Chapter 15
Visual Decision Support for Policy Making: Advancing Policy Analysis with Visualization

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Abstract Today's politicians are confronted with new information technologies to tackle complex decision-making problems. In order to make sustainable decisions, a profound analysis of societal problems and possible solutions (policy options) needs to be performed. In this policy-analysis process, different stakeholders are involved. Besides internal direct advisors of the policy makers (policy analysts), external experts from different scientific disciplines can support evidence-based decision making. Despite the alleged importance of scientific advice in the policy-making process, it is observed that scientific results are often not used. In this work, a concept is described that supports the collaboration between scientists and politicians. We

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propose a science–policy interface that is realized by including information visualization in the policy-analysis process. Therefore, we identify synergy effects between both fields and introduce a methodology for addressing the current challenges of science–policy interfaces with visualization. Finally, we describe three exemplary case studies carried out in European research projects that instantiate the concept of this approach.

15.1 Introduction

The increasing complexity of societal and economic problems in the past decades has brought new challenges to politicians. In order to make sustainable decisions, a profound analysis of the problems and possible solutions has to be performed. The process addressing this challenge, often referred to as policy analysis, is one of the most critical steps in the policy-making process. The creation and analysis of alternative solutions (i.e., policy options) to a public problem remain a complex and challenging task with many different stakeholders involved.

From our experience in European research projects in the field of policy modeling, there mainly exist two methods to make decisions on a profound knowledge basis: data-driven and model-driven approaches. Prominent data-driven methods in the policy-making domain include social media analysis, text analysis (like opinion mining, hot topic sensing, and topic summarization), and statistical data analyses approaches. In this chapter, we focus on model-driven approaches that aim at reflecting complex real-world dependencies between social, environmental, and economical factors that have to be included in the analysis process. The application of these complex models in policy analysis helps to improve decision making by providing insight into the impacts that new policies may induce. To build these complex models, policy analysts often need to collaborate with external experts consulted as advisors. Due to different expertises of these stakeholders, the whole process may suffer from knowledge gaps. This implies challenges to be addressed.

In this chapter, we introduce a concept for visual decision support systems to support the policy analysis stages of the policy-making cycle. These systems include information visualization and visual analytics as possible solutions to bridge knowledge gaps between stakeholders involved in the policy-making process. The methods can help non-IT experts to get access to complex computational models. The coupling of visualization techniques and computational models supports different stakeholders in the policy-making process. The standard policy cycle will build the foundation of identifying the need for objective analysis in the entire policy-making cycle. Therefore, we characterize the main stakeholders in the process, and identify knowledge gaps between these roles. We emphasize the merits of including visualization techniques into the policy-analysis process, and describe visualization as a facet bridging the knowledge gaps in a collaborative policy-making life cycle. After describing our concept, best practices and research approaches will be discussed that have already implemented aspects of our concepts in European research

projects. These approaches are implemented into decision-support systems that include visual interfaces to complex models and enable policy makers, policy analysts, etc. to participate in the analysis of policy options.

15.2   Background

In the following, we first give an introduction to information visualization and related fields. The goal is to provide an overview of the capabilities that these research fields offer for policy making. Second, the discipline of policy analysis is characterized. With this introduction, we intend to harmonize the terminology, summarize different perspectives on the discipline, and identify open problems and challenges that inhibit the field.

