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2	IBM Israel Science and Technology Ltd.	IBM	Israel
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4	Athens Technology Center	ATC	Greece
5	University of Konstanz	UKON	Germany
6	OXFAM Italia ONLUS	OXFAM	Italy
7	WWF - World Wide Fund for Nature	WWF	Switzerland
8	European Union Road Federation	ERF	Belgium

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Executive Summary

This document provides details about the components that comprise the overall system, their functionality, their interactions and their integration. It provides details about the overall architecture of the Consensus tools. It is a "living" document in the sense that it will be formally updated on M30 but also because internally, constant revisions will be made, so as to reflect the changes in the system architecture. Such small changes are inevitable and also desired in the frame of R&D projects and they often reflect the innovative nature of such project.

The document reports on the results of the analysis of the requirements and their assignment to software components. It also deals with the technologies that will be used and proposes a plan for bringing them together. The use of web techniques is suggested concluding to the creation of a mashup web application that will orchestrate and implement the wirings of the HTTP calls between the various web components.

The intended audience of this document are people with a basic understanding of techno-economic models and a good understanding of web technology issues.

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1 Introduction

The Consensus system is a unique case in which models as well as optimization and visualization tools need to be mixed and wrapped into software components that will maintain high levels of performance, scalability, security and usability while providing new functionality through integration. In particular, the sustainability models developed by IIASA and the simplified (elasticity-based) demand model from ERF must both interact with the user and experts so as to define the policy to be modelled, and the input and output data. However, Consensus requires automating this process to a certain extent and ensuring that the integrated set of components for a particular set of scenarios assist the policy maker and the citizens understand the policy objective trade-offs and the consequences of certain decisions.

The goal of Consensus is to develop tools that will provide decision support to policy makers and citizens regarding complex issues such as policy making. The critical points upon which the decision support process is based (Figure 1) are:

- The quantification of a policy scenario to a set of objectives, constraints and trade offs
- The modelling and evaluation/forecasting of the policy scenario outcomes
- The identification of optimal solutions from the set of alternatives
- The visualization of the decision and design space and the provision of insights for optimal options based on user preferences

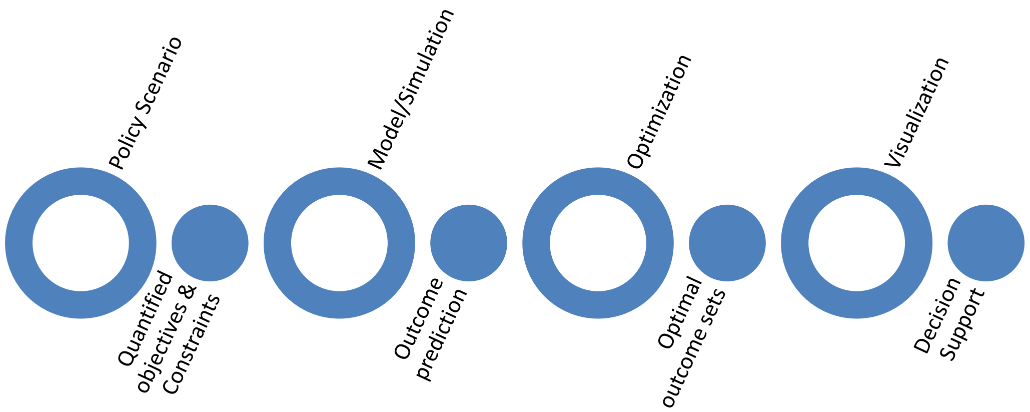

Figure 1: Consensus decision support process

The process starts with the decomposition of a policy that is to be evaluated in multiple objectives and constraints (which describe the policy context as discussed later). The tradeoffs between the objectives are modelled and the consequences of this quantified policy are then predicted. The mapping between objective evaluation sets and outcomes generates a great number of alternative scenarios. The goal is to identify the scenarios that optimize the objectives. This is the role of the optimization phase, in which the solutions are sorted and the dominant ones (pareto frontier) are identified. In the visualization phase the design and decision space are visualized appropriately in order to depict the scenarios. This final phase allows the user to explore the various scenarios through interactive mechanisms but also to receive recommendations based on his/her feedback along with explanations for the various suggestions.

Consensus aims at implementing this process as a web-based software tool. Two variations of the tool will target policy makers and citizens with the goal to provide an in-depth analysis of policies to both these groups. This analysis is expected to strengthen the understanding of the end users of the consequences of the specific policy implementations and in the case of citizens, to retrieve feedback about their preferences; a feedback that can comprise an objective on its own, namely the policy acceptability.

The details about the implementation of these tools are provided in this document. A first analysis of the underlying components and a link to the user requirements is provided along with details about the integration of the set of heterogeneous components that will be developed.

According to the plan, the first versions of the Consensus components will be delivered on M12 (i.e. September 2014). In sequel these components will be integrated and deployed for testing and evaluation that will lead into another round of improvements (through experimentation and development) followed by one final evaluation phase.

The following of this document is structured as such: Section 2 presents the top level architecture and the major conceptual modules that comprise the Consensus system. Section 3 provides descriptions about the functionality and inputs and outputs of the components that will be put together to form the system. Section 4 provides some details about the integration and deployment of the components. Finally, Section 5 discusses some important points in the component interaction explaining the various options.

However before delving into the technical details of the Consensus tools implementation, we provide a small note about the models which differentiate the process from traditional software development.

1.1 About models

The models are meant to simulate a situation/context and generate forecasts about certain metrics that relate to this context and are unknown to the user (and difficult to be calculated, hence, the model). There is a need for the models to receive some input that will define the context and in turn estimate some unknown parameters. Especially in complex models, it is rarely the case that the outcome parameters are independent to one another or that they come in fixed values. Their values often range in intervals and present tradeoffs when selecting one value. This results in the generation of a multitude of options and it is often left to the end user to select which one fits more appropriately to the intended purpose.

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Another point worth mentioning is that in some models it is possible to set up the context and expect an (almost) immediate response for the output but in others the calculations may take up time. The demand model for the pricing schemes is a case of a model that can respond promptly, whereas the environmental model (GLOBIOM) is an example of a model which takes time to crunch new inputs. Note, that the difference lies in the complexity of the problem that they attempt to model and it is not an issue of implementation; even though they do actually rely on different technologies and background theory.

In the case of Consensus the context is defined as a state/instance to which the simulated environment is converging if a policy is applied. Therefore the context is essentially comprised of two things: data and constraints. In the case of GLOBIOM, a simplistic approach to explain its modelled context is to define it as the market demand and supply for biofuels. This context is decomposed in metrics such as land use, land type, GDP, gas price, etc. In the case of ERF's demand model, the context involves a corridor, i.e. a single road that connects two points, and it is quantified by metrics such as traffic, maintenance costs, GDP, etc.

Having stated that, it now becomes clear that the input parameters are meaningful for assisting the end user (policy maker) to define the policy, be it **the degree that biofuel production is subsidized** or the **pricing scheme of a corridor**.

From that point on, there are two potential modes of operations for the simulation modules:

- What if analysis: Given a single well defined set of policy parameters, the simulation engine calculates the consequences of that policy in the objective space.
- Batch Mode: Serving as input for the multi objective analysis modules, the simulation engines (off-line) calculate objective values for wide range of policy alternatives.

The technical solution is becoming more complex because each Consensus model operates on a different mode. This difficulty is explained in detail in what follows and how they affect the architecture.

2 Conceptual architecture

Consensus delivers two main outcomes/tools: the **Consensus MOOViz** (Multi-Objective Optimization and Visualization) and the **Consensus Game**. Even though each one has different objectives, they are sharing a big part of the Consensus background technologies. In what follows we provide some details about these two major outcomes. Indicative use cases provide an explanation of the link of the outcomes to the user requirements [1]. Note that the use cases focus on the user requirements that differentiate the Consensus tools from any other software component. That is, user requirements that can be met by off-the-shelf technical implementations are not addressed in this Section. These are met by the back-end platform that is used for integration and orchestration purposes.

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Furthermore, a top-level architecture is then presented after the description of these two tools, illustrating the intermediate conceptual components and their interactions, serving as an introduction to the following Section (Section 2.3.1).

2.1 Consensus MOOViz

ConsensusMOOViz Is a framework for decision makers to better understand policy context, objectives, alternatives, trade-offs and decision consequences in order to make conscious choices that take into account the wide range of aspects and considerations that are affecting and being affected from the underlined decision context.

Specifically, the ConsensusMOOViz tool is targeted to decision makers in the fields of transport policies and biofuel policies, which are represented by the end user partners within the Consensus project. Nevertheless, the principles and approach aimed to be developed within Consensus, is generic and expandable into many other public domains involving of complex policy context decisions.

The above challenges are tackled through a multidisciplinary partnership between experts from the fields of operational research, decision science, social technologies (gamification, crowdsourcing and social analytics), applied system analysis, visual analytics and domain experts.

The main objective of this Section is to provide a description of the Consensus MOOViz tool that will serve as an introduction to the identification of its architecture, its various components and the relations and interactions between them. As already stated, the proposed design is a live document and will be refined during the project's life-cycle according to valuable feedback and insights acquired.

2.1.1 Targeted Use Cases

The aim of this section is to identify the major use cases and to describe the individual human actors involved in the targeted scenarios:

2.1.1.1 BioFuel Scenario

The following actors have been developed based upon analysis of the stakeholders involved in the biofuel discussions. Furthermore, the actors may include additional character examples than the ones presented in the example below.

i. **Actor 1**: Policy Decision-Maker *(High-level officers of European Union's Units, Organizations or Authorities with an influencing role on biofuel legislation at EU level or implementation at national level at National Departments of Transportation or similar Departments, renewable energy agencies (mainly public), members of the parliament)*

   Sarah is an MEP with a keen interest in biofuels. She has received numerous calls and visits from both pro and anti-biofuel groups, including NGOs, trade representation, industry organizations and farmer groups. She is an active member of her parliamentary group when it comes to determining their position on biofuels. She is aware of the background documents prepared by the EU Commission on the impacts of various biofuel options but would like to further explore these. She is particularly keen

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to understand the trade-offs between various options. Additionally she likes to look beyond the short term legislative cycle and consider long term impacts in her decision making. Sarah is also keen to back her decisions with support from electors and she is aware of the fast that win-win solutions are not always possible and sometimes certain interests will be weight more than others.

ii. **Actor 2**: Policy Analyst *(Civil servants working for policy decision-makers, policy analyst working for corporates, consultants employed from policy-decision makers)*

Jennifer works as a policy analyst for an MEP. She is responsible for preparing the background materials for her MEP. She is aware of the fact that MEPs have lots of issues to deal with and often find it difficult to make decision on complex issues especially when they have to satisfy multiple objectives. She tries to reduce the complexity of issues and if possible presented it in a manner that it is easy to understand (info graphics for example. Jennifer has watched with concern the developments related to the use of biofuel in the road sector, especially because she has supported the various biofuel targets adopted by the EU over the time. She is very keen to reduce and if possible avoid the controversies and would like to learn about impacts, trade-offs and possible solutions using the ConsensusMOOViz tool. She is also keen to learn about public acceptability of certain options.

