Policy Modelling and Simulation Tool

A Simulation Tool for Assessment of Societal Effects of a Proposed Government Policy

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List of Abbreviations

<Abbreviation>	**<Explanation>**
API	Application Program Interface
DSS	Decision Support System
GUI	Graphical User Interface
EC	European Commission
IA	Impact Assessment
ICT	Information and Communication Technology
MCDA	Multi-Criteria Decision Analysis
Sense4us	Data insights for policy makers and citizens (this project)
URL	Uniform Resource Locator (web address)
WP	Work Package

Executive Summary

The deliverable (D6.2) presents a prototype for a policy-oriented modelling and simulation tool that allows users, through a web-based, user-friendly interface, to build a systems model of a public policy problem situation using a graphical representation of the involved actors, the key variables, control flows and causal dependencies. A quantitative dynamic simulation model of the structured problem is used to simulate the system behaviour and responses to changing external factors and policy interventions over time. The tool supports the design of policy options and integrated impact assessment in terms of social, economic and environmental impacts.

The proposed modelling and simulation approach aims to provide: (i) better understanding and transparency by clarifying and sharing the modelling assumptions; (ii) an evidence-based policymaking by bringing facts and abstractions from scientific and experts' knowledge into the modelling process; and (iii) incorporation of the newest management technologies into public decision-making processes, including: cognitive strategic thinking, scenario planning and participation.

Task

The design of an ICT tool for policy makers from the different EU policymaking levels that assists public decision-making processes through participatory modelling of a public policy problem, simulating and visualising the consequences of possible future scenarios and the societal impacts of alternative policy (decision) options.

Design Objectives

1- User-created policy scenarios: Models and simulations are often perceived as black boxes, unintelligible to the users. Allowing users to build "own" models for the policy problem to ensure that policy decisions are based on deep understanding and transparency.
2- Integrated, customizable and reusable models: Defining proper modelling standards, procedures and methodologies to allow model interoperability to create more complex or wider perspective models using existing components or models (blocks) and to ensure long-term thinking by incorporating time aspect into the simulation model.
3- Engagement of decision-makers and stakeholders (even without domain expert skills) in a participatory modelling process.
4- Easy access to information and knowledge creation in order to reduce uncertainty: integration to other work packages to support problem structuring using inputs from WP4 and WP5. It is of interest to see how the information obtained from open data sources and analysis of political discussions on social media and blogs (all available within the Sense4us toolkit) contribute to increased problem understanding.
5- Model validation: in order to ensure the reliability of the model and, consequently, of policies. A model is valid if it is built using the most relevant components and sub-models and is able to reproduce historical behaviour.
6- Interactive simulation: the use of animations and visualization techniques to display the model operational behaviour graphically as the model runs over time.
7- Output and feedback analysis: learning from output analysis, being able to provide a feedback on the simulation process or on the initial modelling assumptions and thus synthesizing new knowledge on the system, when ultimately, a satisfying result has been achieved or when a complete understanding of the system has been gained.

Introduction

Much has been written about the complexity of public policy decision-making problems. Those responsible for creating, implementing and enforcing policies are required to make decision about ill-defined problems occurring in a rapidly changing and complex environments characterised by uncertainty and conflicting strategic interests among the multiple involved parties [1] [2].

"Policy Modelling and ICT-enabled Governance", has emerged as an interdisciplinary umbrella term for a number of research fields, technologies and applications with a common goal of improving public decision-making in the age of complexity and has recently gathered significant attention by governments, researchers and practitioners. It brings together two separate worlds: the mathematical and complexity sciences background of policy modelling and the sustainability, service provision, participation and open data aspects of governance [3].

The ability to detect problems and emergencies, identify risks and reduce uncertainties on the possible impacts of policies are among the key challenges facing the policymaking process. Simulation and visualization techniques can help policy makers to anticipate unexpected policy outcomes. The focus of this study is the prescriptive policy analysis, the impact assessment (IA) carried out at early stages of policy development. This study is done as part of the decision support framework for policy formulation[1] described in D6.1.

In order to conduct a robust and relevant IA that implements the principle of sustainable development, it is required to determine the social, economic, environmental, organizational, legal and financial implications of a new policy [4]. In addition, there are certain key aspects which should be present in order to define the scope of the policy analysis, including:

- (i) Objective(s) of the policy analysis,
- (ii) Space or Geographical area: (global, regional, national, sub-national and local),
- (iii) Time (short, medium and long-term),
- (iv) Types and sectors of the related governmental activities,
- (v) Power (participation of actors), and
- (vi) Engagement of stakeholders.

The impact assessment of policy proposals remains a challenge, since the effects of the alternative policy options are delayed in time and the ultimate impact is affected by a multitude of factors. The following questions have to be dealt with in a transparent manner and from early on in the decision-making processes:

- What is the main purpose(s) of the policy?
- What is the context of the policy (Influencing factors)?
- What are the relevant ways of intervention (policy instruments)?
- What are the relevant impacts which require further analysis?
- Who are relevant stakeholders and target groups which should be consulted?
- What are appropriate methods to assess the impacts and to compare the policy options?

Before proposing a new initiative, the European Commission (EC) assesses the need for EU action and the potential economic, social and environmental impacts of alternative policy

[1] Policy formulation: standardizing or rating, the proposed policy as a viable, practical, relevant solution to the identified problem. The development of pertinent and acceptable courses of action dealing with public problems is an essential part of any policymaking process.

options[2]. Planning of IAs is communicated to the public via roadmaps, consultation of stakeholders and public online consultations including annual revisions of the IA guidelines, in addition, final IA reports are made public[3]. IAs are prepared for these initiatives expected to have significant impacts, including: (i) legislative proposals, (ii) non-legislative initiatives (white papers, action plans, financial programmes, negotiating guidelines for international agreements) and (iii) implementing and delegated acts.

As early as the 1960s, Easton (1965) envisioned the 'Systems approach' as a framework and model to address the central problem of empirical political study [5]. Such a framework assumes that: (i) political interactions in a society constitute a system; (ii) the system must be seen as surrounded by physical, biological, social, and psychological environments, i.e., political life forms an open system; (iii) 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: 'Actors', 'Variables' (the inputs, the processes, the outputs, and the feedback), 'Unit of analysis', 'Level of analysis' and 'Scope' [5]. Introducing the Systems thinking to the policymaking process allows for both a holistic and narrow examination of the public policy problem, the environment, actors and abstract and concrete components.

For purposive, intelligent action, understanding and safety needs, etc., normal people need representations of their action context (mechanisms of external and internal factors affecting decisions), including one's own and other actors' actions. Such internal representations have been called variously mental models, causal or cognitive maps, meaning in general: "*mechanisms whereby humans are able to generate descriptions of system purpose and form explanations of system functioning, observed system states, and predictions of future system states*" [6].

Causal maps can be developed by individual decision-makers to model the structural systemic elements of their situation and show how change is propagated through the system. "*What causal maps contribute is a visual, mental imagery-based, "mind's eye" simulation of the system's behavior for system analysis and social communication*" [7]. It is obvious that such maps can be useful for analysing, developing and sharing views and understanding among key actors also for creating some preconditions for intervention.

Large-scale causal maps can be used to model complex policy problems, representing what a government decision-maker thinks about the drivers, barriers, instruments and consequences of change achieved by a certain policy proposal. Data for building such maps are acquired from the decision makers or from other sources including the WP4 Linked Open Data Search tools, WP5 Social media Analysis tools, and documents such as: previous policy evaluation or impact assessment reports, related research literature and reports from research institutes and NGOs.

To deal with the dynamic complexity inherent in social systems and to infer dynamic behaviour, quantitative simulation is required [8][9]. 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.

Stefano et al. (2014), addressed the challenges facing the model-based collaborative governance and the policy modelling issues in practice. As it was revealed by the results obtained in two subsequent EU FP7 projects: the CROSSROAD project and the CROSSOVER

[2] http://ec.europa.eu/smart-regulation/impact/index_en.htm

[3] http://ec.europa.eu/smart-regulation/impact/ia_carried_out/cia_2015_en.htm

project, the authors inferred that the Systems thinking and System Dynamics approach may prove a useful dynamic tool for next generation policy making, which can be applied in conjunction with other modelling techniques to produce hybrid models for public policy analyses [10].

There exist several software packages[4] for processing causal data, graphing and analysing causal maps. In addition, there exist software packages[5] for quantitative system dynamics simulations, in a strict sense for system performance analysis and prediction. None of them, however, is dedicated to Policy analysis and decision support for policymaking. There is a lack of policy-oriented modelling and simulation tools, whereas the existing econometric models are unable to account for human behaviour and unexpected events and the new social simulations are fragmented, single-purposed, suffer from lack of scalability to the macro level and require high level of technical competency by users.

The opportunity we have here is to create a policy oriented tool that supports systems-based modelling of public policy problem situations and simulation-based impact assessment.

In these contexts we believe that the design of a policy-oriented modelling and simulation tool, as a main component of the Sense4us Policymaking DSS, should be based on:

- **(i) 'Systems approach' to the study of public policymaking;**
- **(ii) User-created policy scenarios;**
- **(iii) Graphical representation of complex problem situations using causal maps as both a knowledge representation technique and Systems analysis tool;**
- **(iv) Scenario Planning and Dynamic simulation modelling**

This allows for a problem definition that: (i) reflects the systemic nature of most of central policy areas, (e.g., Energy, Financial Systems, Innovation/Growth), for which a regulation/policy needs to be based on a view of the system as a whole; and (ii) provides a visual problem model that clearly communicates the policy makers' thoughts and can bring together different policy actors. The main rationale is to support a flexible, informative and a more rational and structured policy making process identifying effective policies by gaining insight from analysis of the system. The argument behind the use of a graphical representation is simplifying and summarising the decision maker's knowledge and information gathered from various online sources about a social, socioeconomic or sociotechnical system and visually simulates the system behaviour and responses to interventions over time. Thus, the causal mapping graphical representation can be used as a contextual framework that highlights knowledge gaps, guides information searching and models the search results from various online and other work packages sources.

The current technical specifications of the implemented online simulation tool is given in Appendix I. Specifications will be updated as development proceeds and are published at Google Docs[6] and the online GUI for the tool is reached through the URL http://dev1.egovlab.eu:4001/.

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[4] For example, CMAP3 – Comparative and composite causal mapping (http://www2.uef.fi/fi/cmap3) and Decision Explorer (http://www.banxia.com/dexplore/index.html).

[5] For example, STELLA (http://www.iseesystems.com/).

