks answers to questions like:

- (i) Have the objectives been met? (Effectiveness);
- (ii) where the costs involved justified, given the changes which have been achieved? (Efficiency);
- (iii) Do the actions complement other actions or are there contradictions? (Coherence);
- (iv) Is the EU action still necessary? (Relevance); and
- (v) Can or could similar changes have been achieved without EU action, or did EU action make a difference? (EU added value).

Equally important in policy analysis is the role of prescriptive analysis (impact assessment carried out at the early stages of policy development), which encompasses the forecasting of consequences if policies were to be implemented and prescriptions about which policies should be implemented. Scientific knowledge is a central influencing variable in the shaping of ideas, applicable particularly in complex policy problems which incorporate a high level of



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## D6.1 Public Policy Decision Support Framework

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(scientific) uncertainty. The commitment to evidence-based policy making approach helps to make well informed decisions about policy programmes and projects by putting the best available evidence from scientific research at the heart of policy development and implementation, this attempt extends the idea of governing based on facts (Davies 2004).



### 3 Literature Review

#### 3.1 Public Policy Analysis and OR Methods

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), perhaps, the best known method for evaluating public policies among both practitioners and researchers, despite some recent criticisms (Ackerman and Heinzerling 2004; Adler and Posner 2006), and cost effectiveness analysis (Dunn 2012). Challenges in those analyses involve how to properly monetize all costs and benefits.

Some limitations of traditional OR methods, such as an overreliance on quantitative data and the use of an expert mode of analysis (Franco and Montibeller 2010), led to the development of problem structuring methods (PSM's). See (Mingers and Rosenhead 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, important intangibles 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).

Much has been written on the complexity of public policy problem situations, which 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?", other benefits typically include lower development effort, higher computational efficiency, and higher transparency.

Since policies are designed to address problems in society, the problem must be kept in mind as the foundation to any policy analysis both if the intent of the analysis is prescriptive or evaluative. 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.

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. The use of a formal methodology for identifying the key variables and links in a complex problem situation may enhance the possibility of reaching a better problem structuring and system dynamics model.

PSMs 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) 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.

### 3.2 System Dynamics Modelling

Another sub-field of OR that has made significant contributions to policy making is system dynamics, see, e.g., (Forrester 1992; Morecroft 1988; Zagonel and Rohrbaugh 2008). In spite of a wide range of applications using system dynamics, most models are created in four stages. Although system dynamics models are mathematical representations of problems and policy alternatives, it is recognized that most of the information available to the modeller is not numerical in nature, but qualitative (Forrester 1992).

By examining the system dynamics modelling process, it is clear that the use of qualitative data is not just appropriate but essential to facilitate the conceptualization and the formulation stages of the modelling process. The four stages of modelling are outlined below, see also (Randers 1980):

- 1- The conceptualization stage (problem definition and system conceptualization): Sterman (2000) recognizes the need to access the client’s mental database, and the written database during the problem definition process.
- 2- The formulation stage (model formulation and decision dynamics): positing a detailed structure and selecting the parameter values, can also contain elements of qualitative data. As, “Omitting structures or variables known to be important because numerical data are unavailable is actually less scientific and less accurate than using your best judgment to estimate their values” (Sterman 2000). Nonetheless, this is the area in which system dynamics practitioners have questioned the use of qualitative variables.
- 3- The testing stage (model testing and evaluation): Model testing should draw upon all sources of available knowledge. The model must not contradict knowledge about the structure of the real system. Structure verification may include review of model assumptions by domain experts or by comparing model assumptions to descriptions of decision making and organisational relationships found in relevant literature.
- 4- The implementation stage (policy analysis and model use): Testing the model’s response to different policies and transferring study insights to the users of the model in an accessible form. The interpretation and use of simulation results by policy makers pose several important challenges associated with understanding the many types of judgments needed during the model-building process, and the judgments needed to assess and use the output of the model (Andersen and Rohrbaugh 1992).



However, 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 dynamics practice through the development and testing of reliable formal protocols that can be replicated and generalized (Luna-Reyes et al. 2003).

### 3.3 Decision Analysis

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). 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.