2.1.1.2 Transportation Scenario

The following actors have been developed based upon field research as well as perception of Consensus end-user partner ERF. Nonetheless, they are entirely fictional and any similarity to persons living is coincidental and unintended. Furthermore, the actors may include more character examples than the ones presented in the example below.

iii. **Actor 3**: Policy Decision-Maker *(High-level officers of European Union's Units, Organizations or Authorities with an influencing role on road-related policies making, National Departments of Transportation or similar Departments, Public Road Development and/or Management Authorities, Road Operators (mainly public))*

George is the General Secretary of a European country's Department of Transportation (DoT). George's Secretariat is mainly responsible for national transport networks' development program, including road network. The current condition of his country's road transport system is of great concern to the DoT and one of the main axes in the political agenda of the respective Minister of Transport. Currently, funds in the national transportation budget in general are depleting and nowadays, George together with the transport policy analysts of his Secretariat are exploring various "user fee" based financing approaches including road pricing schemes for the national road network development program. George believes that such toll based approaches can be proved more viable and fair compared to conventional vehicle registration and fuel tax approaches but a major concern of his is citizens' possible reactions to toll-based approaches.

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iv. **Actor 4**: Policy Analyst *(Civil servants working for policy decision-makers, consultants employed from policy-decision makers)*

Maria works as a policy analyst in George's secretariat. As a civil servant, Maria basically likes to think of her job as "reducing complexity" because she often has to perform and deliver concise and focused analyses, in very short time-spans and with limited data availability in order for her officers to reach decisions, sometimes very sensitive when it comes to public's reactions/acceptance.

Central to her work at this point is the formulation and preliminary evaluation of road pricing schemes potentially suitable for consideration for the national road network development program, ensuring at the same time that public opinion is reflected somehow in the whole process.

2.2 Consensus Game

Two of the most important requirements set to be met by the Consensus project are:

- The education of citizens regarding the consequences of certain policy implementation options.
- The harvesting of user preferences so as to include the public opinion as an objective in the policy making process.

In order to tackle these requirements, Consensus will employ the MOOViz platform that enables the visualization of the policy objective trade-offs -initially aimed for the policy maker- and extend it by adding educational elements such as online assistants, metaphors and visualizations. This platform will be made publicly available on the web. Its backend will rely on an event based architecture, monitoring and collecting user interaction in correlation to the system stimuli (e.g. reactions after educational-purpose pop ups). It is worth mentioned here that the education will primarily focus on explaining (through text, visualizations and examples) the consequences of certain policy implementation options.

Through the collected data -primarily the selections of the users using the MOOViz tool- Consensus will be able to derive conclusions about citizen preferences and relay them in a usable way back to the policy maker.

A major foreseen challenge will be the incentivization of citizen participation, i.e. making the system attractive for the citizens to use it so as to achieve the goals mentioned above; including achieving a critical mass of user preferences that will make them a useful and reliable source of information. This challenge will be addressed by infusing gamification concepts in the main platform, thus leveraging on the people's natural desires for competition, achievement, status, self-expression, altruism, and closure.

The main idea is to introduce users to a collaborative or antagonistic framework in which they will be able to make policy implementation options using the Consensus MOOViz tool as if they are making their decisions and affect a virtual context. The context is a model of a set of parameters that relate to the policy in question. As such, one will be a city in which various socio-economic and environmental parameters will be modelled. The second will be

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a road network in which the modelled parameters will be the road conditions and in consequence the safety, speed, etc. in relation to the game schemes.

The user by participating in the game will be given the chance to make a decision about the policy implementation using concepts of the MOOViz tool. Guidance about consequences as well as insights (like what is a near optimal solution, and what are the trade-offs with respect to another alternatives) will be provided to the citizen before they submit their decision. All users will be able to submit their options until a certain deadline after which the system uses the collected options together with the current context and evaluates its new state. I.e. the context is evolving based on the citizens' collective decisions and time. After that point, a new session begins during which the citizens can submit their new policy implementation options, perhaps in an attempt to revert unwanted consequences of their previous calls. Visualizations will depict the current context state (e.g. a damaged road or a city without green).

In order to provide to the citizens the means to collaborate to achieve the change of the context state to the direction they prefer, a forum will coexist with the rest of the tools so that they can share, debate and defend their options. An analysis of the reasons that led to the evolution of the context towards a certain state will also be available, visualizing the statistics that relate to the citizens' options, highlighting the factors that contributed the most to a possibly rapid change of the state.

At the end of each session players will get assigned with score points according to the environmental state of the city or condition of the road network (e.g. citizens' happiness, financial state etc). The level of each player will rise by one. Achievements will get unlocked according to the policy they choose, in which spectrum it is (which objective is closer to fulfilling) and how optimal it is, their behaviour in the debate (if they convinced other players to choose their implemented policy), how many game sessions they participated in. Users will be part of a leader board (with the provided list of friends) according to their score points. Moreover, the score will be also affected by the likes/dislikes (thumbs up/down) that a user collects in defending her decision in the forum.

The main differentiation between the two scenarios will be in the definition of the virtual context, i.e. the starting conditions that describe the environment which the policy may affect. In the case of the biofuels scenario the context will be a geographic area in which details about the land use and the biofuel demand will be provided. In the case of the road pricing scenario, the context will incorporate notions of a transport corridor, the citizens' capability to spend money for using the road, the maintenance and implementation costs for the corridors, etc.

2.2.1 Targeted Use Cases

In general any citizen is a target user for this tool. Only a few relaxed constraints may apply. One such constraint is for them to be aware of (or willing to learn about) the policy context, i.e. those relevant to biofuels and road pricing correspondingly. Another constraint is for the players to be citizens in countries in which these policies are relevant, e.g. the EU member states, Israel, Japan, USA etc. Another constraint is that the citizens must speak English.

Since we are aiming at a problem of international scope, and given the limited resources available, English is the language of choice.

Finally, it is expected that people involved should have a basic understanding about how web games operate and familiarity with the web in general. Based on these, we provide three indicative use cases that demonstrate the added value of Consensus.

i. Sarah is a citizen concerned about policies made by her local government. She is annoyed by a decision made from her local policy maker and she believes that this option will have opposite results from those expected. She also thinks that there is another specific option which would achieve the goal easier. Obviously there is no way for her to test any of the policies in real life, therefore she decides to take it to ConsensusGame because it is fun and generates knowledge that may help her understand the two problems.

   She opens the ConsensusGame webpage and logs in. Sarah then chooses the policy of interest (biofuels or road pricing) and the website is navigating her to a map of Europe. In the map she selects the area that she wants to see how policies affect the environment.

   She starts playing a game with 3 other citizens. When all players press the start button a pop up window appears, explaining what the problem is (virtual context) in that area is and how players can take action in fixing the problem with the decisions they make during the game (acting like decision makers). The players are indicating that they have finished with reading the description of the problem (e.g. by pressing a button) and then they are moved to the game main page.

   In the game main page Sarah toys with some sliders on the menu and witnesses how various objectives (represented by the sliders) are linked to one another, thus, understanding the trade-offs for each selection of parameters. She wants to select a specific price in a slider but each selection affects the other slider prices. She finally makes up her mind about her preferred policy implementation and presses a button to see an analysis of her choice. She realizes that her choice didn't quite respond to what she had in mind and goes back into toying with the bars. In the meantime other players make their suggestions public and discus about their choices in the chat. Sarah finally has made up her mind and suggests her new solution to the problem. To better understand the issue and what should the solution be she joins the conversation in the chat area along with the rest of the players. Other players comment her choice in the chat area and debate about whether it is the most suitable option to make.

   This discussion makes Sarah realize that Paul's opinion in the matter is better than her original suggestion and chooses to team up with Paul. The timer stops. All players' decisions are taken into account. The game mathematic logic sorts policies based on the degree to which they are optimizing each objective and in turn the winner of the game. Sarah and Paul created the best suggestion for the problem in comparison to the other players. Sarah and Paul win the game and add score points in their accounts.

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ii. Jenny is another citizen in the previous game. She chose to stick to her opinion during the game session and made an inferior suggestion for the problem. Jenny realized her opinion wasn't indeed a better solution at the problem and wants to play the game again and win.

iii. In a different scenario John plays in a game with Anna. Anna thinks like an industrialist and has also played the game before. John thinks like an environmentalist. Both players chat about their opinions and try to convince each other to team up but by the end of the timer there is no common suggestion to the problem. In the end the game shows to both players their suggestions where equally optimal but John won because he suggested something that fulfills most citizens' requirement to happiness. Anna sees in the game that citizens' opinions apart from profit are of equal importance in their suggestions.

2.3 Top-level Design

In this section we present the proposed system design for the Consensus components and the various interactions between them.

The top level design (illustrated in Figure 2), is composed of several major modules that are described in the following Section (Section 3). Some of the components are used by both Consensus MOOViz and Consensus Game, but for the sake of symmetrical presentation we include these in the MOOViz tool.

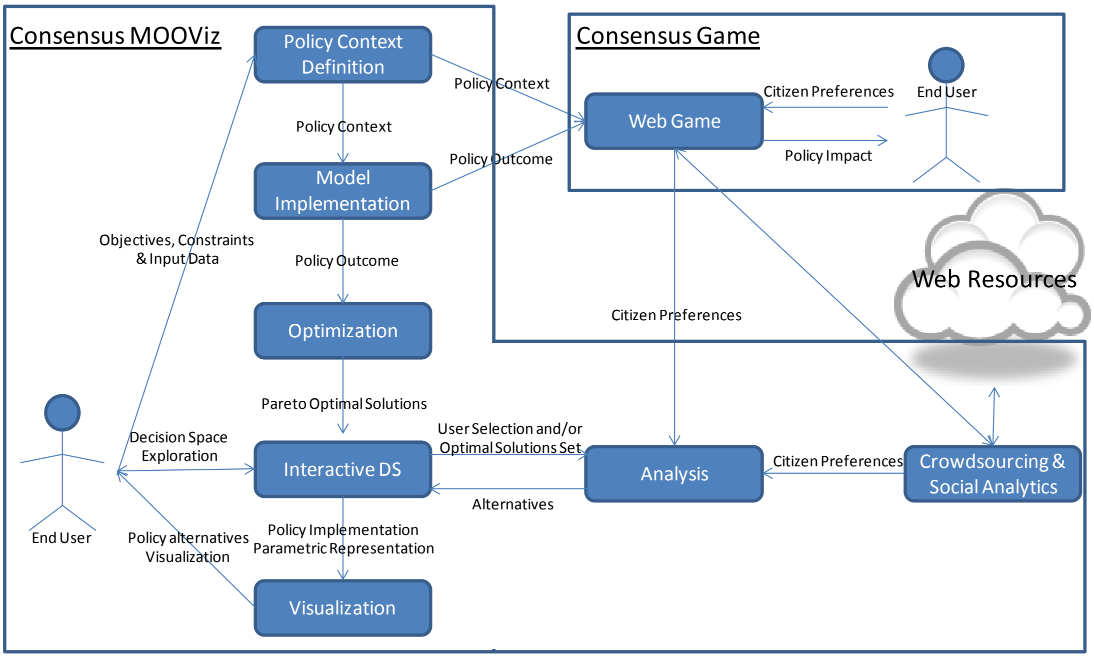

Figure 2: Consensus Tools - top level design diagram

According to Figure 2 the flow is initiated with the end user (policy maker) defining the policy context by selecting the objectives, their constraints and the parameters that define the environment affected by the policy (input data). This is done through a module, called **Policy Context Definition component** which comprises a front end to the **Models'**

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Implementation component. The two models receive these data and are emulating the context generating data about the possible evaluations of the objectives and their tradeoffs. These data are used by the **Optimization component** which sorts the various solutions based on which lies in the pareto frontier. The solutions are presented to the end user who then can explore the decision space and interact by indicating their preferences on certain solutions. This is enabled through the **Interactive Decision Support component** which stands centrally in the main operation of the Consensus tools. On one hand it communicates with the **Analysis Components** which is informed about the user preferences as well as the optimal solution set and suggests back alternatives that are close to user selection but are optimal by giving away a small portion of an objective and gaining great amounts in others. These alternatives are also presented to the end user through the **Visualization component** which makes references to the design space, simplifying the user's understanding about the various options.