[6] https://docs.google.com/document/d/1fBr-pcJLioMccZzf3_VGGPyOnpLJg3c12gdfDbMquPo/edit#

1 Model Description

This section describes our proposed policy-oriented modelling and simulation approach, based on the 'Causal mapping and situation formulation' method, defined by Acar, W., (1983) as a stand-alone method for problem structuring that ties in with dynamic systems simulation as well as the statistical concept of causality [11][12]. The approach defines modelling standards and a procedure for designing integrated, reusable and customizable models. The proposed tool allows users to build a systems model of the policy problem situation, which consists of three main components: Actors, Variables, and Change transmission channels (links).

The user starts from a check-list model of the policy problem, created by identifying the main issues, objectives, key players, relevant policy instruments and direct and indirect impacts. These elements are identified by categorizing the results of the information searching processes done by WP4 and WP5. The user then starts the model building process by adding and linking these elements to a graphical representation. In the resulting model, actors are coupled with their decision variables and sources of change are linked to their consequences. The simulation relies on defining indicators and measures for the different variables and obtaining accurate and enough data.

1.1 Actors

Actors are the governmental bodies (organizations, institutions, committees or individuals) involved in the decision-making process whether executive or legislative. In addition to the potential interested parties and stakeholders including governmental administrations, businesses and citizens target groups. The actors can be classified as:

- <u>Official actors</u> – including both:
  - o <u>legislative actors</u> (Parliament committees, political parties) and
  - o <u>executive actors</u> (Governmental bodies, departments and institutions, chief Executive, staff/officials, agencies, bureaucrats and civil servants)]
- <u>Unofficial actors:</u> [Interest groups, political parties, citizen representative bodies, NGOs, industry/trade Unions, think tanks, media].

		
Executive actor icon	Legislative actor icon	Unofficial actor icon

Table 1 : Simulator icons for actors

1.2 Variables

Variables are factors or events idealised as quantitative variables, or quantified using value scales, so that it is meaningful to talk about change in the form of increases or decreases in their levels. Variables represent abstract or concrete components of the system or the external environment that structure, constrain, guide, influence and indicate impacts of actions taken by actors. The scope of the model is defined by the involved actors and the variables of interest. The system analysis must consider the involved actors as coupled with either an abstract or concrete component. This way, the influence of the actor within and upon the system clearly reveals itself. An actor has control over his decision variables and interests in some outcome variables.

Independent variables (sources of change)

Controllable (decision) variables: These variables are under control of one or more of the actors using various policy instruments. Scenarios of change in these variables represent action alternatives (policy options). These variables reflect the allocation of natural, human and capital resources, the regulatory role of the government, regional and international cooperation and are represented in our model by the following categories and sub-categories of policy instruments under which controllable variables are defined. Table 2 shows these categories and the corresponding icons used for the graphing of the model.

1. Economic Instruments: **1.1 Financial instruments:** 1.1.1 Public expenditure, investment or funding 1.1.2 Public ownership 1.1.3 Subsidies	
1.2 Fiscal instruments: 1.2.1 Taxes, Fees and User charges 1.2.2 Incentives 1.2.3 Loans / Loan guarantees	
1.3 Market instruments: 1.3.1 Property rights 1.3.2 Contracts 1.3.3 Tradable permits / Certificate trading 1.3.4 Insurance	
2. Regulatory Instruments: 2.1 Norms and standards 2.2 Control and enforcement 2.3 Liability	
3. Informational Instruments: 3.1 Public information centres 3.2 Sustainability monitoring & reporting 3.3 Public awareness campaigns 3.4 Consumer advice services 3.5 Advertising & Symbolic gestures	
4. Capacity-building Instruments: 4.1 Scientific research 4.2 Technology and skills 4.3 Training and employment	
5. Cooperation Instruments: 5.1 Technology transfer 5.2 Voluntary agreements	

Table 2 : Simulator icons for policy instruments – controllable sources of change

Uncontrollable variables: These variables are external factors and constraints not under control of any of the actors. Scenarios of change in these variables represent the possible futures. Uncontrollable variables are classified in our model under the following categories in Table.3:

1. Drivers and barriers The drivers and barriers of change, are either associated to the political context (e.g., the political ideology and strategic priorities of the government of the day, the preferences and demands of politicians) or the economic context (e.g., the availability of resources, the economic growth, the economic climate, current and future commitments).	
2. External environment's disturbances and conditions The system representing the policy problem is surrounded by physical, biological, social, and psychological environments that the system needs to adapt to.	
3. Social, demographic and behavioural change e.g., Population growth, immigration, culture, attitudes and behaviours.	

Table 3 : Simulator icons for uncontrollable sources of change

Dependent variables (impacts of change)

Variables representing the consequences of change in the independent variables, are divided into direct impacts, associated with the sources of change, and indirect impacts, associated with the direct impacts. The actors' goals are defined as quantified targeted changes in the impact variables of the impact variables, resulting in a goal vector defined for each of the involved actors. Table 4 shows the different categories of impact variables as related to one of the policy areas.

Economy	Finance	Environment	Community / Social
Energy	Infrastructure	Transportation	Healthcare
Education	Technology	Judiciary and Law	National Security

Table 4 : Simulator icons for policy impacts

Following are impact variables examples to clarify each of the defined categories:

- Economic impacts:

Industry and manufacturing activity – Investment rates – Retail sales – Building permits – New business startups – Stock market indicators – Labour market indicators – Consumer prices (inflation) – Changes in the Gross Domestic Product (GDP) – Income and wages – Imports and exports – Competition … etc.

- Financial impacts:
  General government expenditure, fixed investment, revenue and output – Government deficit and debt – Net Social contributions – Interest rates – Saving rates – Taxes on production and imports – Taxes on income and wealth … etc.
- Environmental impacts:
  Global and EU temperatures – Greenhouse Gases (GHG) emissions – Air pollutants emissions – Ecological footprints – Water pollution – Soil moisture – Hazardous substances in marine organisms – Waste generation and recycling … etc.
- Community / Social impacts:
  Population & Demographics – Living conditions/Quality of life – Poverty – Immigration – Social inclusion – Pensions – Unemployment – Crime – Social protection … etc.
- Energy-related impacts:
  Final/Primary energy consumption by fuel/sector – Energy efficiency – Share of renewable energy – Electricity production/consumption … etc.
- Infrastructure and services-related impacts:
  Freshwater – Sanitation facilities – ICT, mobile cellular and Internet – Paved roads and Road networks – Public facilities – Economic and construction services – Rural areas development … etc.
- Transportation-related impacts:
  Traffic – Air transport, passenger transport and mobility – Motor vehicles – Rail lines, Freight transport – Price indices for transport … etc.
- Health-related impacts:
  Health status (Infant mortality, HIV/AIDS, road traffic injuries) – Health determinants (Regular smokers, consumption/availability of healthy nutrition), Health interventions (health services, Vaccination of children, hospital beds, health expenditure, health promotion) … etc.
- Education and training-related impacts:
  Adult participation in lifelong learning – Low achievers in basic skills – Tertiary educational attainment – Early leavers from education – Early childhood education, Employment rates of recent graduates – Learning mobility in higher education, vocational education and training … etc.
- Science, innovation and technology-related impacts:
  Broadband access – Entrepreneurship – Industry production – ICT investment/added value – Research and Development (R&D) investment/governmental researchers … etc.
- Judiciary & Law / Legal impacts:
  Efficiency/independence of justice systems – Use of ICT for the judicial systems – Judges training on EU laws / laws of member states – Simplicity of EU regulatory environment… etc.
- Security and defence-related impacts:
  Cyber security and information assurance – Defence acquisition and industrial issues – Complex defence programmes - Terrorism, security and resilience … etc.

1.3 Change transmission channels

Links or change transmission channels are cause-effect relationships connecting the model variables, defined by:

a) direction, from an upstream variable to a downstream variable;

b) sign (positive is changes in the same direction or negative if changes are in opposite directions);
c) change transfer coefficient: intensity of the causal relationship in terms of the proportionality ratio of change transfer, how much change is transferred to the downstream variable in case of 1% change in the upstream variable;
d) time lag (if change transmission is not instantaneous) expressed as weeks/months/years; and
e) minimum threshold for the change in the upstream variable (if applicable).

Two types of change transmission channels:

(i) full channel: a double arrow from an upstream variable *X* to a downstream variable *Y*, if *X* is sufficient to induce change in *Y*;
(ii) half channel: a single arrow from an upstream variable *X* to a downstream variable *Y*, if *X* is necessary but not sufficient to induce change in variable *Y.* Half channels from a set of variables such as {*U*, *V*, *W*} to variable *Z, need to be all activated before change can be transferred* to *Z*.

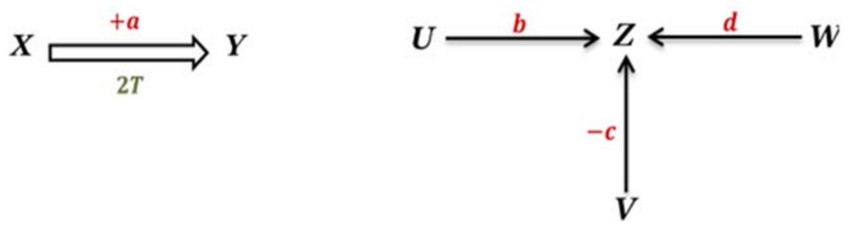


Figure 1 : Change transmission channels

“Additivity” and “Transitivity” are two main characteristics of change transmission in the model that allows running scenarios of change on the causal map. Once initiated in one or more of the independent variables, change is transmitted throughout the network given the transfer ratio and time lag for each channel. For full channels the transmission is automatic, as soon as a variable incurs a change, the channels proceeding from it become activated and transmit to the downstream variables. The same applies for half channels as soon as all half channels converging to a node are activated.

The model is constructed as a causal map or a causal semantic network, (a directed graph, in which variables are represented by nodes, interrelationships are represented by causal links).

- Origins: nodes which have outgoing influences or causal links, but no incoming links;
- Middle nodes: have both outgoing and incoming causal links;
- End nodes: have incoming causal links and no outgoing links.

Sources of change either controllable or uncontrollable are origins of the graph, for a middle node to be a source of change it has to be controllable and all links leading to it have to be time lagged.