Stakeholder analysis to satisfy those involved with, or affected by the decision, is also important to show that the intervention has followed rational, fair and legitimate procedures. 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).

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.

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. 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). There is a lack of operational and/or formal methods for addressing the cognitive activity of designing policy options or alternative actions to be taken. 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.

### 3.4 The Adopted Policymaking Process Model

For the purpose of this research, 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”.

The decision-making process is defined as the cognitive process of selecting a course of action from among multiple alternatives, producing a final choice. 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 on public policy decisions is hard to come by.

Building up on different policy-making process models from literature, we introduce a process model for policy-making, which is divided into three stages: the problem identification stage, the policy formulation stage and the policy implementation stage. The model acknowledges the continuous nature of the process, indicating that policy-making is an ongoing, continuous process that requires continuous assessment, evaluation, and reaction.

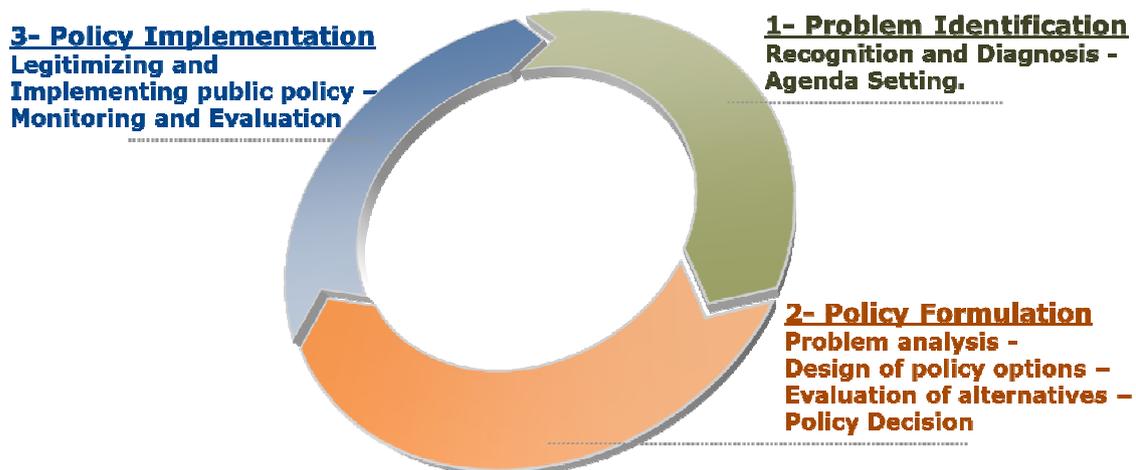


Figure 3 : Policy-making Process Model

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



## 4 Decision Support Framework for Public Policy Development

In Figure 4 we present a framework for decision support for public policy development. The framework maps decision support methods and techniques to the activities (tasks) indicated in the policy formulation stage of the process model discussed in section 3.4.

The framework contains a set of interrelated policy analysis activities, listed below, which may be decomposed into sub-activities.

1. Policy problem structuring and modelling – using problem structuring in terms of a causal graph, a topology of causalities connecting the problem variables. Causal mapping is a soft OR modelling method described in details in section 4.1.
2. Design of policy options through simulating policy consequences and possible future scenarios – using scenario planning approach and the analytical capabilities of the causal mapping method.
3. Policy decision after evaluation of policy options – using MCDA and preference elicitation methods to define a common policy appraisal format.

Furthermore, channels conveying data or objects are related to activities. Two types of channels are:

- Input (arrow from left) / output (arrow to right): describes what knowledge or object is input/output of an activity.
- Resources (arrow from below): 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 work done. Thus, the arrows in Figure 4 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.

In Figure 4 the main activities are described along with the underlying methods and the tools to be developed for the Sense4us toolset.