On an optional, alternative workflow, the Analysis Component can be also fed with citizens' preferences on policy implementations (options from the decision space or evaluations of the objectives) which are acquired from the **Crowdsourcing or the Social Analytics components**. These are harvesting public opinion from the web (mainly social feeds) using data mining techniques and machine learning but also they directly elicit the citizens' opinion by allowing them to evaluate objective sets (i.e. policy implementations) and show preference through a **Web Game**. These preferences are used by the Analysis component so as to suggest alternatives that are both optimal but also preferable (i.e. the public opinion is used as yet another objective) to the policy makers.

In what follows we map each of the requirements and associated functionalities requested by the users in [1] to the components that must implement this functionality and assign it to a respective partner.

2.3.1 Requirements analysis

The following analysis bridges the top-level design mentioned above with the component functionality that is presented in Section 3. In some cases the use of a technology is a more appropriate response to the requested functionality rather than the development of a component.

ID	Functionality	Component/Technology	Responsible
CM.GN.1	The tool and supporting systems should be capable to run on standard PC or Laptop, on organization's intranet or through the web.	The Consensus Tools will operate over the web, largely relying on client-side technologies that will allow it to operate in all the latest versions of the web browsers. When computationally intensive tasks are required, these will be executed by server-side resources invoked over HTTP or HTTPs where appropriate	ATC
CM.GN.2	User login data as well as input data should be secured.	Standard cryptography methods and protocols will be employed for the encryption of user credentials and data	ATC

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ID	Functionality	Component/Technology	Responsible
CM.GN.3	Only authorized users may have access to the tool.	Access control will be achieved by an appropriate (off the shelf) authorization and accounting system	ATC
CM.SI.1	The tool should be capable of supporting the agenda of the user in terms of the: project description, alternative policy measures, policy objectives, evaluation criteria, indicators for measurement of criteria, priorities (weights) or visualization of preferences and public participation needs. According to the pre-defined lists of schemes, objectives, criteria, indicators, weights and visualization possibilities, the user shall be able to select/define her own. Nonetheless, especially for criteria there will be an option for the user to add/remove by her own.	Policy context definition	ATC
CM.SI.2	Usually the input received from users on data they base their decisions on is not enough. Thus, the system will have to challenge and allow users to perform evaluation even with limited data or only qualitative descriptions. Forms will be provided so as to allow the user to enter her own data where applicable. Optimised and clear forms encourages user to finish them. If possible, for some quantitative data, the tool would suggest default values.	• Policy context definition • Social analytics & crowdsourcing	ATC, NTUA
CM.DM.1	The tool will automatically generate or extract alternatives taking into account the scope and constraints defined by the user.	• Models • Policy context definition • Analysis	IIASA, ERF, ATC, IBM
CM.DM.2	Criteria priorities should be allowed (if the user wishes to) by introducing –and be able to experiment with- weights or by visual means to perform exploration of the alternative space in order to identify the best alternatives.	• Models • Policy context definition • Visualization • Interactive Decision Support • Optimization • Analysis	IIASA, ERF, ATC, UKON, IBM
CM.DM.3	There should be a scale to interactively filtering out un-desirable alternatives through quantify or qualitative criteria.	• Visualization • Interactive Decision Support • Social analytics & crowdsourcing	UKON, IBM, NTUA
CM.DM.4	Whenever some or even all the decision parameters change, the tool must be able to evaluate again the alternatives according to changed parameters.	• Models • Policy context definition	IIASA, ERF, ATC
CM.DM.5	The tool should be flexible and adaptable to varying decision making contexts / application scenarios.	Models	IIASA, ERF

ID	Functionality	Component/Technology	Responsible
CM.DM.6	The tool should take into consideration former decisions taken under similar circumstances. Therefore, the knowledge/history data-base should allow to store and consult available and suitable previous examples or role models for the case.	Interactive Decision Support	IBM, ATC (for the persistence)
CM.OP.1	Having an accurate result makes users feel comfortable with what they are doing, makes them trust the tool.	Models	IIASA, ERF
CM.OP.1	The tool should deliver easily understandable representation of main result. This includes both, visualization of input (e.g. costs) and visualization of output (e.g. summarizing impacts, statistics, graphs etc.)	Visualization (design and decision space)	UKON
CM.PF.1	The usability of the tool shall be as easy as possible, and the set up parameters must be in the proper way so as to provide the users a good response time when they request for an analysis to support their decision making process.	• Policy Context Definition • Visualization • Models	ATC, UKON, IIASA, ERF
CM.PF.2	Message boxes / tool tips should be available for displaying control information, warning information, warning questions and errors whenever needed.	All components with an interface	All
CM.US.1	Terminology must be familiar and understandable to all possible users.	All components with an interface	All
CM.US.2	All concepts in the user interface must be consistently applied and designed. Consistency of a tool not only allows users to become familiar with new applications more quickly, but also helps create a sense of comfort and trust in the overall environment.	Use of common design patterns, CSS	ATC
CM.US.3	Users must have full control of the tool. They must never have the feeling of the application controlling them.	All components with an interface	All
CM.US.4	The tool should not display redundant information unless it is required for specified reasons. The system must give the feeling of reliability and be time-saving for the user.	All components with an interface	All
CM.US.5	The tool must prevent the user from (unknowingly) taking severe actions. The user should be able to undo or reset changes or actions easily. To be flexible about mistakes makes the system more dependable and makes the user feel friendlier with the tool, while increasing efficiency.	All components with an interface	All
CM.US.6	The user should be able to easily modify or cancel input	All components with an interface	All

ID	Functionality	Component/Technology	Responsible
CM.US.7	When users log off, the system should be able to save the work done so far and check if there is any pending task that must be done and warn the user in case some data could be lost or not properly processed.	DB	ATC
CM.US.8	Error messages should be clear to assist users understand them. The tool should show an error message displaying information about error occurrence, type of error and correction possibilities.	All components with an interface	All
CM.US.9	The application will be initially in English (other language version should not be excluded). Interfaces will be provided to allow for a translation of the tool set.	All components with an interface	All
CG.GN.1	Ideally it would nice to be drivers in real life or at least car-owners, in order to have a realistic sense of trade-off	• Web game • Public Acceptability model (social analytics & crowdsourcing)	NTUA
CG.GN.1	User login data (in case of login).	Web game	NTUA, ATC
CG.VS.1	The game should adapt optimisation tool's output to deliver easily understandable representations of the main result to road and biofuel users not familiar with the policy context.	• Optimization • Web game	NTUA, ATC, IBM
CG.TT.1	The game should provide users optimisation tool's output in a flexible format so the user can understand and play with the objectives and the tradeoffs between them	• Optimization • Web game	NTUA,ATC, IBM
CG.TT.2	The game should be able to grasp users subjective preferences about the objectives and/or alternatives	• Analysis • Web game	NTUA, IBM
CG.US.1	Terminology must be familiar and understandable to all possible users.	Web Game	NTUA
CG.US.2	The application will be in English. Interfaces will be provided to allow for a translation of the tool set.	Web Game	NTUA, ATC
CG.US.3	The game should largely rely on visualizations	• Web Game • Visualization	NTUA , UKON
CG.US.4	Visualizations should be interactive and intuitively educating the citizen	• Web Game • Visualization	NTUA , ATC, UKON
CG.US.5	The Game should introduce the citizen to the concept, precisely and in a simple and engaging way. (People don't even know the problem let alone the solution)	Web game	NTUA, ATC
CG.EN.1	The game must focus on collaboration and not on competition between players	Web game	NTUA
CG.EN.2	The Game should last really short	Web game	NTUA

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ID	Functionality	Component/Technology	Responsible
CG.EN.3	The Game must ensure that the decomposition of policies is clear as this is what users want to get	• Web game • Policy Definition Context	NTUA, ATC
CG.EN.4	The Game score must be calculated based on algorithms, not based on subjective mechanisms	Web game	NTUA
CG.EN.5	The Game must maintain a good balance between content and game mechanics in order to be attractive	Web game	NTUA
CG.CO.1	The Game should include a debate tool in which people will be able to talk about policies	Web game	NTUA, ATC
CG.PO.1	The Game should not be integrated to Facebook and probably any other such platform, but instead be an independent implementation.	Web game	NTUA, ATC
CG.PO.2	The Game must have a built-in and independent to anything else authenticating mechanism	Web game	NTUA, ATC

According to this analysis, we defined the functionality and inputs and outputs of the various components with the intention to meet the user requirements while at the same time fulfilling the project's high level vision. These are described below.

3 Components

The conceptually independent components that comprise the two systems (MOOViz and Game) are described in this Section. Emphasis is put on the description of the components' functionality, in the details of their operation, the technologies they use and their inputs and outputs. We start with the two models and continue with the pure software components. For readability purposes we present the top level design figure here too.

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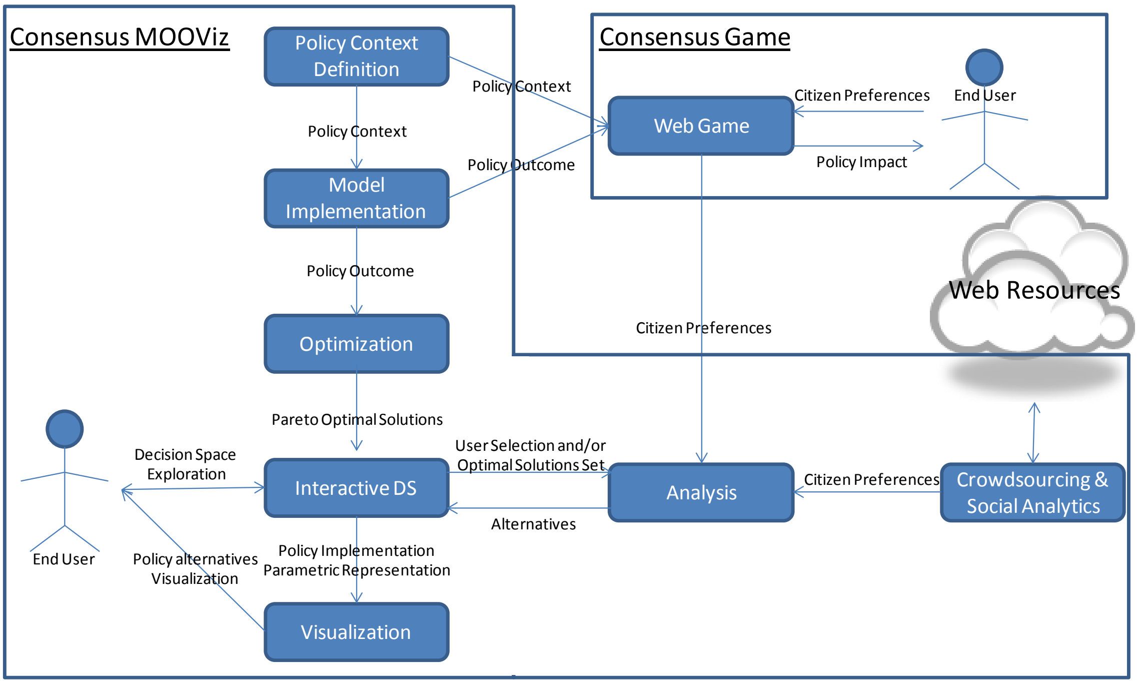

Figure 3: Consensus Tools - top level design diagram

Note that the components are presented as standalone modules here. Details about their integration are provided in Sections 4 & 5.