In highly connected situations, closed loops of cause–effect relationships may exist. Loops are mutual causal relationships because in a loop the influence of an element comes back to itself through other elements. Simulation of scenarios of change allows analysis of the loop effect over time. A feedback loop challenging the change back to its starting node has to be time lagged. The causal loops in the model structure are checked while saving the model with the time lags of 0 are not allowed. This way, the change in this node at the beginning of a scenario will cause a second wave of change reaching at this node after the time lag; this change is in turn propagated again through the network.

2 Fundamental simulation concepts

2.1 State of the system

The "status quo level of the system" or the *baseline scenario*, is a projection of the characteristics and behaviour of the system at the beginning of the analysis. It is used as a point of comparison.

The model is expressed in terms of percentage change relative to the baseline scenario, thus the initial values of relative change for all variables in the system are set to zero, i.e. the initial state in terms of the relative change is the null vector (0, 0, …, 0).

The simulation runs are based on discrete time points (T_0, T_1, T_2, …, T_n), and the user is required to define a time step T, time period between two consecutive time points as a number of weeks, months or years; and maximum number of iterations (*n*) for the simulation.

The *state of the system* at time T_i is then defined as the values of all variables in the system at time point T_i of the simulation run, given a specific scenario of change.

The *desired state* of the system is given by targeted changes in a set of impact variables of interest to the decision-maker, represented in a *goal vector*. Each actor has a goal vector reflecting the targets of that actor.

2.2 Scenarios of Change

The long-term implications of policy making imply the need to consider the range of possible futures, sometimes characterised by large uncertainties. "Scenarios" are a main method of projection, trying to show more than one picture of the future. Scenario analysis is designed to improve decision-making by allowing consideration of future conditions or outcomes and their implications.

"*The analysis of scenarios of change allows the design of strategies to take place in spite of the messiness of the situation*" [13]. Scenario-driven planning is a widely employed methodology that helps decision makers devise strategic alternatives and think about possible futures. It 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 [14].

A qualitative analysis of the causal mapping model can show the opportunities for policy interventions to achieve targeted increases or decreases in impact variables defined as policy objectives. The policy options represent different combined and controlled changes in the system inputs to produce the targeted outcomes. By quantifying these changes, scenarios of change can be defined as a combination of specified percentage changes occurring at a specific time point or at successive time points. Quantifying the policy goals in the form of a goal vector defined for each actor allows the analysis of these scenarios with respect to goal achievement. In addition, structural analysis of the causal map, can support scenario analysis (e.g., reachability analysis shows the ability of a scenario of change triggered at an independent variable to achieve a particular goal if the goal variable is reachable from this variable).

A "pure scenario" is a scenario of change in one particular independent variable, while a "mixed scenario" is a scenario of change in more one than one independent variable. We also need to differentiate between "alternative futures", scenarios of change in uncontrollable independent variables caused by natural or external forces, and "alternative actions", scenarios of change in controllable independent variables willed by actors.

The alternative futures reflect the concept of "uncertainty": each possible future provides a projection of changes in uncontrollable sources of change, a probability is assigned to each of the possible futures. The alternative actions by actors reflect the different policy options, i.e., the changes of controllable sources of change as policy instruments, given some future circumstances. The user can define as many scenarios of change as needed, using combinations of alternative futures and courses of action by actors. A friendly user interface for scenario triggering is designed to allow creating scenarios. In this way, analysing the behaviour of the system under various conditions yields a much deeper understanding of the problem and supports the design of policy options.

2.3 Goal feasibility and compatibility

The design of policy options can be described in terms of planning of means and resources. The formulation and evaluation of policy options can be addressed by answering questions like:

- What variables are relevant and controlled by actors of the problem and what constraints apply to them?
- What variables are relevant but are not subject to control?
- How do controlled and uncontrolled variables interact to produce an outcome?
- What are the actions needed to generate a desirable state of the system or to block the occurrence of an undesired one?
- What are the costs and benefits of these actions?

Decision-makers at senior levels of government operate within a finite set of available resources and timelines. Furthermore, there are inherent constraints that the decision-maker needs to consider, such as annual cycles for strategic planning, budget, and legislation. Legislative and political imperatives add to the complexity of government policy decision-making and the selection of policies.

For an actor, the triggering of change in one the controllable variables imposes the expenditure of funds and resources. If an actor has the required resources and/or funds available for a course of action that realizes his goals, assuming inactivity of other actors and external environment, then his goal vector is "internally feasible". If the required resources are not available, then there is an intrinsic problem of consistency between the actor's goals and capabilities.

When considering the moves of other actors and the changing external environment, if no pure or mixed scenario can be found to realize the actor's goals, then his goal vector is said to be "infeasible". If it was found as an "internally feasible" goal, then the actor has a problem to synchronize with the other actors. If a scenario could be found to realize the actor's goals, then his goal vector is said to be "feasible". If it was not found as an "internally feasible" goal, then the actor is benefiting from interacting with the whole system in turning potential problems and constraints into opportunities.

The concept of compatibility is connected to the concept of feasibility. Components of a single goal vector, as well as goal vectors of different actors are called "compatible" if a scenario of changes can be found to realize them jointly. Goal compatibility is a graded concept; two goals that can be realised by the same pure scenario are more compatible than two goals requiring a mixture of pure scenarios.

2.4 Tactics and Game theoretic analysis

The competitive analysis aims at establishing counterplans at the earliest time, by anticipating the evolving circumstances and the competitors' moves. 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 the utility each actor has in the alternative courses of action, while accounting for the possible alternative futures.

A *tactic* is simply a sequence of changes triggered at controlled variables by an actor that would help realize his goal vector. A tactic is a course of action logically paired with an alternative future and what other actors might do.

Simulation of the alternative futures would bring up the various vulnerabilities of the system. Then the design of policy options can take place based on the provided insight from analysis of different pure and mixed scenarios of change. Policy options can be viewed as a defensive tactic if the actions taken by actors are subsequent to the change in uncontrollable sources or it can be viewed as an offensive tactic if the actions precede the change in uncontrollable sources.

A policy option can be either the combination of actions taken by the involved actors that may achieve the policy targets in a cooperative decision-making (co-decision legislative) situation; or the sequence of actions taken by the focal actor to preempt/counter natural, external forces and/or other competitors' moves in a competitive decision-making situation.

The Game theoretic analyses are based on the idea of a 'tactic' as a sequence of moves to preempt or counter nature's or other competitors' moves. It then allows either to devise one tactic for the set of actors involved in a cooperative decision-making situation which would yield optimal result in achieving the policy objectives; or to devise one tactic which would yield optimal results for the focal actor in a competitive decision-making situation.

The *effectiveness of a tactic* of an actor is a measure or at least an evaluation of the degree to which it helps him realize his goal. The *efficiency of a tactic* is a measure of the use of resources to realize the goals. Both the tactical effectiveness and efficiency need to be measured in comparison to the competing tactics the actor might choose from and also in connection to the tactics and futures the actor aims at countering or preempting.

The following steps are needed in order to be able to compare the alternative tactics by an actor to counter a scenario of change or to rank different actors in a given scenario of change according to effectiveness and efficiency of their tactics:

1- Define a preference profile for each actor, in relation to policy impacts and goals: a ranking of the goal vector components to allow comparison of tactics based on realising the goals and a preferred change direction in each of the other impact variables to compare tactics based on their side effects in addition to policy targets[7].
2- The time steps required to achieve the targeted change in goal variables and the stability of outcomes can be used to assess tactical effectiveness.
3- Define a *cost function* for changes triggered at the controlled sources of change for each actor. As a default, the cost function can be in the form of a value scale for the cost associated to levels of change in each controlled decision variable, so that tactics can be ranked according to efficiency, (i.e. use of natural, human and capital resources).
4- For each scenario of change, analysis of changes in goal variables can provide ranking of tactics of the different actors according to tactical effectiveness, while analysis of changes in controlled variables can provide ranking of tactics according to tactical efficiency.

[7] For example, the goal vector (0, +20%, -15%, 0, +10%) corresponding to outcome or impact variables V1, V2, V3, V4, V5 respectively. Can be ranked as: V3, V2, V5, V4, V1 or can be given weights showing the relative importance of each goal component as (0, 0.3, 0.5, 0, 0.2)

3 Simulation Process

3.1 Generating Scenarios

The identification and creation of new alternatives is one of the most important aspects of any decision support. If the decision alternatives under consideration are weak, it will lead to a poor choice [16]. Thus, support in the generation of feasible options is important for policy formulation.

The simulation is run upon the policy problem model (causal map), and the set of goal variables with 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 database stores the system state at each time step of the simulation run, for each specific scenario of change. An initially large sample of scenarios generated by, e.g., full factorial design or Latin hypercube sampling, can be a starting point with unsatisfactory scenarios (not realising the goal vector or being dominated) are filtered out, while scenarios deemed efficient (according to some predefined decision rule based upon resource constraints and goal compatibility) are suggested as policy options for further evaluation.

3.2 Graph change analysis

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 tool should provide visualizations of the scenarios and a way of sorting them according to the impact assessments.

The use of discrete time points and a maximum number of iterations for the calculation of change transfer and the system state, allows computation in case of successive lagged changes in sources of change and also makes it possible to trace the change transfer along causal loops without the need for calculating the limit behaviour of the loop. This solves the computational complexity problem of infinite causal loops.

The main assumption for transmission of change is that "the percentage relative change in a downstream variable Y is a linear function of the percentage relative change in an upstream variable X". There can be objections to the basic linearity of the system, but for long-term planning it is important to keep the structure of the model simple. In addition, the definition of time lags, minimum thresholds quantifications of the change transmission channels besides the existence of the half channels add a meaningful dimension of nonlinearity to the model.