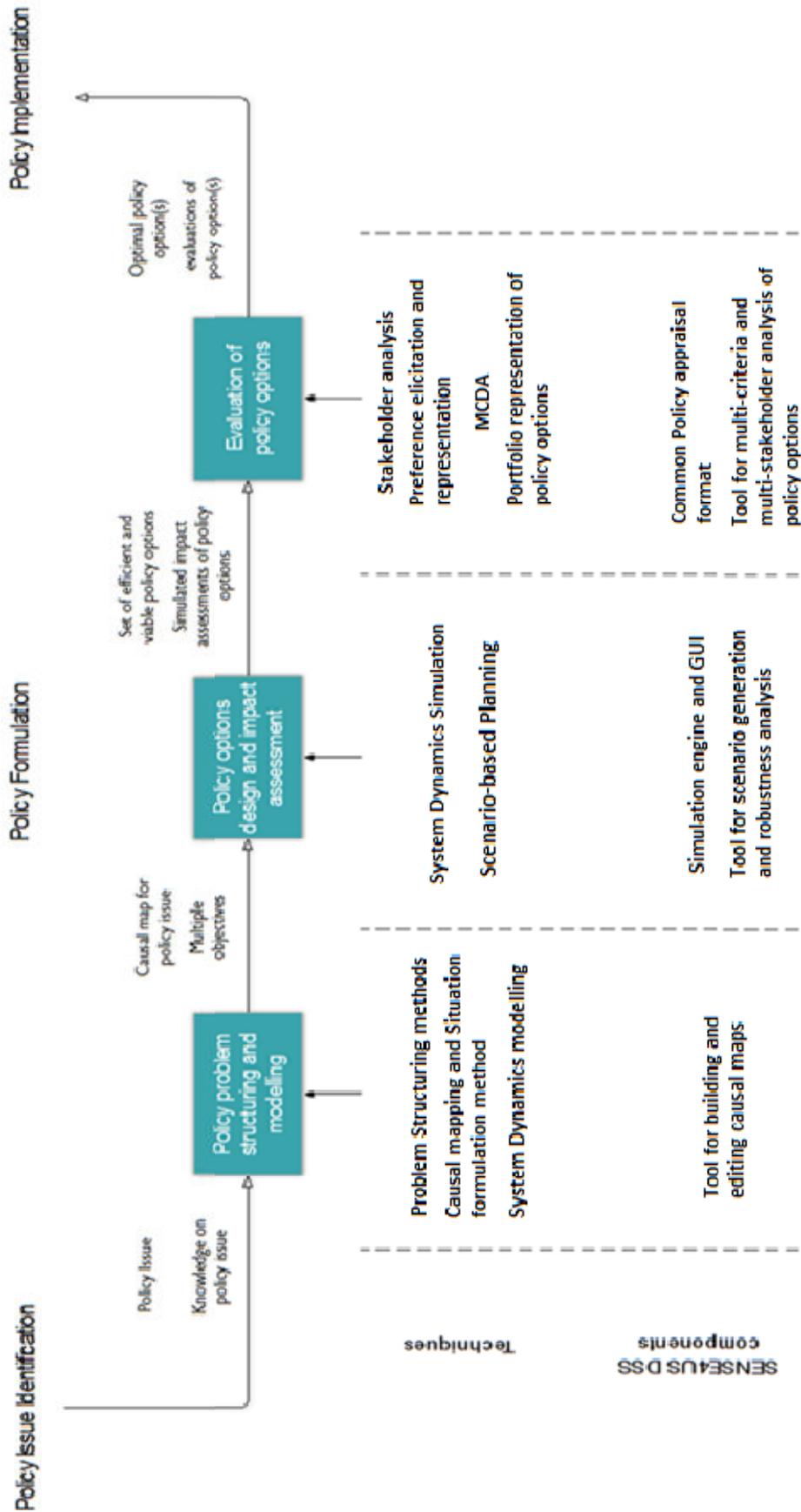


Figure 4 : Decision Support Framework



### 4.1 Policy Problem Structuring and Modelling

The manner in which a problem is set or framed constrains solution and generation of action alternatives. In the approach selected within the Sense4us project, we construct a model of the problem that is adequate for its solution in a graphical representation, a causal diagram that maps all relevant problem variables and defines their interdependencies. In addition, multiple perspectives of the problem from different actors can be represented and analytically debated for improving the decision-makers' understanding of the problem situation and sharing it with other decision-makers. Goals for different actors of the problem can be defined to facilitate negotiation and compromises needed.