3.1 Environmental Modelling framework for Consensus

The purpose of the GLOBIOM model is to provide data input for the multi-criteria analysis (MCA). Therefore the model will run different biofuel policy scenarios and provide thereby a "scenario surface" for the MCA. The model will report outputs for each of the scenarios and thus create the space upon which the MCA will conduct their optimization.

In general, the role of GLOBIOM in Biofuel Policy assessment, in the Consensus framework, can be identified in Figure 4.

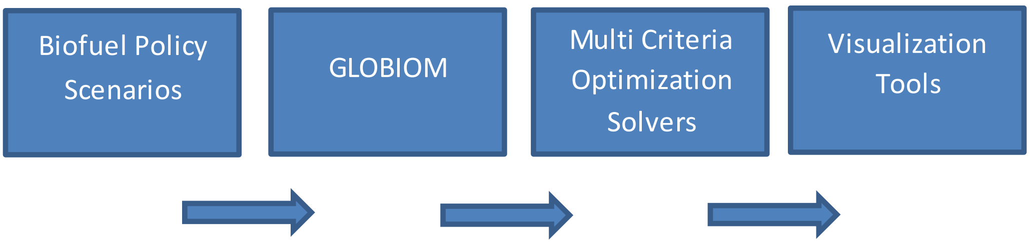

Figure 4: GLOBIOM in the Consensus Framework

3.1.1 Conceptual structure

The Global Biosphere Management Model (GLOBIOM) has been developed and is used at the International Institute for Applied Systems Analysis (IIASA). GLOBIOM is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors. It is global in the sense that

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it encompasses all world regions. Partial denotes that the model does not include the whole range of economic sectors in a country or region but specializes on agricultural and forestry production as well as bioenergy production. However, these sectors are modelled in a detailed way. Table 1 presents some key information about the model while Figure 5 illustrates the model structure graphically followed by technical representation of the model structure (key variables, parameters, indexes, equations etc.).

	GLOBIOM
Model framework	Bottom-up, starts from land and technology
Sector coverage	Detailed focus on agriculture, forestry and bioenergy (Partial equilibrium)
Regional coverage*	Global (28 EU Member states + 25 regions)
Resolution on production side	Detailed grid-cell level
Time frame*	2000-2050 (ten year time step)
Market data source	EUROSTAT and FAOSTAT
Factor of production explicitly modelled	More detailed on natural resources (land, water)
Land use change mechanisms	Geographically explicit. Land conversion possibilities allocated on grid-cells taking into account suitability, protected areas.
Representation of technology	Detailed biophysical models estimates for agriculture and forestry with several management systems
Demand side representation	On representative consumer per region and per good, only reacting to price
GHG accounting*	12 sources of GHG emissions covering crop cultivation, livestock, land use change etc.

Table 1: Main structural elements of GLOBIOM

The model is coded in GAMS (General Algebraic Modelling System) software which is a high-level modelling system for mathematical programming and optimization. It consists of a language compiler and a stable of integrated high-performance solvers. GAMS is tailored for complex, large scale modelling applications, and allows to build large maintainable models that can be adapted quickly to new situations (http://www.gams.com).

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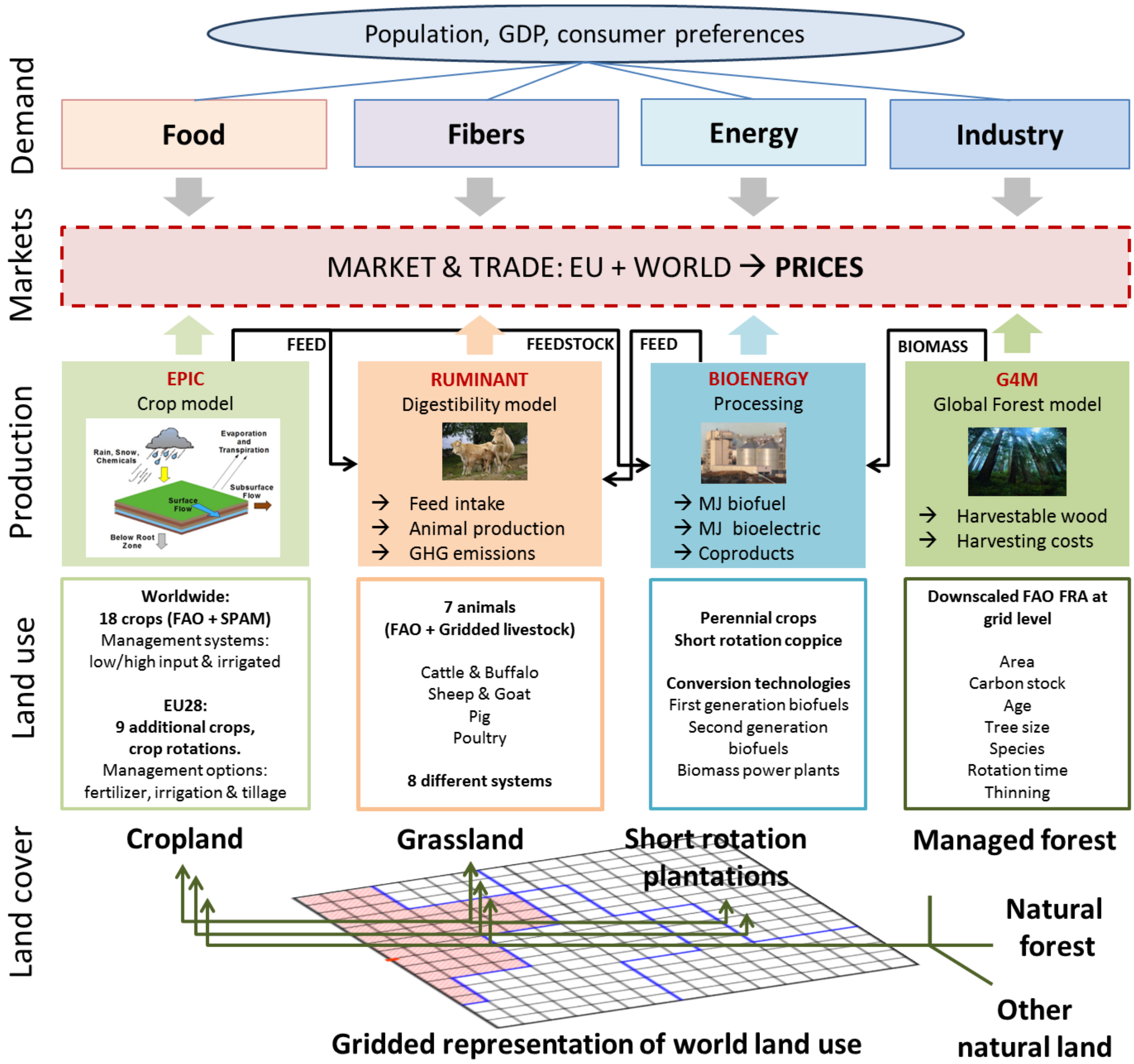

Figure 5. Overview of the GLOBIOM model structure

3.1.2 GLOBIOM - Formal description

Variables

D demand quantity [tonnes, m3, kcal]

W irrigation water consumption [m3]

Q land use/cover change [ha]

A land in different activities [ha]

B livestock production [kcal]

P processed quantity of primary input [tonnes, m3]

T inter-regionally traded quantity [tonnes, m3, kcal]

E greenhouse gas emissions [t CO_2eq]

L available land [ha]

Functions

φ^{demd} demand function (constant elasticity function)

φ^{splw} water supply function (constant elasticity function)

φ^{lucc} land use/cover change cost function (linear function)

φ^{trad} trade cost function (constant elasticity function)

Parameters

τ^{land} land management cost except for water [$ / ha]

τ^{live} livestock production cost [$ / kcal]

τ^{proc} processing cost [$ / unit (t or m3) of primary input]

τ^{emit} potential tax on greenhouse gas emissions [$ / t CO_2eq]

d^{targ} exogenously given target demand (e.g. biofuel targets) [EJ, m3, kcal,…]

α^{land} crop and tree yields [tonnes / ha, or m3 / ha]

α^{live} livestock technical coefficients (1 for livestock calories, negative number for feed requirements [t/kcal])

α^{proc} conversion coefficients (-1 for primary products, positive number for final products [e.g. GJ/m3])

L^{init} initial endowment of land of given land use / cover class [ha]

L^{suit} total area of land suitable for particular land uses / covers [ha]

ω irrigation water requirements [m3/ha]

ε^{land}, ε^{live}, ε^{proc}, ε^{lucc} emission coefficients [t CO_2eq/unit of activity]

Indexes

r economic region (27 aggregated regions and individual countries)

t time period (10 years steps)

c country (203)

o altitude class (0 – 300, 300 – 600, 600 – 1100, 1100 – 2500, > 2500, in meter above sea level)

p slope class (0 – 3, 3 – 6, 6 – 10, 10 – 15, 15 – 30, 30 – 50, > 50, in degree)

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q soil class (sandy, loamy, clay, stony, peat)

l land cover/use type (cropland, grassland, managed forest, fast growing tree plantations, pristine forest, other natural vegetation)

s species (37 crops, managed forests, fast growing tree plantations)

m technologies: land use management (low input, high input, irrigated, subsistence, "current"), primary forest products transformation (sawnwood and woodpulp production), bioenergy conversion (first generation ethanol and biodiesel from sugar cane, corn, rapeseed and soybeans, energy production from forest biomass – fermentation, gasification, and CHP)

y outputs (primary: 30+ crops, sawlogs, pulplogs, other industrial logs, fuel wood, plantations biomass, processed products: forest products (sawnwood and woodpulp), first generation biofuels (ethanol and biodiesel), second generation biofuels (ethanol and methanol), other bioenergy (power, heat and gas)

e greenhouse gas accounts: CO_2 from land use change, CH4 from enteric fermentation, rice production, and manure management, and N_2O from synthetic fertilizers and from manure management, CO_2 savings/emissions from biofuels substituting fossil fuels

I. Objective function

$$
\mathrm{Max}\ WELF_t = \begin{aligned}[t] & + \sum_{r,y} \left[\int \varphi_{r,t,y}^{demd} \left(D_{r,t,y} \right) \mathrm{d}(\cdot) \right] - \sum_{r} \left[\int \varphi_{r,t}^{splw} \left(W_{r,t} \right) \mathrm{d}(\cdot) \right] \\ & - \sum_{r,l,\tilde{l}} \left[\int \varphi_{r,l,\tilde{l},t}^{lucc} \left(\sum_{c,o,p,q} Q_{r,t,c,o,p,q,l,\tilde{l}} \right) \mathrm{d}(\cdot) \right] \\ & - \sum_{r,c,o,p,q,l,s,m} \left(\tau_{c,o,p,q,l,s,m}^{land} \cdot A_{r,t,c,o,p,q,l,s,m} \right) \\ & - \sum_{r} \left(\tau_{r}^{live} \cdot B_{r,t} \right) - \sum_{r,m} \left(\tau_{r,m}^{proc} \cdot P_{r,t,m} \right) \\ & - \sum_{r,\tilde{r},y} \left[\int \varphi_{r,\tilde{r},t,y}^{trad} \left(T_{r,\tilde{r},t,y} \right) \mathrm{d}(\cdot) \right] \\ & - \sum_{r,e} \left(\tau_{t,e}^{emit} \cdot E_{r,t,e} \right) \end{aligned} \qquad (1)
$$