Change transfer coefficients are dimensionless, since changes in the model variables are expressed in terms of percentage relative changes (relative to the status-quo level of the variable). Assuming that dX/X represents the relative change in a variable X, then the relative change dY/Y in a downstream variable Y is given by Equation 2.1 for a full channel, where a is the real valued change transfer coefficient for the link XY.

$$\frac{dX}{X} = a\frac{dY}{Y} \qquad (2.1)$$

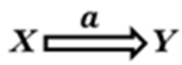


Figure 2 : single full channel example

In the case of multiple channels such that change is transferred to variable *Z* from channels *XZ* and *YZ*, then given that both channels are activated the change is additive according to Equation 2.2.

$$\frac{\mathrm{d}Z}{Z} = a\frac{\mathrm{d}X}{X} + c\frac{\mathrm{d}Y}{Y} \tag{2.2}$$

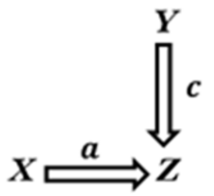


Figure 3 : multiple full channels example

In the general case, given a set of activated channels {X_1Z, X_2Z, …, X_nZ} going into *Z*, then

$$\frac{\mathrm{d}Z}{Z} = \sum_{i=1}^{n} a_i \frac{\mathrm{d}X_i}{X_i} \tag{2.3}$$

For half channels, change transmission is sub-additive. Consider the case of three half-channels all of which have to be activated to allow change transfer to node Z. If t_X, t_Y, t_W are the times at which upstream links XZ, YZ, WZ become activated and t_a, t_c, t_d are the time lags of these links; then times at which the signal to change reaches *Z* from each of the upstream nodes *X*, *Y*, *W*, are: $t_X + t_a$, $t_Y + t_c$, $t_W + t_d$ respectively. Change occurs at *Z* at the latest of the three times. [11]

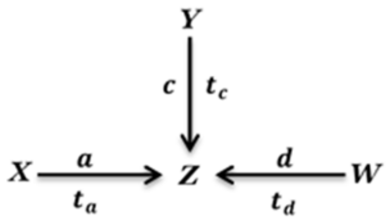


Figure 4 : multiple half channels example

3.3 Data, forecasting and predictive validation

There are historical methods of validation, including: Rationalism – logic deductions from the assumptions are used to develop a valid/correct model; Empiricism – every assumption and output is empirically tested; Positive economist – most important is the predictive ability of the model. Based on these three historical methods of validation, Naylor and Finger (1967) proposed a multistage process of validation consisting of [15]:

- Developing the model assumptions based on theory, observations and domain knowledge;
- Validating assumptions, where possible, by empirically testing them;
- Comparing or testing the input/output relationships of the model against the real system.

<u>Predictive Validation:</u>

The model is used to predict (forecast) the system's behaviour, and then comparisons are made between the system's behaviour and the model's forecast to determine if they are the same. Once validated by reproducing historical behaviour, the model allows understanding of the

ultimate policy impacts, detecting problems and evidencing the emergence of initially unperceived risks, through its ability to infer what will be the likely outcomes of the alternative futures or actions taken by actors of the system.

Simulation of validated models ensures long-term thinking through simulating over long time periods while still being confident on the outcomes. The scenario analysis should be complemented by controlled experimentation based on statistical theory, (e.g., forecasting models and regression models).

Appropriate, accurate and sufficient data are needed for: (i) building the conceptual model – developing mathematical and logical relationships to represent the problem entity for the intended purpose of the model; (ii) validating the model; (iii) performing experiments on the validated model.

The availability of historical time series, allows for validation of the model in order to assess the correctness of the modelling assumptions, before assessing the consequences of the scenarios of change (policy impacts).

Sensitivity analysis:
Changing the values of the internal parameters of the model to determine the effect on the model's behaviour. These parameters are SENSITIVE, can cause significant changes in the model behaviour and should be made as accurate as possible before using the model.

4 Policy Analysis Model building Process

We suggest a step-wise procedure that enables the user to build a causal mapping simulation model for the policy problem at hand and allows to organize the storage and retrieval of the different policy issues, the resulting models, models' components, data sets and simulation runs in the decision support system database. The cases of policy analysis on the sense4us platform are defined as 'policy problems' and several impact assessment models can be defined for each policy problem.

Each policy problem is described and classified using a friendly GUI that takes the form of a questionnaire and is considered as the dialogue subsystem of the DSS. The following steps show the process of defining a policy problem and building search queries to identify elements of the policy model from the various information sources.
Note that:
- The two main elements of the policy model of interest here are:
  1- Actors:
    a) Official actors (executive – legislative)
    b) Unofficial actors (Including interested parties and stakeholders)
  2- Variables:
    a) Controllable independent variables (policy instruments)
    b) Uncontrollable independent variables (external factors and constraints)
    c) Dependent variables (policy impacts)
- The Ultra Low Emission Vehicles (ULEV) Uptake policy problem (described in Appendix III) is also used as an illustrative example:

Step 1. Define a policy problem

A policy problem is defined using a title and an optional short text description by the user and is given an ID by the system.
1- Policymaking level: (EU level, National level, Local level)
2- Geographical area: (A set of EU countries – EU level; A country and a set of local regions – National level; A local region – Local level).

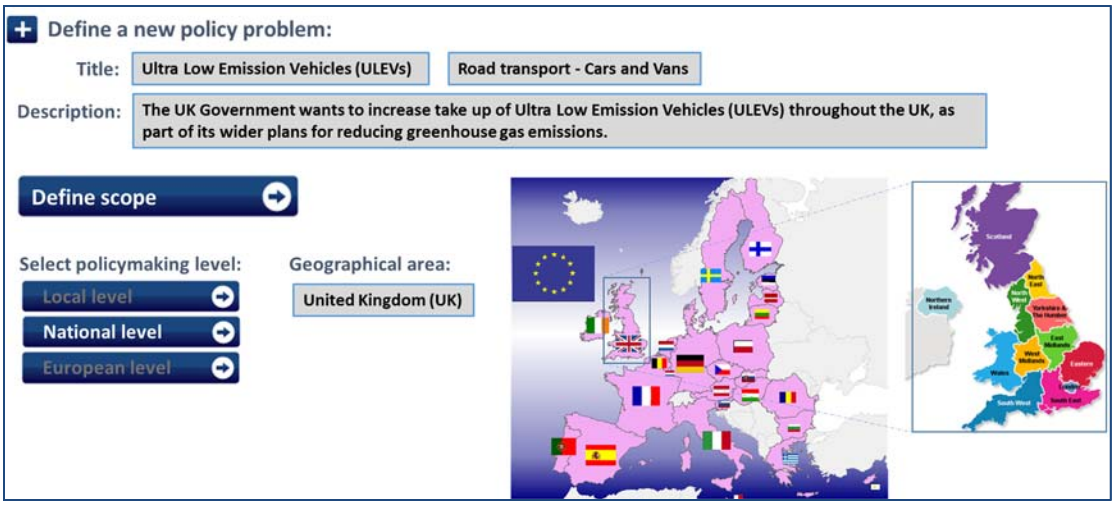


Figure 5 : User interface for defining a new policy problem

Step 2. Define scope of the policy analysis model

The user sets the boundaries of the policy impact assessment, as a guideline for the modelling process and as an output to other tools in the Sense4us toolkit to guide the search processes. This includes defining the objective(s) of the policy analysis, the time aspect of the analysis and the related policy domain or governmental activity (the list here might vary according to the

policymaking level). The aim of this description or classification is to facilitate the query processes to reuse model components from stored policy models, identify trends in groups of policy problems and to provide inputs to the Sense4us toolset to guide the information searching process.

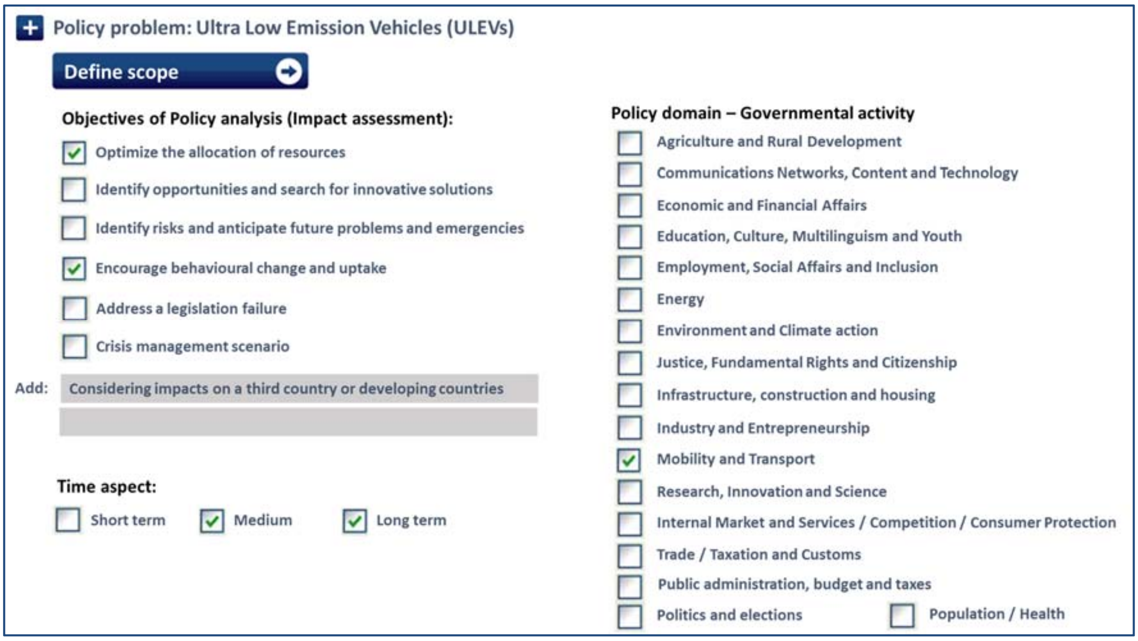


Figure 6 : User interface for defining scope of the policy model

Step 3. Building information search queries and processing of results

There are several possibilities to be investigated through the implementation and development of the user interface on how to build information search queries and data exchange between the different work packages.

- *A basic search using keywords of the policy problem title.* Here, the objective of this basic search is to help the user to identify: (i) the different ways of referring to the policy problem in online information sources; and (ii) the main issues or the sub-problems, in order to make sure that the resulting information model is covering and connecting these main aspects of the policy problem. An example is shown in figure 7, from which we can notice that the Electric Cars policy problem is mentioned using different terms in the information sources and can be divided into four sub-problems using terms of the top results of the basic search.
- *Iterative information searches.* In addition to the search queries built within the WP4 and WP5 tools, the user interface of the modelling tool allows building search queries using keywords of the identified main issues, also allows building queries using single text items (concepts that qualify as model variables). For example, one concept to be searched for surroundings, two concepts to be searched for interlinking using the WP4 LOD search tools or running Twitter searches using the WP5 tools.

Also, concepts from the visualized search results in LOD surroundings map or the SentiCircles can be sent to the policy model when identified by the user as candidate model components.