The approach is based on the "Causal mapping and situation formulation" method developed by William Acar (Acar 1983). 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, change transfer coefficients, time lags, minimum thresholds, status-quo level of the system, current state of the system, and goal vector showing the targeted changes in outcome variables relative to status-quo values, it can be one-dimensional or multi-dimensional..

The rich computational semantics of Acar's causal mapping approach support automated modelling and simulation in ways that other varieties of cognitive mapping and causal mapping do not. The method enhances the causal mapping with rich computational properties by including indications not only of the 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 available historical data to produce forecasts.

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 negotiate 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:

- (a) Major assumptional analysis (validity of the major aspects of the graph elements and relationships); and
- (b) 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.

- (a) Scenario simulation: running change scenarios on the graph – transfer of change from origins throughout the network. (see section 4.2)
- (b) Goal negotiation analysis: Goal feasibility and compatibility of goals (existence of a scenario to realize a goal or goals jointly). Effectiveness or efficiency – expression of outcomes in comparison with objectives.



A causal diagram for the policy problem situation can be constructed in one of the following ways:

- Defined by a single user, the policy analyst or a domain expert;
- Developed as a joint model of the problem through a synthesis analysis of multiple users' subjective views representing different vantage points. A public policy problem is a complex situation that has to be viewed from several angles simultaneously in order to be assessed. Views of different actors neither coincide nor are altogether unrelated. An overlap must exist in choice of variables and links. Reality is somewhere between the two extremes of: a single problem definition to be agreed upon by all involved parties and disjointed pieces of insight.
- Derived from qualitative data analysis of verbal descriptions of the problem using Natural Language Processing (NLP) and Text analysis techniques. Key information sources for a public policy problem include: (i) Public policy evaluations and impact assessment reports from governmental institutions' websites; (ii) Reports from industry, research institutions and NGO's; and (iii) Published literature (mainly from refereed journals). Causal diagrams may be redundant or insufficient at capturing the richness of information contained within verbal descriptions. In addition, the subjectivity associated with diagram drawing by multiple users makes the process a source of potential conflict. While constructing those diagrams by using text analysis could be a more objective way for diagram drawing based on scientific evidence.

The phase of diagram construction and analysis is a purely qualitative modelling process. After structuring a qualitative model, then the structure is improved quantifying the change transfer channels. 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.

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 model intended to be used by policy makers.

The design conditions or requirements 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 analyzing 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, tactic, strategy, strategic flexibility, strategic consistency ... etc; and
- (vii) conceptualization: employing OR concepts such as notions of "feasibility", "probability", "cardinal utility", "optimality" and "linearity assumptions".



In order to support this activity Sense4us project aims to build a web-based tool for constructing a causal mapping model of the problem. The tool should provide a friendly GUI for users to provide required inputs, a data format for storing built models and parsing them to the simulation engine (see section 4.2), and finally the component for visualization of constructed models.

### 4.2 Policy Options Design and Impact Assessment

The analysis of change scenarios (Schoemaker, 2002) allows the design of strategies to take place in the messiness of the situation. 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 “Causal mapping and situation formulation” method is a powerful tool for scenario-driven planning. A policy proposal (action alternative) is represented by a scenario of change from the status-quo level of the system. A base line scenario is defined with initial values for the problem’s key variables with zero initial relative changes. 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 transfer 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.

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.

In addition to the following notions captured in the causal mapping method and classified as analysis of compatibilities and feasibilities:

- “Optimality”, relating willed scenarios to the level or degree to which the goal vector is realised (Cardinal utility).
- “Reachability” to goal components from the graph’s sources of change.
- “Dominance” reducing the number of scenarios.
- “Resource constraint”, cost of input triggers of certain magnitude at a node. Triggering a scenario may impose on the controlling actor the supply of funds and resources. That should be also taken into account when tabulating the potential moves of the other actors.
- “Goal feasibility”, (feasible and infeasible goals).
- “Goal compatibility”, goal vectors of different actors is compatible if a scenario can be found to realize them jointly.

The simulation is run upon the policy problem model (causal map) defined at the previous activity, whereas the set of objectives 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.