Exogenous demand constraints

$$
D_{r,t,y} \geq d_{r,t,y}^{targ} \qquad (2)
$$

II. Product balance

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$$D_{r,t,y} \leq \sum_{c,o,p,q,l,s,m}\left(\alpha^{land}_{t,c,o,p,q,l,s,m,y} \cdot A_{r,t,c,o,p,q,l,s,m}\right) + \alpha^{live}_{r,t,y} \cdot B_{r,t} + \sum_{m}\left(\alpha^{proc}_{r,m,y} \cdot P_{r,t,m}\right) + \sum_{\tilde{r}} T_{\tilde{r},r,t,y} - \sum_{\tilde{r}} T_{r,\tilde{r},t,y}$$
(3)

III. Land use balance

$$\sum_{s,m} A_{r,t,c,o,p,q,l,s,m} \leq L_{r,t,c,o,p,q,l} \quad (4)$$

$$L_{r,t,c,o,p,q,l} \leq L^{init}_{r,t,c,o,p,q,l} + \sum_{\tilde{l}} Q_{r,t,c,o,p,q,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t,c,o,p,q,l,\tilde{l}} \quad (5)$$

$$Q_{r,t,c,o,p,q,l,\tilde{l}} \leq L^{suit}_{r,t,c,o,p,q,l,\tilde{l}} \quad (6)$$

recursivity equations (calculated only once the model has been solved for a given period)

$$L^{init}_{r,t,c,o,p,q,l} = L^{init}_{r,t-1,c,o,p,q,l} + \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,l,\tilde{l}} \quad (7)$$

$$L^{suit}_{r,t,c,o,p,q,l,\tilde{l}} = L^{suit}_{r,t-1,c,o,p,q,l,\tilde{l}} + \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,\tilde{l},l} - \sum_{\tilde{l}} Q_{r,t-1,c,o,p,q,l,\tilde{l}} \quad (8)$$

IV. Irrigation water balance

$$\sum_{c,o,p,q,l,s,m}\left(\varpi_{c,l,s,m} \cdot A_{r,t,c,o,p,q,l,s,m}\right) \leq W_{r,t} \quad (9)$$

V. GHG emissions account

$$E_{r,t,e} = \sum_{c,o,p,q,l,s,m}\left(\varepsilon^{land}_{c,o,p,q,l,s,m,e} \cdot A_{r,t,c,o,p,q,l,s,m}\right) + \varepsilon^{live}_{r,e,t} \cdot B_{r,t} + \sum_{m}\left(\varepsilon^{proc}_{r,m,e} \cdot P_{r,t,m}\right) + \sum_{c,o,p,q,l,\tilde{l}}\left(\varepsilon^{lucc}_{c,o,p,q,l,\hat{l},e} \cdot Q_{r,t,c,o,p,q,l,\tilde{l}}\right)$$
(10)

3.1.3 Input

Several datasets are used in different formats to feed the GLOBIOM model:

Official statistics

- FAO statistics: country level production and demand quantities, prices etc.
- EUROSTAT: country level production and demand quantities, prices etc.
- ...

GIS datasets

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- Land cover map: providing land cover information on the Simulation Unit level.
    - Global Land Cover 2000:
    - CORINE land cover
- Topography: soil, slope and altitude characteristics to delineate Simulation Units [2]
- Biodiversity maps: spatially explicit high biodiversity maps [3]
- Soil carbon maps: soil carbon content for different land uses [4], [5]
- …

Biophysical model inputs

- EPIC: Crop sector inputs (e.g. crop yields, fertilizer and water requirements, soil organic carbon etc.)
- G4M: Forest sector inputs (e.g. mean annual increments, harvesting costs etc.)
- RUMINANT: Livestock sector diets, productivities and GHG emissions

Driver datasets

- POLES/PRIMES energy models: Bioenergy demand projections
- Shared Socioeconomic Pathways (SSP) database: Population and GDP projections
- …

The datasets used enter the model in various formats (e.g. csv, excel or gdx files). For more detailed information on the input datasets used we refer to [6] and [7].

3.1.4 Output

The model provides results for the agricultural, forestry and bioenergy sector for the different biofuel scenarios. Below we list most important default output parameters. Regarding the format of the model output the GAMS software is flexible and model results can be reported in most common output formats such as csv, excel, gdx etc.:

Economic

- Market prices for the different commodities
- Global consumer and producer surplus
- Demand quantities for the different commodities
- Supply quantities for the different commodities
- Bilateral trade flows
- Yields

Environmental

- Fertilizer use
- Water use
- GHG emissions
- Land use change areas
- Deforestation areas
- Conversion of biodiverse areas

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- Intensification

Social

- Calorie consumption per capita
- Food prices

Besides the outputs mentioned above, a number of additional parameters will be implemented and reported in the course of the project to better assess sustainability of biofuels and the different trade-offs related to that policy. For more information on the additional metrics we intend to implement in the model we refer to Deliverable 2.1.1. For more information on general model outputs we refer to [6], [7].

3.2 Transport Modelling framework for Consensus

The purpose of the Transport Model (TM) is to support the genesis of the final set of road pricing policy scenarios for the multi-objective solver, in terms objectives' (resulting) values for each road pricing policy option examined.

More specifically, the TM is indented to allow the development of reliable estimates of toll revenues (or revenues' proxies) and traffic changes, along with all related traffic-impacts such as environmental and safety impacts, for each road pricing policy option.

TM will be tested during the transport pilot execution.

In general, the role of TM in Road Pricing Policy assessment, in the Consensus framework, can be identified in Figure 6.

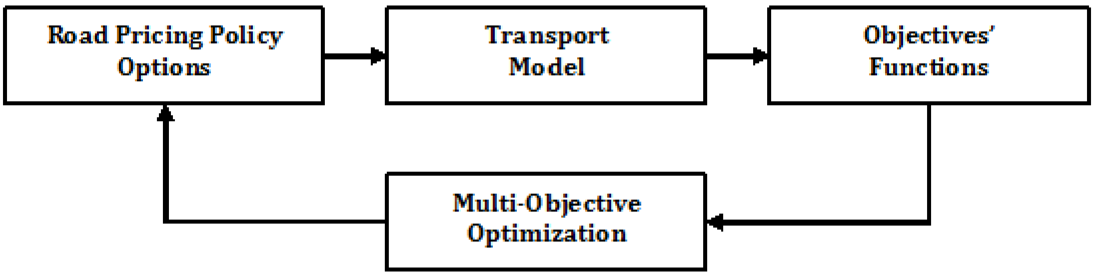

Figure 6: Transport Model in the Consensus Framework

3.2.1 State-of –the Art review and Synthesis of Existing Techniques

Two main transport model types exist [8], namely:

- Conventional, three and four stage transport models: These are the most commonly used in practice and are extensively available.
- Simplified models: These are sometimes applied to make rapid progress in particular circumstances.

Conventional models are the most well-known transport modelling technique. Typically they require (a) demand data describing travel between zones (O-D matrices usually based on surveys), (b) highly detailed network characteristics (zones, links –multimodal- connecting zones, capacity of the linkages between zones etc.), (c) background socio-economic data

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(population, land-uses developments, GDP per capita, car-ownership, etc.) and (d) a number of assumptions (growth rates for socio-economic data and other values i.e. value of time, vehicle operating costs etc.). Their basic strength is they can produce very detailed operational results; mainly regarding trip movement patterns and traffic volumes.

However, transport objectives now extend far beyond operational transport considerations for private car traffic, and include requirements to contribute to economic growth, better health, safety, accessibility and environmental and economic conditions. For these and other purposes, such as testing demand management options or price-based measures, conventional transport models are limited and other approaches are needed [8].

So, more comprehensive model based techniques to identify overall trends and outcomes, especially at the strategic scale, are needed [9], such as simplified models.

Simplified models represent the transport system with a high degree of network and zonal aggregation. Simplified models can be thought of as “emphasizing the use of readily available data and the communicability of simpler model features and results in order to supplement the information and capability of existing models” [10]. Simplified models produce mainly “indicative” or “approximate” forecasts, rather than conventional transport models which attempt to provide “precise” or “accurate” results. A number of simplified models have been developed internationally, for example, the Strategic Transport Model, developed and applied in the UK [8]. Simplified models have also been applied in developing countries [11], [12].

Three main types of simplified models exist [8]: Simplified demand models (mode choice models, elasticity based models), Structural models (generalized relationship models, regression based models) and Sketch models (highly simplified conventional transport models employing simplified techniques i.e. elasticity-based).

Simplified models have a number of comparative strengths [8], including potential for greater segmentation of demand type (behaviour and dynamic aspects than is normally possible in conventional transport models), speed and low cost of use, transparency/ease of understanding and use and testing flexibility and accessibility.

A particular strength of an elasticity based approach is the range of literature on the subject that can be incorporated without extensive data collection.

To this end, a simplified sketch/elasticity based model will be developed for use in the Consensus framework, since

- the Consensus transport policy scenario concerns examination of price-based policies (road pricing) and the inherent structure of conventional models tend to make them unresponsive to such policy options testing (at least not without substantial modification);
- the development of conventional transport model development would require (a) the availability of a respective modelling software and (b) large amount of demand data (i.e. survey based origin-destination data) and highly detailed (multimodal)

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transport network representation and as such is rather impossible to be developed and validated/calibrated in the Consensus framework;

- there is a rather limited time-frame during, Consensus project, for the transport modelling procedures;
- the quantity and quality of publicly available data and literature/research/case studies support more the development of simplified model based on elasticities.

3.2.2 Model's Conceptual Structure

The main product will be a spreadsheet-based sketch planning model that can be used to efficiently assess traffic and other impacts (primarily environmental and safety) associated with road pricing policy options as well as the expected revenues.

The structure of the excel-based spreadsheet will offer:

- an Input Data manipulation interface allowing the user to enter his/her readily available data concerning the specific policy options under examination; and –in the case of limited data availability- provide the user with a set of default data in order to assist him/her to make reasonable assumptions without much risk.
- a Computational interface; on a first level for the defensible simulation of traffic changes per policy option examined and on a second level for estimating the traffic-related impacts (environmental emissions, safety impacts), as well as toll revenues calculation (according to the expected traffic and the toll-structure). The functions/algorithms behind this computational interface will be heavily based of respective transport modelling literature and practices and more specifically on elasticities of demand with respect to various factors (as included in the input data).
- an Output interface allowing the user to view results in terms of revenues (or revenues proxies i.e. relative revenues), traffic changes/ estimates, traffic-related impacts (environmental i.e. air pollution and noise, safety) estimates. These Outputs will be in-line with the related objectives/criteria functions (else indicators measurement methods) in order to be ultimately used into the multi-objective solver.

A simple User Guide will be briefly described in a separate worksheet.

TM's structure is presented in Figure 7.

The TM is currently under construction, nonetheless the general idea of data sets, algorithms to be developed (using excel functions' and/or macros) and possible outputs, is provided next in paragraphs 1.3.1 to 1.3.3.