The information sources labelled in figure 7 are:

- #Evidence: evidence online sources, experts' and scientific knowledge about the problem either mental or written
- #WP4: Linked open data search tools of WP4
- #WP5: Public online policy discussions' Topic labelling and Sentiments analysis tools of WP5

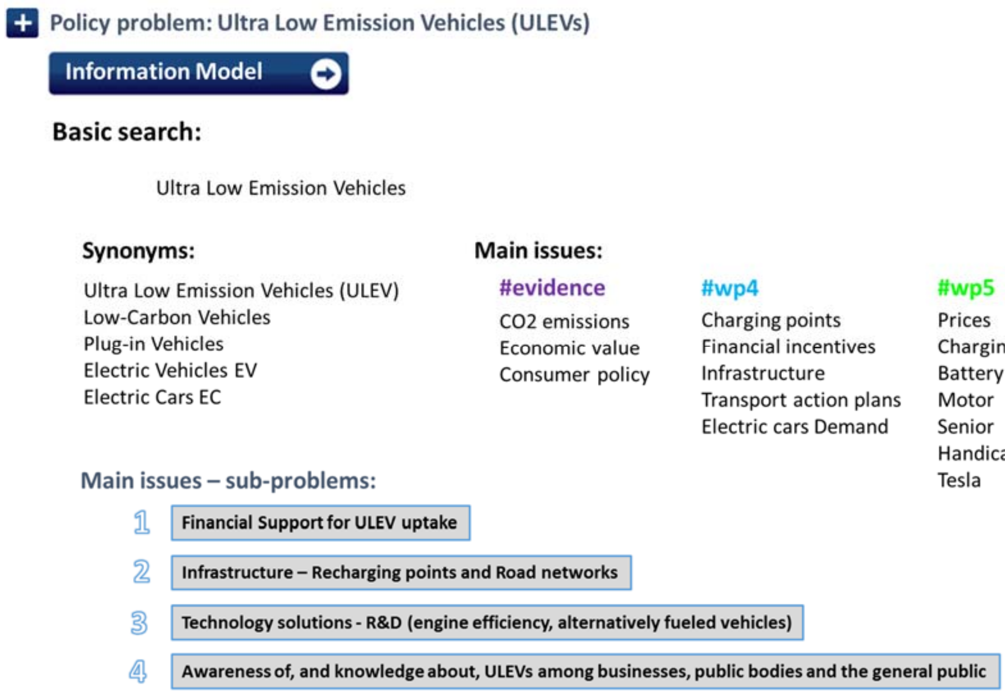


Figure 7 : Example for a basic search query using the policy problem title

Different sets of keywords for the different categories of the policy model elements can also be used for building search queries or for processing of the results. The objective is to build an information model of the policy problem, listing the model components associated to the main issues and categorised as actors, external factors and constraints, policy instruments and policy impacts. The user interface also enables the user to select the areas of policy impacts of interest for the policy problem at hand as shown in figure 8.

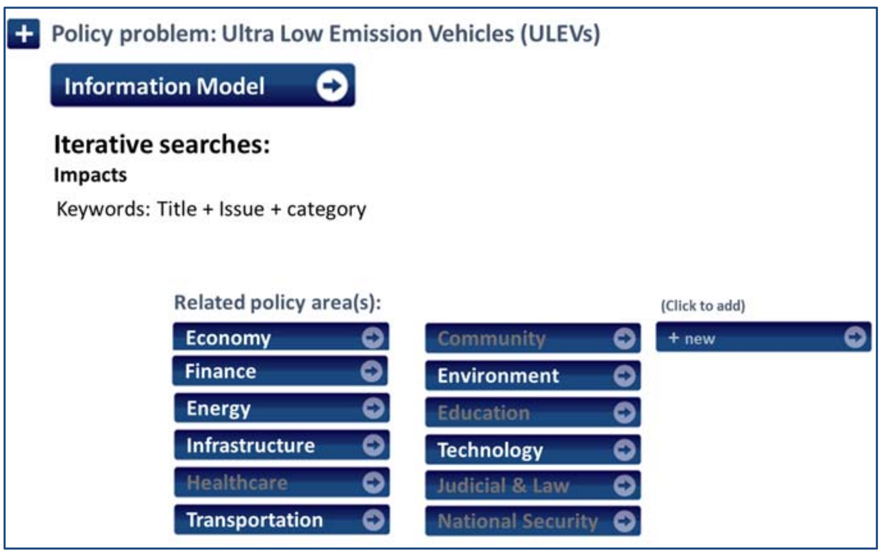


Figure 8 : User interface for selecting areas of policy impacts

These sets of keywords are to be reviewed and updated through learning from the search results and users' inputs. Note that the keywords are considered in singular/plural noun/adjective forms, and in different languages, if needed. Tables 5 shows a set of suggested keywords for actors. Keywords representing the different citizen target groups can also be added (e.g., male/female, infants/children/young adults/adults/senior citizens/ elderly/old aging, handicap/special needs).

Official Actors	Agency	Civil	Directorate	Legal/Legislative	Political
	Attorney	Commission	Executive	Member	Public
	Authority	Committee	Federal	Ministry	Secretary
	Board	Council	General	Office	Section
	Bureau	Department	Govern	Parliament	State
	Cabinet	Deputy	Institute	Party	Unit
Unofficial Actors	Association	Employee	Group	Organisation	Trade
	Business	Exporter	Importer	Producer	Trust
	Citizen	Federation	Industry	Professional	Union
	Community	Foundation	Manufacturer	Research	University
	Company	Development	Partner	Society	User
	Consumer	Donor	Private	System	Worker

Table 5 : Keywords for actors

Similarly, Table 6 shows a set of keywords for the different policy instruments used for the controllable sources of change.

Economic policy instruments:					
Financial	ownership	procurement	expenditure	fund	subsidies
Fiscal	incentives	tax	fee	charge	loan
Market	rights	contract	permit	insurance	property
Regulatory policy instruments:					
access	conformity	equity	norm	regulation	
compliance	control	law	pricing	restriction	
compulsory	enforce	Liability	protection	standard	
Informational policy instruments:					
advertise	campaign	awareness	knowledge	promote	
advice	Information	gestures	Pilots	symbols	
Capacity-building policy instruments:					
capacity	research	train			
develop	skill	innovation			
Cooperation policy instruments:					
Agreement	Technology transfer		Treaty		
External factors and constraints:					
Attitude	Economic growth	behaviour	Objective		
Context	Population growth	demographic	Resource availability		
Commitment	External environment	International	Global		

Table 6 : Keywords for sources of change

Examples for sources of keywords and terms in relation to EU policy domains:

(1) Thematic glossaries on the European commission website:
http://ec.europa.eu/eurostat/statistics-explained/index.php/Thematic_glossaries
(2) IATE - The EU's multilingual term base:
http://iate.europa.eu/SearchByQueryLoad.do?method=load
(3) Glossary of financial terms:
http://www.afme.eu/Glossary-of-financial-terms.aspx

Step 4: Data exchange with other work packages

The information search results are sent via an API to the policy modelling and simulation tool. The concepts categorized as different model elements and associated to the main issues, constitute an information model of the policy problem that can be used as a basis to build a mental model (causal map) of the policy problem.

For the purpose of the data exchange protocol, we have defined codes for the 20 categories of the model elements (as shown in table 7).

1	Official actor	11	Energy-related impact
2	Unofficial actor	12	Environment-related impact
3	Economic policy instrument	13	Social impact
4	Regulatory policy instrument	14	Infrastructure-related impact
5	Informational policy instrument	15	Transport-related impact
6	Capacity-building instrument	16	Health-related impact
7	Cooperation instrument	17	Education-related impact
8	External factors & constraints	18	Technology-related impact
9	Economic impact	19	Judicial / Legal impact
10	Financial impact	20	Security & Defense-related impact

Table 7 : Coded categories of model elements

In addition, codes for the main issues need to be defined. For the ULEV use case, for example, the main issues are coded as: 1- Support; 2- Infrastructure; 3- Technologies; 4- Awareness. Table 8 shows examples for some information search results with the corresponding codes.

Text item	**Category**	**Main issue**
"Department for Transport"	1- Official actor	
"Plug-in Car Tax treatments"	3- Economic instrument	1- Support
"Funding for charging infrastructure"	3- Economic instrument	2- Infrastructure
"Regulating access to chargepoints across UK"	4- Regulatory instrument	2- Infrastructure
"Investment in R&D"	6- Capacity building instrument	3- Technologies
"Promote public understanding of availability of support"	5- Informational instrument	4- Awareness
"Governmental spending - Transport"	10- Financial impact	1- Support
"Number of publicly available chargepoints"	14-Infrastructure-related impact	2- Infrastructure
"ULEV battery capacity"/ "charging time"	15- Technology-related impact	4- Technologies

Table 8 : Examples for the categorised search results

The exchange of data is done using json files format. An example that shows the structure of the json file is shown below:


```
{
   problemTitle: "Ultra low emission vehicles (ULEV) uptake",
   problemId:   "UK-N-T-005-2014",
   userId:        150,
   textItems: [
      {
          category:   3,
          mainIssue: 1,
```

```
      text:      " Plug-in Car Tax treatments "
    },
    {
      category:  1,
      text:      "Department for Transport"
    }
    {
      category:  3,
      mainIssue: 2,
      text:      " Funding for charging infrastructure "
    },
    {
      category:  5,
      mainIssue: 4,
      text:      " Promote public understanding of availability of support "
    },
    {
      category:  10,
      mainIssue: 1,
      text:      " Governmental spending - Transport "
    },
    {
      category:  14,
      mainIssue: 2,
      text:      " Number of publicly available chargepoints "
    }
  ]
}
```


Here we have four properties of the root object: 'problemTitle' is a string, 'problemId' is a string, 'userId' is a number, 'textItems' is an array consists of: 'category' (number), 'mainIssue' (number) and 'text' (string).

A null category means that the text item is not categorized, i.e., none of the filtering keywords exist to put it in one of the categories.

A null mainIssue means that the item is not associated to a specific main issue.

Step 5: Iconic representation of the model elements.

In this step, the user can select elements from the information model, imports elements to the graphing canvas where an icon is assigned to each elements. Figure 9 shows the information model that appears as an expand/collapse tree on the right panel and the toolbar on the left panels for the different categories of the model elements on the simulation tool interface in the model building mode.