To support this activity the Sense4us DSS is equipped with a simulation engine and a tool for scenario generation. 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 implemented scenarios and a way of sorting them according to the impact assessments.

### 4.3 Evaluation of Policy Options

At the final activity “Evaluation of policy options” designed policy options are comprehensively evaluated. The evaluation of the performance of policy options is then guided by a decision analysis approach, requiring a relevant MCDA model, a method for policy makers’ and stakeholders’ preferences elicitation and a mechanism for utility estimation. A decision analysis toolbox will be designed taking into account the many potential stakeholders and possibly many decision-makers with differing preferences and a portfolio representation of policy options.

There are three main tasks in structuring MCDA evaluation models: the *representation of objectives* in a value tree, *the definition of attributes* to measure the achievement of objectives and *the identification of decision alternatives* (Franco and Montibeller 2011).

The multi-criteria analysis component requires defining common policy appraisal format, whose function is threefold: 1) to serve as a criteria model for policy appraisal, 2) To prescribe a structured procedure for policy appraisal, 3) to define a data format for a policy option appraisal.

Additionally, having preferences elicited in a structured way enables further stakeholder analysis. Such analysis allows identifying and locating conflicting interests, estimate potential controversy and conflict- proneness for a given policy. Finally, portfolio representation of policy options enables defining balanced and consensus policy options. This lays grounds for the structured negotiation process (see the project DoW: Task 6.5 Structured Negotiation).

The multi-criteria analysis component requires defining common policy appraisal format whose function is threefold: 1) to serve as a criteria model for policy appraisal, 2) To prescribe a structured procedure for policy appraisal, 3) to define a data format for a policy option appraisal. The stakeholder analysis component requires a similar format for profiling stakeholders. The aforementioned methods are to be implemented as web-based computer tools, requiring a GUI, an evaluation engine and service (which partly exists from previous development projects), and a database for storing input models and their evaluation results.



## 5 Computer-Based DSS for Policy-Making

### 5.1 Requirements for a DSS for Public Policy Development

In order to create an effective DSS that assists policy making process, it is expedient to apply the system integration principle. The factors determining the requirements for the public policy making DSS are as follows:

- 1) Principle model of the policy decision process (model section 3.4).
- 2) Methods for implementation of its components (the rational composition sets of methods are to be compiled for each component of the model).
- 3) Decision-maker(s), stakeholders and the relationships among them.

We started with determining the primary requirements for the decision support system for public policy making from three perspectives: Information requirements, Processing requirements and Technical requirements.

#### ***Information requirements***

“The emergence of inter-networking technologies and electronic markets provides an information rich but analysis poor environment for strategic management” (O’Brien 2002).

Information requirements for decision making are derived (or should be derived) from the management control system of interest. In case of public policy decision-making, we have decisions for which adequate models cannot be constructed. Research is required to determine the information requirements for this type of decision-making.

In this context a review of policy making literature and strategic theory is appropriate in that it can provide a basis for building an information requirements framework.

#### ***Processing requirements***

The design of a “simulation tool” for policy decision support needs to take into account the contexts of the process of policy development as it involves different entities and influenced by different factors. Formulating and understanding the situation and its complex dynamics, therefore, is a key to finding holistic solutions.

“The messiness of reality requires a shift from problem formulation to situation formulation” (Acar 1983). Taking into consideration that situation formulation is a group affair, and then user management and collaborative editing are two requirements for the modelling tool.

Comprehensive Situational Mapping (CSM) is a systematic approach to problem structuring, using the Causal mapping method. CSM makes explicit multiple decision-makers’ cognitive understanding of the problem in an integrated causal semantic network or causal map. CSM provides a basis for a structured process approach to policy formulation that integrates the quantitative modelling approach of operations research and intuitive dialectical process consulting. CSM’s structured approach provides the processing requirements for a public policy DSS and a knowledge representation framework (Druckenmiller et al. 2009s).