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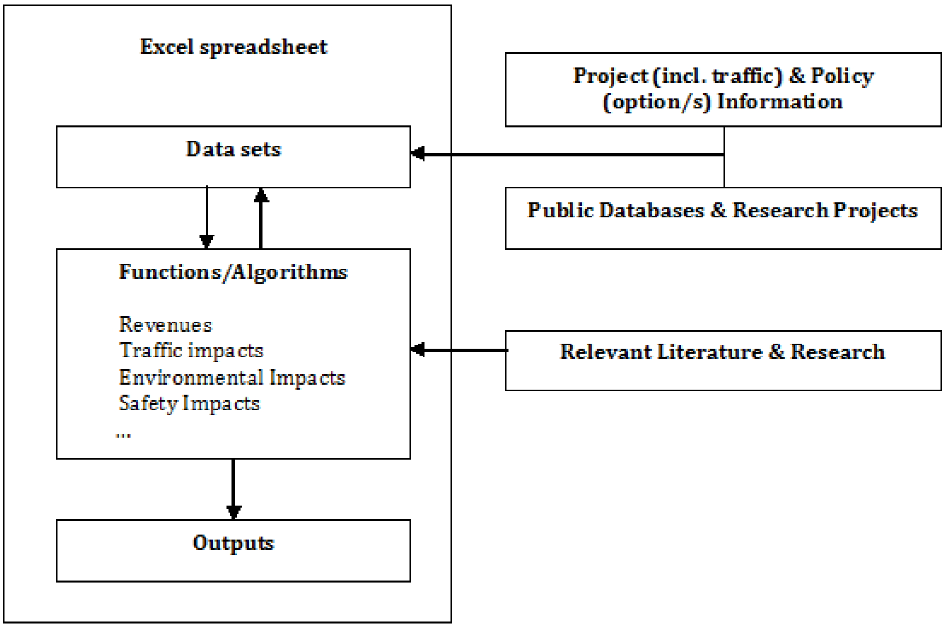

Figure 7: Transport Model Structure

3.2.2.1 Data sets

The necessary data for TM set-up include, as already mentioned, either readily available to the user data or a database of default values for the user to view and choose/make reasonable assumptions without much risk. Overall the necessary data include (initial/draft non-exhausting list):

- General Project Information, names or characteristics of the specific road project on which the various road pricing policies will be tested: project description name, opening year and years of assessment; project area and main characteristics - influenced area/environment, total length of tolled project, segments and timing of segments that make up total length; number if lanes etc.; and maximum ADT per lane (capacity) – this parameter caps the amount of traffic that can be considered at maximum for revenue generation, particularly in out years when compound growth could cause the total vehicles to reach unrealistic levels.
- Traffic Data Input, in terms of the current (if the road project exists) or the user's estimates (if it's a new project) of traffic for the analysis period: traffic volumes as ADT (average daily traffic) – current volumes; and current (or assumed future) growth rate for ADT (without tolls).
- General Policy Option/s Information. These inputs are those that directly describe toll rates and assumptions on toll collection: road pricing policy option/s type - flat-rate, distance-based, congestion or environmental charging; toll collection technique; price level and structure; equivalent toll revenue days; and implementation and operation cost.
- Socio-economic and financial data, to be used for the estimates of traffic changes and the traffic-related impacts that tolling will have: GDP, interest rates, inflation rates etc.; unit values of factors affecting -or be affected by- traffic - Value-of-time, Vehicle operating costs, other generalised cost factors as gas prices etc.; unit values

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of factors affected by traffic – external costs unit values; and demand elasticities with respect to various factors

Data to support assumptions (mainly -but not only- the socio-economic) will be collected from publicly available databases (i.e. EUROSTAT, UITP-Mobility in cities etc.) as well as EC research projects (UNITE, HEATCO, IMPACT etc.). Elasticities of demand specifically, will be provided from a wide literature of transportation modelling and economics as well as road pricing case studies worldwide. The rest should (ideally) be readily available to the user.

3.2.2.2 Algorithms

The basic function/algorithm of the TM concerns the estimation of traffic (or traffic changes) based on elasticities of demand with respect to various (Input) factors.

We assumed that the volume of traffic on a road section is a function of the monetary and time costs of using the section, the monetary and time costs of using –if exist- alternative/parallel free road or modes, the level of economic activity, and the generation and attraction factors at the origins and destinations [13]. Monetary cost is defined as the sum of three components: toll, gasoline cost, and other vehicle operating costs. All the monetary variables can be inflated by the CPI. The level of economic activity was measured as real gross domestic product (GDP); given that trips on road are undertaken for both leisure and business purposes, we used real GDP rather than disposable income in order to better capture the level of economic activity. Finally, the amount of traffic on a road section depends on the size of the potential market for each of them, which was determined by generation capacity and attraction of the origins and destinations, such as population and employment.

The demand function can therefore be expressed as follows:

$$Y_{it} = f\left(GDP_t, GP_t, RT_{it}^R, OC_{it}^R, TC_{it}^R, OC_{it}^o, TC_{it}^o, O_i, D_i, u_{it}\right) \quad (1)$$

where:

R = Road section (under examination),

o = alternative (other) routes,

Yit = traffic volume on motorway section i in period t ,

GDPt = real national GDP in period t ,

GPt = gasoline price in period t deflated by the CPI,

RT_{it}^j = Road toll on section i in period t deflated by the CPI,

OC_{it}^j = other vehicle operating costs (i.e., other than tolls and gasoline), j = R, o,

TC_{it}^j = time costs on section i in period t, j = R, o,

Oi = generation factors on section i,

Di = attraction factors on section i,

uit = error term, normally distributed with mean 0 and variance σ2.

Some of the above variables can be further expressed into (other) functions. The alternative route choice for instance can include the following logit equation [14]:

$$\text{Alternative Route Share} = 1 - [1 / (1 + \exp(\alpha * \Delta T + \beta * \text{Cost}/ \ln(\text{Inc}) + c + \text{TCT\_bias}))] \quad (2)$$

where:

exp = Base of natural logarithm (ln)

ΔT = time saving between toll road and non-toll road travel, in minutes

Cost = toll cost in €

Inc = median zonal annual household income

α = time coefficient

β = cost coefficient

c = toll road bias constant

TCT_bias = bias towards selecting toll routes using the specific payment/toll collection technique

However, this is an ideal model. Through, wide (available) literature and research, empirical specifications will be used to limit/ identify the final demand function's form, including dummy variables.

Then, for the estimation of traffic changes based on toll (as an depended variable) changes, partial functions theory will be used; in short the % change in traffic is a weighted average of % changes in each factor affecting traffic, where elasticities are the factor weights [15].

$$y = f(z1, z2,..) \quad (3)$$

and

$$\Delta y = (\text{partial } f/\text{partial } z1)\ \Delta z1 + (\text{partial } f/\text{partial } z2)\ \Delta z2 + ..$$

$$\Delta y/y = (\text{partial } f/\text{partial } z1)\ \Delta z1/\Delta y + (\text{partial } f/\text{partial } z2)\ \Delta z2/\Delta y$$

$$= (\text{partial } f/\text{partial } z1)\ \Delta z1/\Delta y\ (z1/z1) + (\text{partial } f/\text{partial } z2)\ \Delta z2/\Delta y\ (z2/z2) \quad (4)$$

$$= \text{El.y w.r.t } z1\ (\text{partial } z1/z1) + \text{El.y w.r.t } z2\ (\text{partial } z2/z2).$$

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Individual traffic demand (y) elasticities with respect to various factors (z1, z2) such as those presented in equation (1) (other routes availability, toll-price, travel time costs, other operating costs, increased capacity etc.) will be obtain from literature (as mentioned in paragraph 1.3.1)

If traffic changes are estimated, their further use into estimation of traffic-related impacts and revenues is quite easy.

Concerning the traffic-related impacts, EU research studies like UNITE, HEATCO, IMPACT etc. provide rough estimates of environmental, safety etc. levels and/or external costs with respect to traffic (vehicle-kilometers traveled). Concerning revenues estimation that's a straightforward calculation based on expected traffic and the respective toll price and structure.

3.2.2.3 Outputs

The TM has three levels of Outputs that a user can review. These reflect results for all policy options examined; in summary for each policy scenario and comparatively among the scenarios -including the base case/no-road pricing policy scenario- per output category and in total.

More analytically, the three levels are:

- All Outputs per Policy Scenario (Summary),
- Comparison of Scenarios Summaries, and
- Comparison of Scenarios per Output category

And the Output categories planned to be included:

- Revenues estimations
- Changes in traffic volumes and related factors (travel times, average speed, kilometers traveled)
- Changes in accident rates (or accidents probability)
- Changes in emissions (air and noise)

Based on the above outputs it will be possible, using the objective functions (indicators' measurement method) identified, to provide the necessary input to the multi-objective solver.

3.3 Policy Context Definition Component

This is an interactive (front-end) module, whose main purpose is acquiring the user input for defining the policy context parameters.

In order for the tool to be useful for resolving the concrete problem under investigation, the concrete context parameters need to be set. The context includes the general context attributes and parameters of the problem and optionally, setting more advanced parameters for fine tuning the context (if exist, this option will be limited to experts, power users and analysts in order to keep a simple mode of operation and usability for the

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conventional users). In cases when the decision maker has additional constraints on the viability of the proposed output policies that might disqualify some of the potential solutions. The context definition phase shall be used for this purpose as well as directing the simulation engine into a relevant class of alternatives if such exists.

In the regular mode of operation, the objectives those in the core of the policy decision problem are well structured and pre-defined. If more objectives are concerned, the user may select, customize or define and the specific set of objectives that is most relevant from her perspective on the problem.

The policy context is scenario specific; therefore this part shall be diversified for each of the scenarios. The decision context (e.g. mechanism for selecting the relevant objectives) will be common if applicable.

3.3.1 Input

Context parameters, interactively provided by the user.

3.3.2 Output

Policy Context Parameters (and possibly Gamification Parameters, Crowd Sourcing Parameters).

3.4 Optimization component

Applying the simulation results and constraints (defined in the policy context) the module shall extract an optimal set of policy alternatives.

Unlike single objective decision problems, for a nontrivial multi-objective optimization problem, there is no single solution that simultaneously optimizes all the objectives at once. In that case, the objective functions are said to be conflicting, and there exists a (possibly infinite number of) Pareto optimal solutions. A solution is called non-dominated, if none of the objectives can be improved in value without degrading some of the other objective values. Without additional subjective preference information, all Pareto optimal solutions are considered equally good.

Therefore, the result output from this phase is a set of potential policy alternatives each of which are efficient and reside on the Pareto front.

The optimization module is planned to be implemented as a server side component using the Java environment**.**

3.4.1 Input

Collection of potential policy alternatives and their calculated objective measures, a set of constraints defining valid solutions, and potentially some subjective preference information.

3.4.2 Output

Collection of potential policy alternatives and their quantitative consequences in the objective space.

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3.5 Interactive Decision Support Component

The *Interactive Decision Support* module is aimed at enabling the user to interactively explore the optimization results, understand trade-offs and select preferred alternatives.

During the exploration phase, the system shall provide the user interactive, analytics and visual means to explore and understand, the different policy alternatives and objectives and their mutual trade-offs. The user is able to interact with the policy alternatives, understanding the trade-offs, compare between alternatives, filter out alternatives, etc.

The visualization of alternatives in this module is provided in the objective space, and therefore it is common for both scenarios. Nevertheless it enables to invoke the decision space visualization which is concrete for each of the scenarios.

The systems shall provide means to drill down, assess, compare and analyze the different policy scenarios. She can focus on specific alternatives for better understanding them, compare alternatives for understanding where each of them outperforms the other, and perhaps even construct her own policy, and reveal its power with respect to the policies that automatically generated by the model. Then, after exploring the alternatives and revealing their advantages and limitations is to make the decision. The decision maker may gradually eliminate in-appropriate alternatives until the best one is chosen. Or decide for his/her favorite alternative among the entire set.