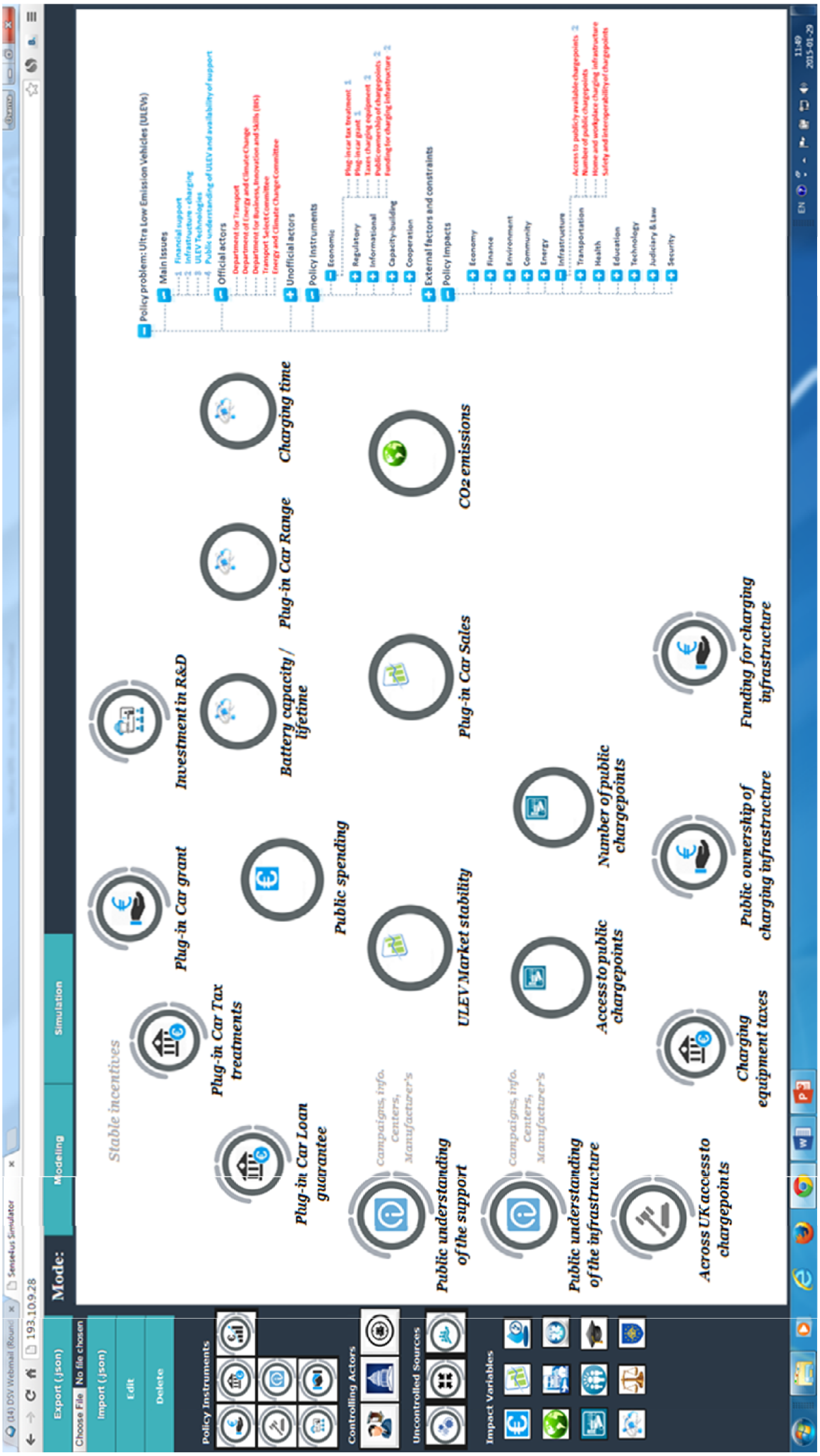


Figure 9 : Import concepts to the causal map graphing canvas

Step 6. Define actors' powers and goals

For each actor of the model, define the actor's controlled sources of change, goal vectors and preferences of goals realization (i.e., ranking of the goal vector components). In addition, for each impact variable a preference of the change direction, which can be "increase", "decrease", or "no change").

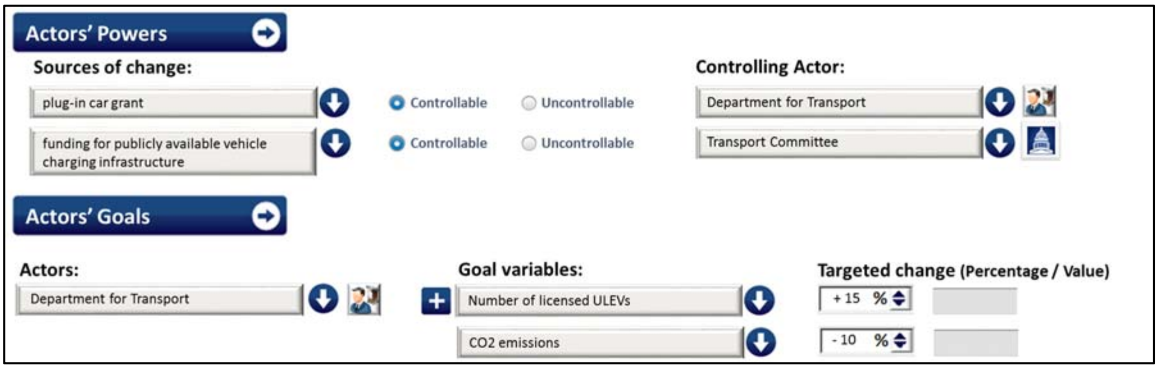


Figure 10 : User interface for defining actors' powers and goals

Step 7. Define indicators and measures for model variables and links to time series

This step involves the definition of how to measure the concepts and decide which indicators should be used. The indicators should be relevant to the scope, easy to track over time, measurable through quantitative metrics or value scales. Open governmental data portals provide statistical data and indicators for the different policy domains.

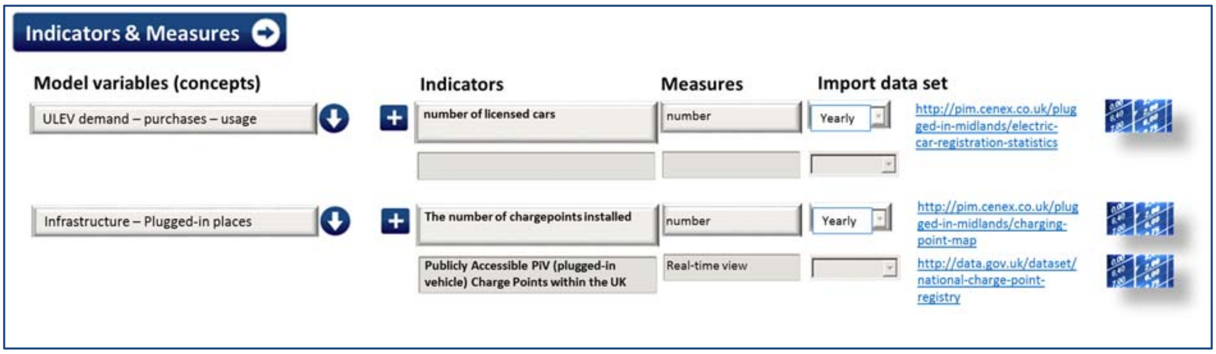


Figure 11 : User interface for defining measures and mapping time series to them

The user can be supported with the key indicators related to the different policy domains to be used for simulation. There exist a set of indicators and measures for which numerical data sets and time-series are available on open data portals, For example:

(1) EuroStat – European Commission Statistics:
 http://ec.europa.eu/eurostat/data/browse-statistics-by-theme
 http://ec.europa.eu/eurostat/web/sdi/indicators
 http://ec.europa.eu/health/indicators/echi/index_en.htm
(2) Data catalogue of the organisation for economic cooperation and development (OECD):
 https://data.oecd.org/
(3) World Bank data catalog: http://data.worldbank.org/
(4) European Environment Agency: http://www.eea.europa.eu/themes

Step 9. Define the causal links and interrelationships:

Using the tool, the user can connect the nodes using two types of the causal links or change transmission channels, described in section 1.3.

Step 10. Edit nodes' and links' properties

Add a description of each variable, the status-quo level and measurement unit of the selected indicator. For the sources of change, define the maximum and minimum possible values and steps for change to allow for automatic scenario generation. Define quantifications of the causal links and verify them through statistical analysis of the data sets for indicators. In case of unavailability of statistical data, the quantification can be done based on available expertise or scientific evidence.

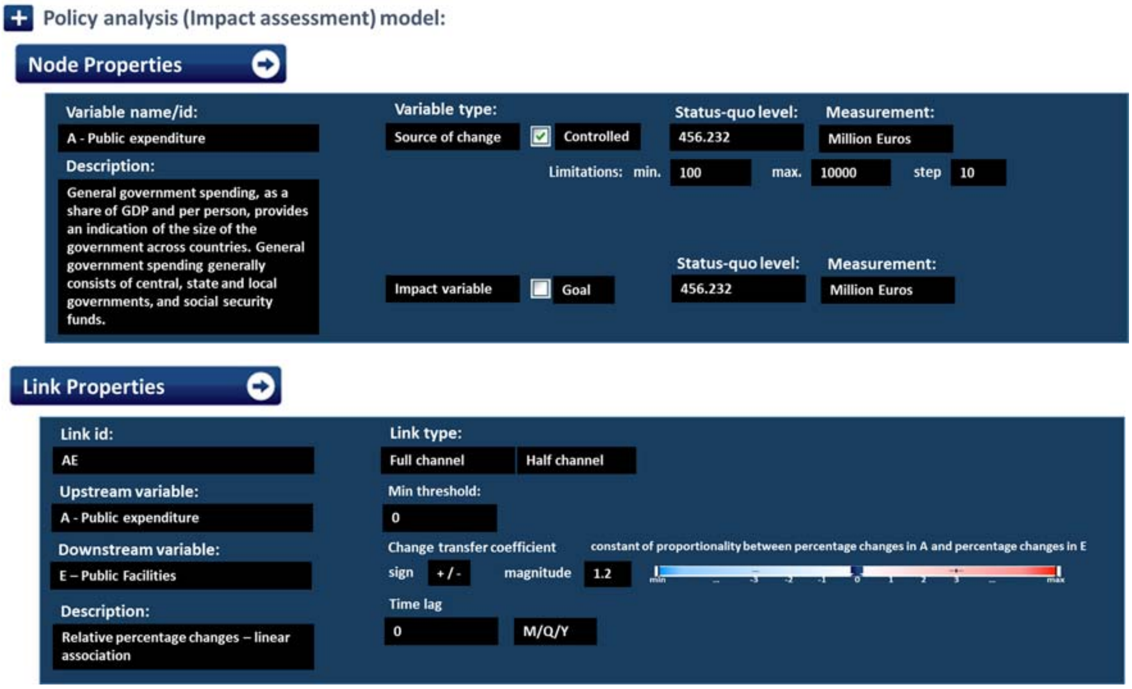


Figure 12 : Edit node and link properties

Step 11. Define and simulate a scenario of change

Switch to the simulation mode of the tool, define a scenario of change, the time step and max number of iterations and simulate this scenario as in figure 13.