#### ***Technical requirements***

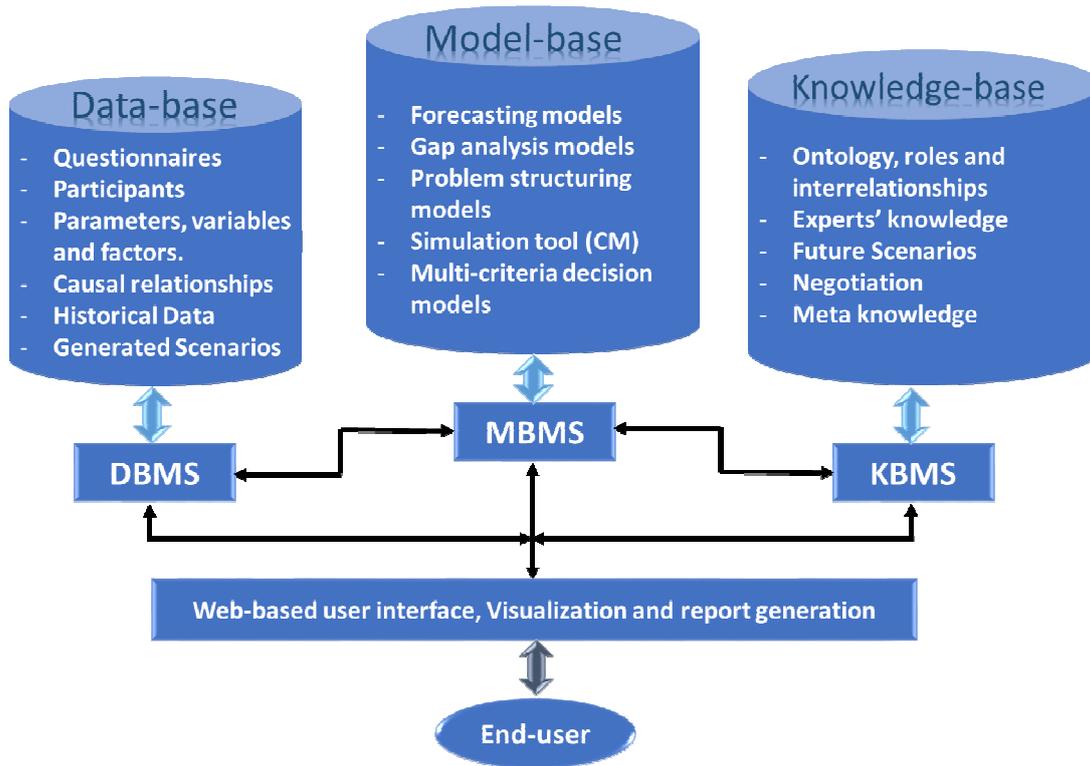
A mathematical model is a deliberate act of representing a problem we are concerned with in a “scientific form”. The usefulness of mathematical models lies in the fact that they allow us to test real world behaviour in an artificial setting, thus being easy and inexpensive to perform in repetition. With ever-increasing computer power we are able to deal with increasingly large and complex data sets. The use of systems dynamics simulation models can



allow us to capture the complexity of policy problem situations. Dynamic simulation allows us to observe the behaviour of a modelled system and its response to interventions over time, and dynamic simulation models 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. Repeating this process one can move through time step-by-step over any desired time interval. Simulation aids our capacity to make predictions of future states. As long as the model describes reality with sufficient accuracy, the modelling process and its outcomes can be used to improve our understanding of the problem as a necessary step towards affecting sustainable and effective change.

Additionally, systems modelling and simulation supports policy analysis and evaluation. System dynamics modelling consists of qualitative/conceptual and quantitative/numerical modelling methods and the models are causal mathematical models (Sterman 2000). The first step in any system dynamics modelling project is to determine the system structure consisting of positive and negative relationships between variables (sometimes called factors), feedback loops, system archetypes, and delays. This understanding of system structure requires a focus on the system as a whole and holistic system understanding is a necessary condition for effective learning and management of complex systems as well as consensus building. These are important goals in their own right, see (Chun and Park 1998; van Groenendaal and Kleijnen 1997).

## 5.2 Proposed Framework for a Public Policy DSS



**Figure 5 : 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.



## 6 Concluding Remarks

The use of a formal methodology for defining and structuring a complex problem situation, by identifying the key variables, links and parameters, enhances the possibility of reaching a more consensual formulation and thus a better system dynamics model for increased problem understanding.