The decision support module is planned to be implemented as a client side Dojo Widget.

3.5.1 Input

Optimization Results and Insights extracted by the Analysis component.

3.5.2 Output

Visual Interactive decision support.

3.6 Analysis Component

This component deals with the analysis of the different policy alternatives and objectives, their mutual trade-offs, and aggregation of user preferences. The Analysis module is also responsible for integrating the input gathered from the public through Consensus Game and the Sentiment analysed by the crowd sourcing component into the decision support module.

The analysis results shall allow performing clear pair-wise analysis of the differences between different alternatives. Furthermore, given a policy alternative that is preferred by the user but not optimised, the system shall identify and advice an alternative the is outperforming the former. If applicable, the system shall capture the decision maker's preferences and recommends on the most desirable option according to her preferences. The preference elicitation itself may be explicit or implied from the user interaction with the system.

The analysis module is planned to be implemented as a server side component using the Java environment**.**

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3.6.1 Input

Optimization Results, User Interaction footprint, Public Acceptability through consensus game, sentiment through Crowd Sourcing Analysis.

3.6.2 Output

Trade-off Analysis, Optimised settings for the interactive decision support.

3.7 Visualization Component

To come up with a web-based visual analytics tool meeting all requirements and being suitable for the presented use cases we need 3 different software components:

1. **Data Module:**
   This module is responsible for loading the data and storing it appropriately. Additionally, pre-calculations will be performed like e.g., aggregation, normalization etc. As a result this module contains information about the raw input file, as well as enriched information about the data (e.g., metainformation).
   Technologies used: HTML, PHP, JavaScript, SQL
2. **Analytics Module:**
   The *analytics module* accesses the *preprocessing module* and collects all the relevant information necessary for our custom automatic algorithms (e.g., clustering, correlation, etc.). The results of this automatic analysis can be stored together with a unique identifier to be able to access the original raw data and draw conclusions.
   Technologies used: PHP, JavaScript, SQL, external libraries (KNIME, R etc) as appropriate
3. **Visualization Module:**
   The *visualization module* has access to the *data module* and the *analytics module* to be able to collect all the relevant data/information. As a first step the results for the automatic analysis of the *analytics module* are visualized and can be interactively explored by the user. Next, the user can either access the analytics module by adjusting input parameters for the automatic analysis or she or he can demand for further details accessing the data module and collect the raw information.
   Technologies used: HTML, CSS, PHP, JavaScript, D3, SQL

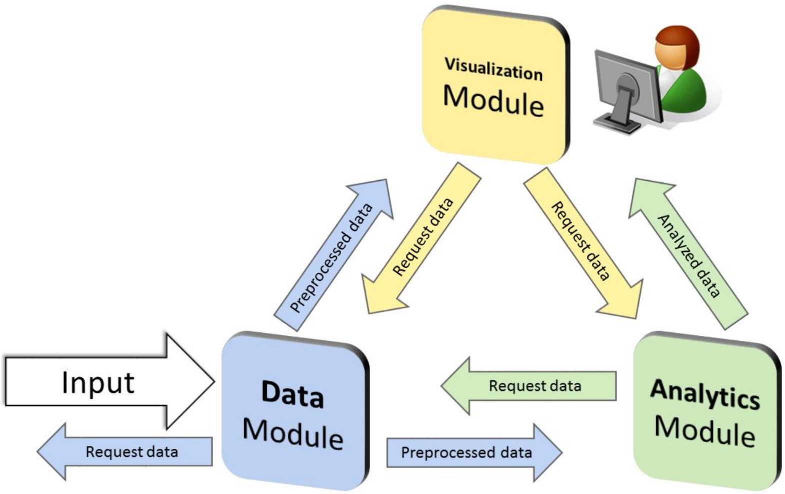

Figure 8: Visual Analytics Tool-Components: The data module requests the raw data as a common .csv file. After preprocessing the data it will be stored in a database accessible via the visualization module and the analytics module. The analytics module makes use of the preprocessed data and enriches the database with additional information.

3.7.1 Input

The input of the tool is a complete parametric representation of an alternative policy implementation. The data module expects a common .csv file as input.

3.7.2 Output

There will be only a visual output, the visualization of the policy alternatives.

3.8 Web Game

The main idea is to introduce users to a collaborative or antagonistic framework in which they will be able to make policy implementation options using the Consensus models as if they were their decisions and affect a virtual context. The context in this case is a model of a set of parameters that relate to the policy in question. As such, one context relates to a virtual city in which various socio-economic and environmental parameters are modelled. The second will be a road network in which the modelled parameters will be the road conditions and in consequence the safety, speed, etc in relation to the paying schemes.

By participating in the game the user will be given the chance to make a decision about the policy implementation by actually modelling the input to a probable output. Guidance about consequences as well as insights (like what is a near optimal solution) will be provided to the citizen before they submit their decision. In each game session the group will have a specific amount of resources (that ideally are linked to real world resources) to spend in policy implementation so as to resolve a specific problem that they are assigned with. Players will be able to submit their options until a certain deadline, after which the system uses the collected options together with the current context and evaluates its new state. The best policy implementation (according to a point system predefined for each policy) among the policies selected is implemented/adopted, thus affecting the virtual context. The player or alliance that picked that scenario that is regarded the best wins and gets score points according to a rating system. The result of the implementation leads to a new state/context. After that point, and if users desire it (single game, 2 or 3 continuous games) a new session might begin during which the citizens can submit their new policy implementation options, perhaps in an attempt to revert unwanted consequences of their previous calls. If the game is set for continuous games the budget for the next session will be calculated according to the previously implemented policy. Visualizations will depict the current context state (e.g. a damaged road or a city without any green).

In order to provide to the citizens the means to collaborate to achieve the change of the context to the direction they prefer, a chat interface will coexist with the rest of the tools so that they can debate and defend their options. An analysis of the reasons that led to the evolution of the context towards a certain state will also be available, visualizing the statistics that relate to the citizens' options, highlighting the factors that contributed the most to a possibly rapid change of the state. This will be done through the Social Analytics component described in Section 3.9.

Furthermore, the game will anonymously collect and synthesize the preferences of the users which will then be reported in the Analysis component. This essentially forms a crowdsourcing task that is described in Section 3.10.

3.8.1 Input

A virtual policy context, in the form of a parameter vector.

3.8.2 Output

User preferences both based on the most favored decision but also based on data analytics in the generated text in the chat.

3.9 Social Analytics Component

In order to objectively measure the public acceptability for a certain policy, or even policy parameter, a specialized system must be created. This system will essentially be a sentiment analysis tool. This tool will be able to analyze the current public acceptability, based on data as similar as possible with the data to be tested and provide us with an objective prediction of the public acceptability to be expected for a certain policy parameter. Thus a public acceptability prediction model will be created and integrated in with other prediction models, providing the policy makers with a more accurate view on the effects that a policy will have.

For this component we plan to use a web service architecture, employing java classes that can be used through a RESTful API. The inputs and outputs of this API are discussed below.

The actual analysis will be conducted either on a central physical machine that will receive the API calls and employ the algorithms developed, or on a cluster of computers that will be orchestrated by this central physical machine. The cluster may be needed if the execution time required by the algorithms surpasses a usability threshold. This cluster could be a physical one or a virtual one using cloud technologies. Either way if such a distributed solution is required we will be using the Hadoop framework.

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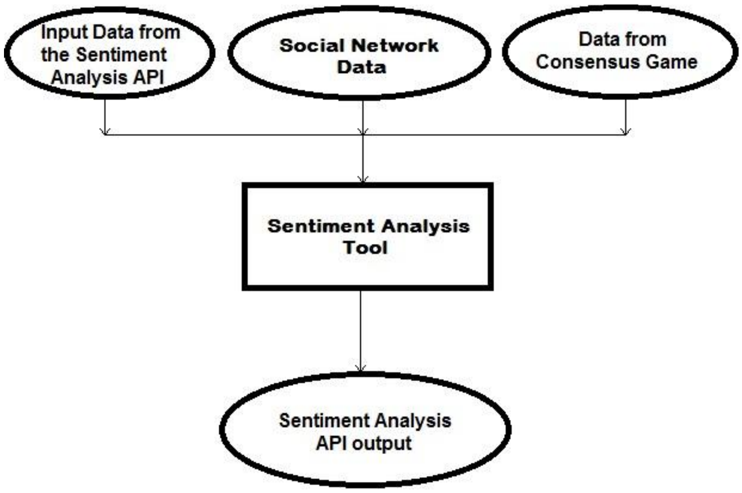

Figure 9: Sentiment Analysis workflow

The sentiment Analysis tool will consist of a number of natural language processing methods and machine learning algorithms. Those methods and algorithms will be combined in a software component developed for the Consensus project. In this component a software controller may be required in order to decide which combination is best to be used in order to analyze each different input. For example if the input text is of small length (up to 140 characters) we could use a combination of 4-Gram Graphs and Multilayer Perceptrons, but if the text is of larger length (about 700 words for example) maybe this combination is not only taking too long to show results, but it could also be less effective.

The following diagram shows the inner design of this analytics tool. We can see that the machine learning algorithms will be trained with pre-collected data and then test the input text or collection of textual data. These pre-collected data could be updated in regular intervals, with new data, increasing the accuracy of the algorithms. To apply this update we have to retrain the algorithms with the updated dataset. This procedure takes time and thus it should not be done too often to avoid system downtime.

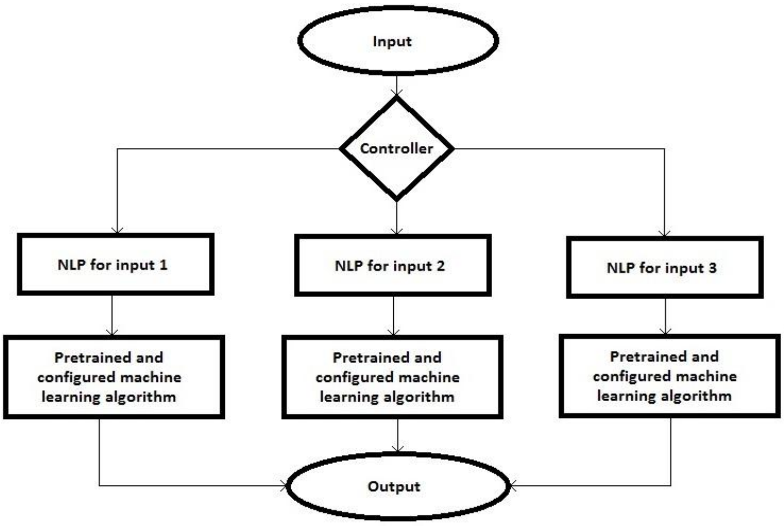

Figure 10: High-level depiction of the algorithm steps

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If we want a simpler solution, we would just skip the implementation of the controller and choose one of the possible input types. This way we would have a specialized system that will only work with one type of input but it will demand less resources.

3.9.1 Input

Depending on the application the inputs vary as presented below:

- A text. That text could be anything, from a single tweet to a short paragraph about a specific subject.
- A set of tweets. In this option the input can be consisted of a set of short texts (tweets) or even a set of full tweets containing the text, the author, the date and other info about each tweet.
- A subject. In this option we could input a specific subject and the algorithms will automatically detect relevant data on the social networks and analyze them.