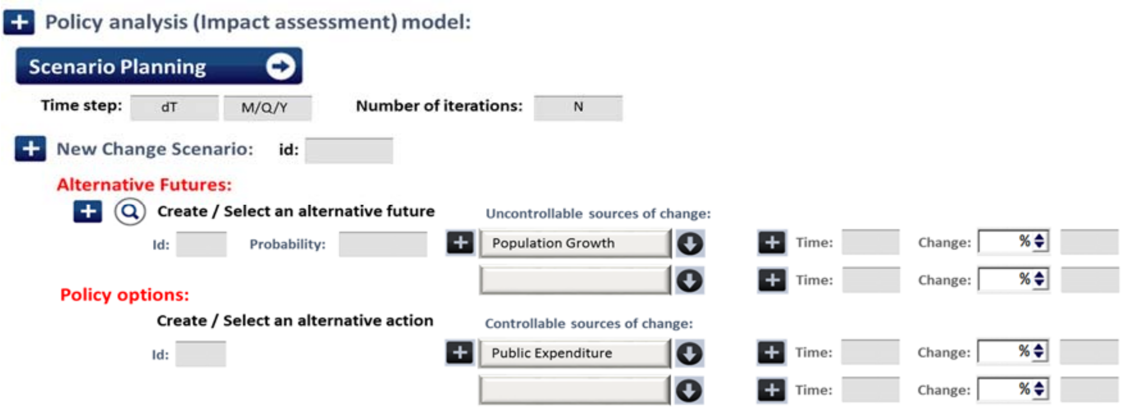
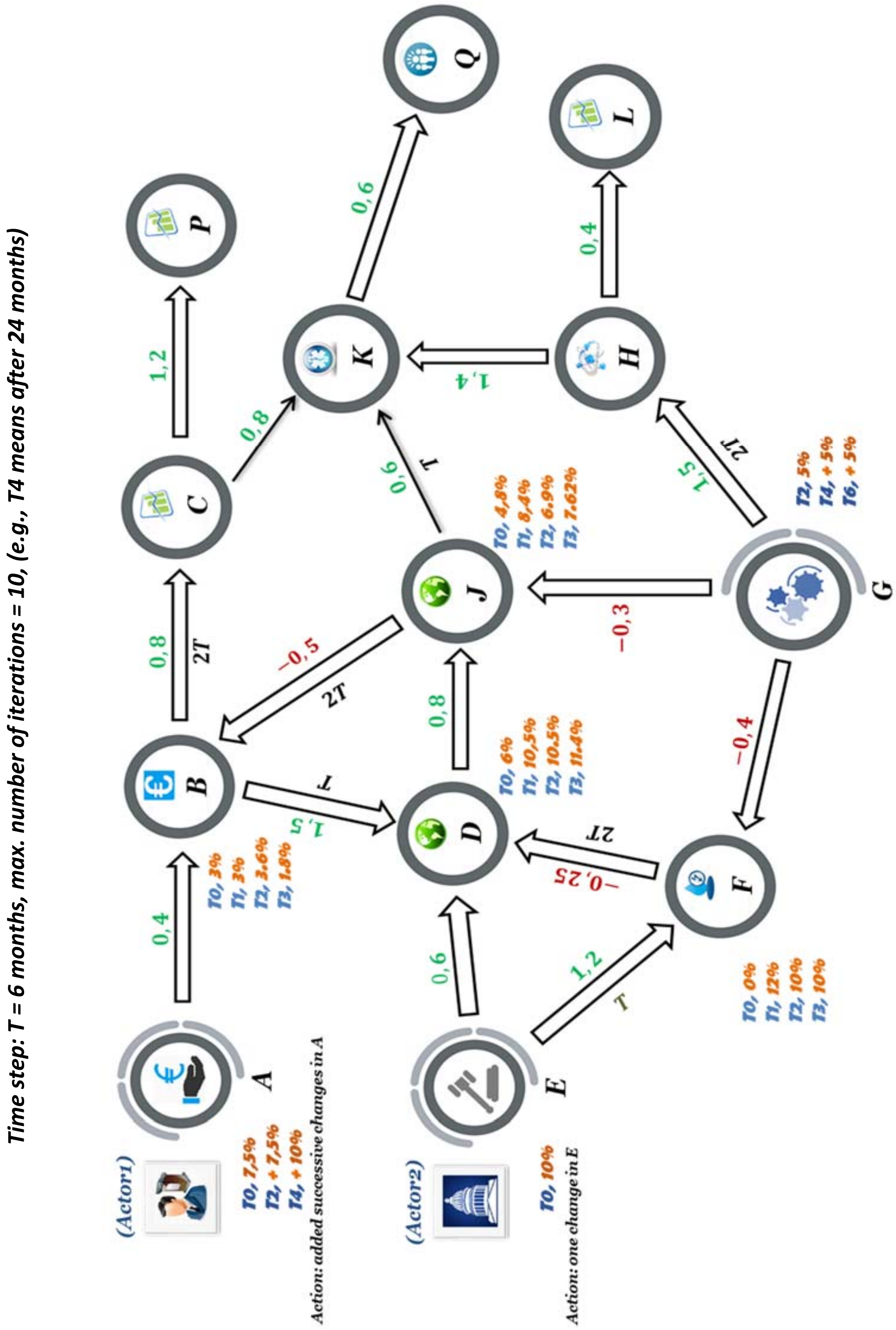


Figure 13 : User interface for defining a scenario of changes and the scenario simulation as viewed on the causal mapping canvas

Generate and run different scenarios of change to design and simulate policy options. Start with the “Reference scenario”, (Do-nothing option– no policy intervention takes places), followed by a set of pure scenarios then mixed scenarios for each actor and finally simulate combinations of the courses of actions by multiple actors “policy options”.
Results for each simulation run are visualized using simple charts and stored in the database for further analysis (impact assessment of policy options).
A toy example of a quantified simulation model with results for few time steps is shown in figure 14.

Figure 14 : Causal mapping model example



Below is a description of the model components of the toy example:

(i) two controllable sources of change: (**A)** is controlled by an executive actor **(Actor1)** through a financial policy instrument and **(E)** is controlled by a legislative actor through a regulatory policy instrument;

(ii) an uncontrollable source of change **(G)** that represent an external barrier or a driving force for change;

(iii) direct impact variables: **(B)** financial impact, **(D)** environmental impact, **(F)** energy-related impact, **(J)** environmental impact and **(H)** technology-related impact;

(iv) indirect impact variables: **(C)** economic impact, **(K)** healthcare-related impact, **(P)** economic impact, **(Q)** social impact and **(L)** economic impact;

- In sum, the model has 13 nodes: 3 origins **A**, **E** and **G**; 7 middle nodes and 3 end nodes **P**, **Q** and **L**; and 17 change transmission channels all are full channels, except for **CK** and **JK** are half channels.
- The defined time step T=6 months, the maximum number of iterations is 10. Starting point of the analysis is T_0=0 and ending at T_{10}= 60 months (5 years).
- The example shows a scenario of changes composed of: a possible future (lagged changes in the uncontrollable source **G**) and a policy option (actions taken by actors, an increase 10% in **E** at T_0 and consecutive lagged increases in **A**: 7.5% at T_0, 7.5% at T_2=12 months and 10% at T_4= 24 months).
- The model contains a causal loop **BD**-**DJ**-**JB**
- Goal vector corresponding to outcome variables **P, Q** and **L** respectively: for actor1 (+20%, +10%, 0) and for actor2 (0, +15%, +10%).

5 Conclusion

The main contribution of this design research study is defining standards and a procedure for policy modelling and simulation based on the information gathered from various online sources, including Linked open data search results from WP4 and evidence extracted from online public political discussions by WP5. In order to create customisable and reusable models, the approach introduces standardised categories and subcategories of the model elements (e.g., executive actors, policy instruments, external factors, policy impacts …), to be defined in relation to a definite set of the main issues or sub-problems identified by the user through the modelling process. It also introduces a procedure for defining indicators and measures and quantifying the change transfer throughout the model.

A prototype for the policy-oriented modelling and simulation tool presented in this report, has been implemented in a Node.js environment and is accessible both from a web-based graphical user interface as well as a hosted API. The prototype provides a fully computerised object-oriented implementation of the model building, scenario triggering, scenario simulation and game theoretic computations.

The modelling approach is based on "Acar's Causal mapping and situation formulation method", with the following modifications and enhancements: First, defining the causal links based on causal inferences extracted from verbal description of the problem and quantifying change transfer using time-series from trusted data sources, instead of merely estimations by the decision-maker. Thus, it results in a mathematical model that identifies influences and trends building on reliable historical data to produce forecasts. Second, linking to game theory concepts to perform competitive analysis for the involved actors. Third, creating scenarios of change in terms alternative futures and alternative courses of action (policy options), instead of defining individual scenarios by the decision maker. Finally, the discretization of the simulation runs over time and defining a maximum number of iterations allows analysis of successive waves of changes entered at the sources of change and allows computations of causal loops with no need to calculate their limit behaviour.

The simplicity of the proposed policy modelling approach allows engagement of a wide range of policymakers and stakeholders in a unified method in which barriers, constraints, dilemmas, assumptions, dependencies, delays, goals, reference, future and planned scenarios are described and analysed.

Being both intuitive and analytical, it allows the planners to monitor the changes to their system and its environment and analysing their implications, in order to understand the cost of action and inaction, and reach satisfactory and optimal tactics and strategies in each specific situation. For instance, this might be helpful in investigating the technological extrapolation scenarios in which there is no agreement.

Enhancements and Future work

- Integration of text analysis algorithms for causal inference extraction from textual data using Natural Language Processing.
- Integration to Multi-criteria decision analysis (MCDA) models - building criteria models and data formats for policy appraisal based on the problem model and simulation results. (D6.3)
- Consideration of more complex forms of the cause-effect relationships (influences or causal links), including: time-/ value- dependent change transfer coefficients or differential equations.

- The simulation as a serious game. Adding the formal structural elements of games — e.g., fun, play, rules, a goal, winning, challenges, competition, in addition to the feature of processing or debriefing using artificial intelligence techniques.