The presented approach is combining scenario planning and MCDA. Scenario planning helps decision-makers in devising strategic alternatives (policy proposals) and thinking about possible future scenarios, while MCDA can support an in-depth performance evaluation of policy proposals as well as in the design of more robust and better options. In general, further research on how scenarios are constructed and how to address issues of robustness in scenario planning is needed.

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.

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.

In the outlined decision support framework, we aim to involve the end user in all stages of the modelling process by providing a user-friendly interface for data input. The proposed modelling method can be used as a training technique on real policy problems, thus combining theory and practice.



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## APPENDIX I

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### 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<sub>2</sub> 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.

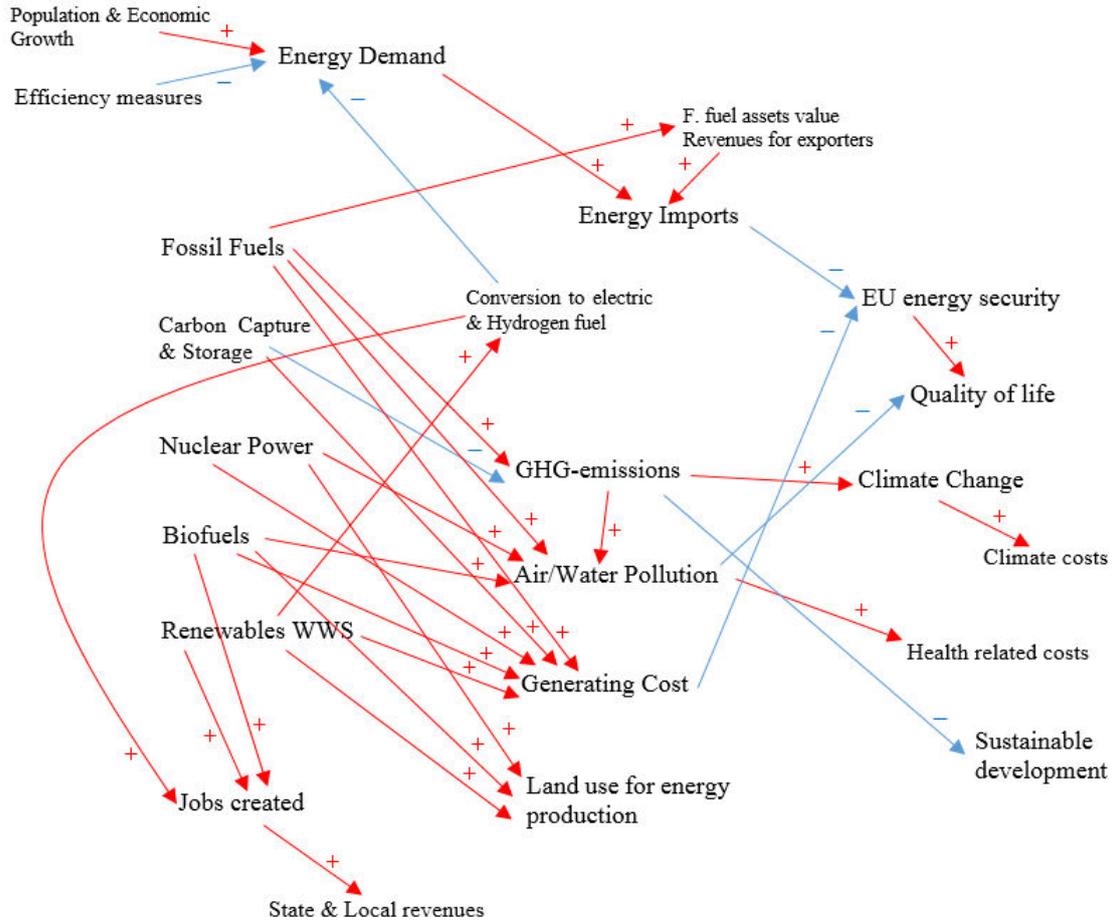


Figure A1 : A qualitative causal diagram of the problem