3.9.2 Output

Following the input patterns the outputs of the data analytics component will be:

- A numerical value showing the level of public acceptance towards the analyzed subject. In that case -1 would be hatred towards the subject, 0 would be neutrality and 1 would be complete acceptance. For example the number 0.3 would show a slight tendency towards acceptance.
- A vector showing the possibility of each acceptability category being the dominant one. Each vector consists of the possibility that the analyzed subject is accepted by the public, the possibility that the public is neutral towards the subject and finally the possibility that the public would not accept the subject. That way the vector showing absolute acceptance would be {1,0,0}, the one showing absolute neutrality would be {0,1,0} and the one showing absolute negativity would be {0,0,1}. A vector showing a slight tendency towards acceptability would be {0.3,0.7,0}.

3.10 Crowdsourcing Component

Public acceptability of a policy can be sought in social media and web sources, however, such (raw) data obtained from (Social) Web feeds often contain variable amounts of “noise”, misinformation and bias (which can get further “amplified” through the viral nature of social media) and will usually require some advanced forms of filtering and verification by both machine-based algorithms and human experts before becoming reliable enough for use in decision-making tasks. WSARE (What’s Strange About Recent Events)-type algorithms [16] and platforms such as SwiftRiver [17] (open source, provided by Ushahidi) can prove helpful in trying to filter the Social Web “firehose”.

Through the Web Game it will be feasible to crowdsource the task of analyzing public opinion and acceptability of certain policy implementations. Citizens will use the game mechanics to implicitly express preference in specific implementations, e.g. by:

- Selecting a policy implementation by evaluating the objectives

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- "Liking" or "disliking" (approving/disapproving) a certain selection made from another user

These actions explicitly or implicitly declare preference and by taking into consideration the crowdsourcing component can identify the most prominent options and the outliers. These can then be reported back to the Analysis component for further processing and conclusions.

3.10.1 Input

The inputs of the component are certain events which denote preference on vectors which represent a policy implementation.

3.10.2 Output

The outputs of the component are sorted vectors (i.e. ranked policy implementation options) and mean values (i.e. an ideal policy implementation that on average is preferred).

4 Integration

The components of the Consensus tools are largely dependent on different technologies which makes the integration a challenging task. This is why a loosely coupled architecture is favoured with each component operating in isolation and autonomy, preserving its own persistence layer and exposing a web interface. The backend that will orchestrate the various components, will host possibly "orphan" components and will guarantee the non-functional requirements of the system will be either the Java Enterprise Edition or the ASP.NET Framework. Both these infrastructures can accommodate a variety of heterogeneous technologies and provide guarantees on the quality of service.

Web methods are going to be employed that will enable the communication between the various loosely coupled components. As we will describe later on in this Section, these methods vary depending on the components.

The majority of the components that do not interact with the models are based on compatible web technologies, such as Javascript and various Javascript libraries (client side) and PHP and Java (server side). In some occasions the interfacing between client and server will take place through web service interfaces.

In what follows we provide an overview of the technologies that each components uses.

Component	Code in...	Container needed
Environmental Modelling framework for Consensus	GAMS	GAMS
Transport Modelling framework for Consensus	MS EXCEL	Excel
Policy Context Definition Component	C# and Javascript	MS IIS & any browser
Optimization component	Java EE (Servlets, JSP, JSF)	WebSphere application server
Interactive Decision Support Component	DOJO Widget (Javascript)	any browser
Analysis Component	Java EE (Servlets, JSP, JSF)	WebSphere application server
Visualization Component	PHP and Javascript	Apache Tomcat & any browser
Crowdsourcing Component	PHP and Javascript	Apache Tomcat & any browser
Social Analytic Component	Java EE (JAX-WS/RS)	Glassfish Application Server
Web Game	PHP and Javascript	Apache Tomcat* & any browser

Table 2: Languages and containers for each component technology (*Drupal CMS will be used in this case)

The general deployment plan is illustrated in Figure 11. The diagram depicts how the various components are hosted in different containers and expose different technology interfaces (HTML, Web services, etc). The main integration and orchestration platform will be based on a mashup established upon ASP .NET or Java EE. Note that the Web Game is going to be a standalone component, developed in Drupal and whatever technical communication will take place through custom websockets calls so as to enable synchronization and avoid the pitfall of Cross Origin Resource Sharing (CORS) AJAX calls.

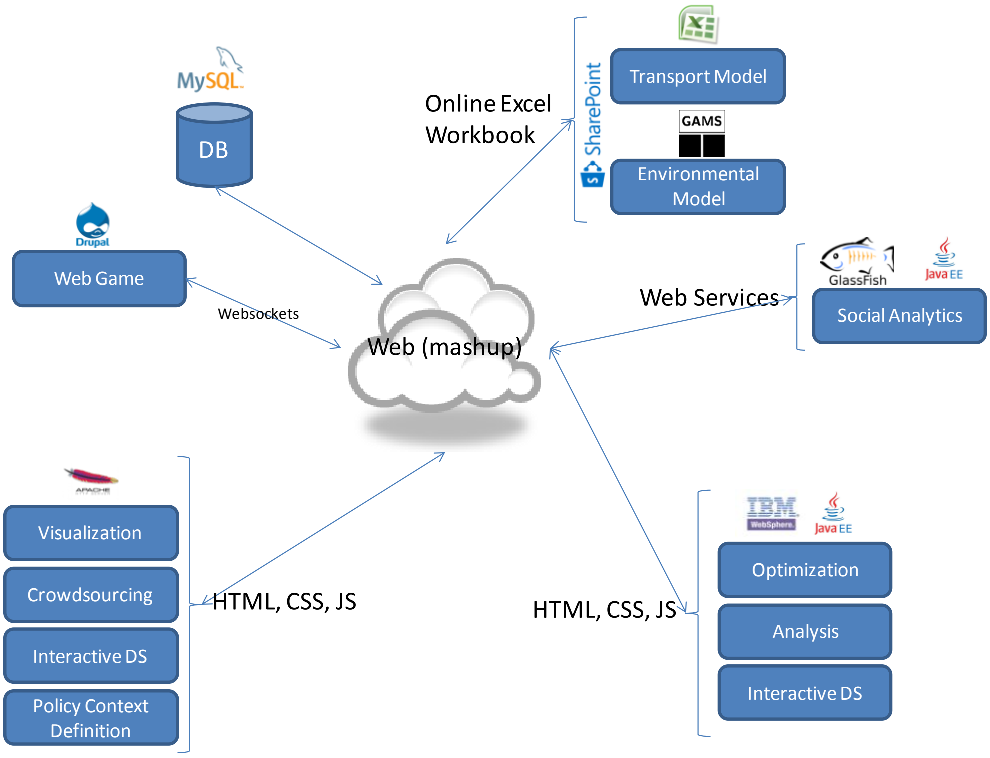

Figure 11: Deployment integration diagram

A point worth noting is the interaction between the models' implementation and the rest of the components. As stated in previous Sections, the models are built on top of proprietary containers (GAMS, MS Excel) which are required for the code to be executed. By default, a model is not an automated component that coordinates with the input data sources and delivers the output in an easy-to-interface method. Therefore the question about how the models will interface to the rest of the components persists. The preferable option is to employ MS Sharepoint, a container that makes Excel Workbooks available online. This is an ideal solution for the transportation model: it will allow us to provide inputs and retrieve the output directly from MS Excel, through the Excel REST API[1], automating the process. In the case of the environmental model, we will have to employ the MS Excel interface of GAMS[2] and be able to use the GDX facilities in GAMS to read data from Excel and to write data to Excel.

[1] http://blogs.office.com/2013/12/17/excel-rest-api-in-sharepoint-online/
[2] http://interfaces.gams-software.com/doku.php?id=excel:excel

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The alternative to this plan is presented in Figure 12. The idea is to use an intermediate file server in which the models will store the outcome files. The communication with the rest of the components will be asynchronous. They will pull the files from the file server whenever the data are required. A script on the server side or a wrapper on the client side will transform the file data to useful data formats that can load onto the component's host memory. This option will remain as a backup option in case we meet difficulties in using or purchasing the Sharepoint platform and the respective interfaces.

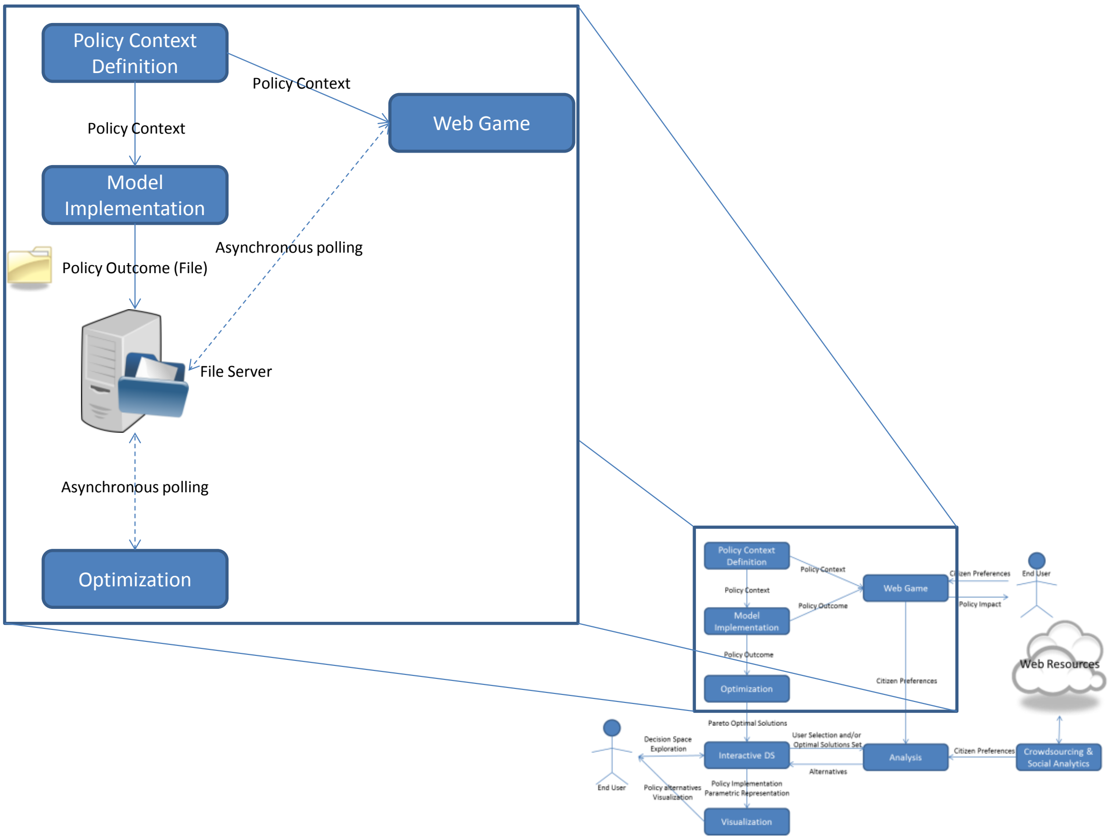

Figure 12: Backup plan for the implementation of the model interfacing with the rest of the components

5 Component Interaction

Given that the majority of components are following the REST paradigm, returning HTML and Javascript, their interfaces are simple HTTP endpoints. The main task of the integration is to present a user interface and meet the non-functional requirements (security, usability, etc) and most importantly, to orchestrate the invocation of these HTTP endpoints and organize the results in a usable way.

The social analytics component comprises the main exception in which the plan is to expose a REST web service interface. This component will serve HTTP POST requests. The body of the requests will contain the document for which we need to analyse its sentiment, and the body of the response will contain a JSON file with a numeric value representing the sentiment that the document expresses.

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