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APPENDIX I – Computation Algorithm

Below we provide the computation algorithm for the simulation runs in pseudo code.

```
Modelling mode:
Results in a stored model of the policy problem with data for the
different categorised components
Actors: Actor 1, … , Actor P
Variables: V1, … , Vm
  Number of nodes m
  Number of Uncontrollable origins m1
  Number of Controllable origins m2
  Number of Dependent variables m3 = m – m1 – m2
Links: L (a,b), a~=b and a,b = 1, …, m   (array of records, each
record contain link parameters)
Define Actors' powers and targets
The controlled variables by each actor
The targeted changes in outcome variables for each actor

Simulation mode:
Input time step T
Input max number of iterations n
Define a scenario of change:
  // Alternative future: AF1
   For uncontrollable variables k:  1-> m1
           Define change instances: time point Ti and amount of
change relative to baseline
  // Policy option: PO1 (combination of actions by multiple
actors)
   For controllable variables k: 1 -> m2
           Define change instances: time point Ti and amount of
change relative to baseline
Scenario Triggering and scenario simulation
For i = 0 to n    // loop1
//  Insert records into the simulation_runs table under the key
AF1, PO1 and Ti
     For j = 1 to m    // loop2
      If variable Vj is a source of change
      Planned change = change instance for sources of change
      variables defined in AF1 or PO1
       End if
       For each incoming link L(*,j)
        If link L(a,j) is not time lagged
         Transmitted change = transmitted change instance defined
       for variable Vj at Ti
        End if
        If link L(a,j) is time lagged
         Delayed change = delayed change instances defined for
       variable Vj at Ti
        End if
       Net change = Planned change + transferred changed + delayed
       change
       For each outgoing link L(j,*)
```

```
        If link L(j,b) is not time lagged
          Define a transmitted change instance for variable Vb at
        Ti (Net change * change transfer coefficient of the link)
         End if
        If link L(j,b) is time lagged
          Define a delayed change instance for variable Vb at
        Ti+lag (Net change * change transfer coefficient of the
        link)
         End if
        End loop 2
End loop1
// Repeat for different combinations of alternative futures and
policy options
// Use the simulation runs table for further analysis

// For each scenario of change, rank actors according to tactical
efficiency and tactical effectiveness. Rank tactics of an actor
according to tactical efficiency and effectiveness for the
implemented scenarios of change.
```

APPENDIX II – TECHNICAL SPECIFICATIONS

Infrastructure

The implementation of the simulation tool is split up between two servers. One pushing the front-end to a client, and the second one calculating and storing simulation calculations. In this way we separate cycle eating tasks from the user's client. Since the server is doing the calculations, we already have access to networks or similar structures and are able to save relevant data as we see fit. The front-end client running in any modern browser will fetch and push information to the back-end server, e.g., loading networks, saving networks, and simulating change. This is done through AJAX calls. Both servers work, right now, without any kind of authentications. This means anyone, with enough wit, could gain access to extra tools to deny services. Although, it's probably better as the denier to abuse NTP servers or something similar. Don't host and advertise this tool publicly. If you do, implement user management. These repositories are meant as a proof of concept.

Front-end server

Language/s

Javascript running through Node.js in the back-end. Javascript running through clients' browsers. CSS3/HTML

Libraries (as seen in package.json)

/* External */
body-parser
cookie-parser
connect
ejs
ejs-locals
express
iconv-lite
browserify
immutable
uglify-js
watchify

/* Developed in-house */
rh_config-parser
rh_cookie-cutter
rh_fe
rh_fe-controller
rh_logger
rh_router

Description

This server exposes all the public javascript relevant to the front-end. It is running behind an MVC framework because it makes it easier to organize and split up entry-points for pre-loading models etc. The client is based on a framework called Immutable which encourages 'data-in,

data-out'. Almost all of the interface is generated from settings-files. The core of the client is within main.js which initializes the environment.

Back-end server

Language/s
Javascript running through Node.js

Libraries (as seen in package.json)
/* External */
body-parser
connect
cookie-parser
debug
ejs
ejs-locals
express
iconv-lite
pg-sync

/* Developed in-house */
rh_config-parser
rh_cookie-cutter
rh_database-layer
rh_fe
rh_fe-controller
rh_logger
rh_model
rh_model-layer
rh_router
rh_user-manager (implemented, but not authorizing)

Description
The aspect of this server is just to expose an API without any kind of coupling. The reference sheet may be found under Resources below. Right now the biggest part of this server is to save and load data, and simulate changes in a network.The API's entry-points is exposed using MVC design. All calls are REST based, and will comply to those standards. GET requests will recieve data, POST will save data, PUT/PATCH will update data, and DELETE will remove data. The structure of the requests and responses is available in the reference sheet.

Resources

Node.js
https://nodejs.org/
Immutable.js
http://facebook.github.io/immutable-js
Front-end repository
https://github.com/eGovlab/sense4us-simulation
Back-end repository
https://github.com/Rhineheart/sense4us-simulation-server
Back-end API reference sheet
https://docs.google.com/document/d/1HtlTy9CVvz7yrX5IGCr8ITfIKfl0H-XtbZ7c-SolNFI/edit?usp=sharing

APPENDIX III – Policy use cases

Use case 1 – Ultra Low Emission Vehicles (ULEVs)

Source:

(Online) House of Commons, Transport Committee, (2012),'Plug-in vehicles, plugged in policy?', Fourth Report of Session 2012–13, available on: http://www.parliament.uk/documents/commons-committees/transport/Plug-in%20vehicles%20239.pdf (Accessed 1/7/2015)

Description:

Policy aim:

The UK Government wants to increase take up of Ultra Low Emission Vehicles (ULEVs) throughout the UK, as part of its wider plans for reducing greenhouse gas emissions.

Policy context:

The Climate Change Act established a legally binding target to reduce the UK's greenhouse gas emissions to at least 80% below base year (1990) levels by 2050.

The Government has stated that, by 2050, domestic transport will need to substantially reduce its emissions.

Part of the UK Government's "vision" for reducing emissions is ultra-low emission vehicles (ULEVs) including fully electric, plug-in hybrid, and fuel cell powered cars. Its report on delivering a low carbon future states:

"Over the next decade, average emissions of new cars are set to fall by around a third, primarily through more efficient combustion engines. Sustainable biofuels will also deliver substantial emissions reductions. As deeper cuts are required, vehicles will run on ultra-low emission technologies such as electric batteries, hydrogen fuel cells and plug-in hybrid technology. These vehicles could also help to deliver wider environmental benefits, including improved local air quality and reduced traffic noise".

The Government's policies in this area include: (i) pressing for strong EU vehicle emissions standards for 2020 and beyond in order to deliver improvements in conventional vehicle efficiency and give certainty about future markets for ultra-low emission vehicles; (ii) providing around £300 million in the 2010-15 Parliament for consumer incentives, worth up to £5,000 per car, and further support for the research, development and demonstration of new technologies; and (iii) providing a £560 million Local Sustainable Transport Fund over the lifetime of the 2010-15 Parliament, to support people to make lower carbon travel choices, such as walking, cycling or public transport.

Use case 2 – Proposal for a Regulation of the European Parliament and the Council of EU on: "Personal protective equipment" (PPE[8])

Source:

(Online) European commission (EC), (2014) Impact Assessment report, Industry and Entrepreneurship, 'Regulation on personal protective equipment', available on: http://ec.europa.eu/smart-regulation/impact/ia_carried_out/cia_2014_en.htm#entr (Accessed 1/7/2015)

Description:

Volume of the EU market:

€ 5.9 billion, almost 30% of the global market; At least 4000 Companies; 43% of the total EU manufacturing workforce.
Top Manufacturers: Italy, Germany, France, UK, (50% of EU production)
Users: 30% private individuals and 70% Enterprises (manufacturing, construction, mining, healthcare, agriculture and public services)
The problem has a regulatory nature – regulation failure of the PPE Directive:

- Products on the market that don't ensure an adequate level of protection
- Market surveillance and risks related to PPE types not covered by the directive
- Divergent approaches of the notified bodies.

General Objectives:

- High level of health and safety protection for PPE users.
- Free movement of PPE and a fair playing field for PPE economic operators.
- Simplify the EU regulatory environment related to the field of PPE.

Actors:
A co-decision legislative procedure, involving the following directorate general of the European commission:

- DG-ENTR: Enterprise and Industry
- DG-SG: Secretariat-General
- DG-SJ: Justice and Consumers (JUST)
- DG-EMPL: Employment, Social Affairs and Inclusion
- DG-SANCO: Health and Food Safety

Interested Parties and Stakeholders:

- Member states
- Notified Bodies and representatives from standardisation organisations.
- Market surveillance authorities
- PPE manufacturers federations and trade associations

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[8] PPE: Any device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards.

Examples of PPE are safety helmets, ear muffs, safety shoes, life jackets but also bicycle helmets, sunglasses and high-visibility vests. Certain types of PPE are excluded from the scope of the PPE Directive, namely PPE specifically designed and manufactured for use by armed forces or in the maintenance of law and order, PPE for self-defence, PPE designed and manufactured for private use against atmospheric conditions, damp, water and heat, PPE intended for the protection or rescue of persons on vessels or aircraft, not worn all the time and helmets and visors intended for users of two- or three-wheeled motor vehicles.

- PPE employees / workers
- PPE users / consumers

Consistency with other policies and objectives: This initiative is in line with:

- The Council Directive on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace
- Commission's policy on the Single Market
- EC's policy on better regulation and simplification of the regulatory environment.

The New Legislative Framework (NLF), a common framework for the marketing of products. Its objectives in PPE sector include: (i) Reduce the amount of products on the market of low quality (don't ensure adequate level of protection); (ii) Accreditation, market surveillance and controls of products from a third country; (iii) Unsatisfactory performance of certain notified bodies; and (iv) Inconsistencies in legislation and complexity of implementation for authorities and manufacturers.

EU action - added value:

- Approximation of the laws of the member states related to PPE.
- Avoid distortions in the EU market

Main Issues:

- Extension of product coverage
- Application of conformity assessment procedures
- Changes in basic health and safety requirements (sufficient and clear)
- More effective Market surveillance

Figure 15 presents a causal mapping model for the PPE use case policy problem. The model shows the actors' participation in a co-decision legislative procedure. The model shows two policy options, with the legislative option more effective in achieving the policy objectives. Links are variably marked with positive and negative signs indicating signs and intensity of the causal relationships.

Figure 15 : Causal map of the PPE use case