15.2.1   Information Visualization and Visual Analytics

Information visualization is defined as "the use of computer-supported interactive, visual representations of abstract data to amplify cognition" (Card et al. 1999). In this definition, several aspects of information visualization are highlighted. First of all, as a research discipline from computer science, its solutions are provided as software. Second, these software solutions address the visual representation of data through visual artifacts or diagrams. The artifacts consist of basic visual elements that have been presented in the theory of graphics by Bertin (1983). In contrast to the static visual representation, information visualization deals with the interactive visual representation of data. Hence, an important aspect lies in the possibility of the user to interact with graphics generated by the software. Zoom and filter operations on the data are examples for user interaction. As a further aspect, information visualization deals with abstract data in contrast to scientific data. While scientific data are typically physically based reflecting at least some geometric information, abstract data such as economic data or document collections are not. Finally, the goal of information visualization is to amplify cognition. Cognition is defined as the acquisition of knowledge and insight about the world (Card et al. 1999). With information visualization, the user is enabled to gain knowledge about the internal structure of the data and causal relationships in it. Thereby, vision as the human sense with the highest bandwidth is exploited to support the comprehension of information. "Visual representations and interaction techniques take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once" (Thomas and Cook 2005).

Following Stephen Few, the purpose of information visualization is to support the exploration, sensemaking, and communication of data (Few 2009). Extracted from his work, Fig. 15.1 provides an overview of the broader data visualization field. Here, the activities addressed by data visualization are exploration and sensemaking
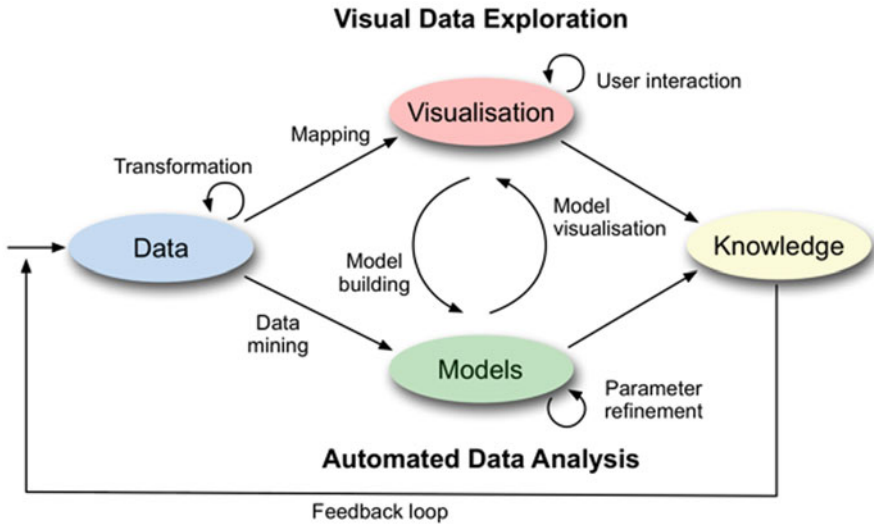
Data Visualization		
Activities	Exploration Sense-Making	⇨ Communication
Technologies	Information Visualization Scientific Visualization	⇨ Graphical Presentation
Immediate Goal	Understanding	
End Goal	Good Decisions	

Fig. 15.1 A characterization of data visualization by Stephen Few (2009). Distinction between activities addressed by data visualization. Exploration and sensemaking as analysis tasks. Communication as knowledge transfer task. Technologies differ with respect to presented data (information visualization for abstract data and scientific visualization for physically based data) and interaction capabilities of the technologies, e.g., graphical presentation does not imply user interaction. Understanding of provided information as intermediate goal. Good decisions based on derived knowledge as the end goal

as analysis tasks, and communication as knowledge transfer task. While exploration and sensemaking have the goal to extract knowledge from data, the purpose of communication is the transfer and presentation of these analysis outcomes. The applied data visualization technologies in Fig. 15.1 are information visualization, on which we focus in this approach: scientific visualization and graphical presentation. Information visualization can be used for both analysis and presentation. However, the choice of information visualization techniques and their use will differ with the task, data, and users involved. As an intermediate goal, data visualization attempts to support the understanding of the information hidden in the massive amounts of data. The ultimate goal is to support good decision making based on the knowledge extracted from the data.

Information visualization emerged from research in human–computer interaction, computer science, graphics, visual design, psychology, and business methods (Shneiderman and Bederson 2003). It allows to intuitively access results of complex models, even for nonexperts, while not being limited to intrinsic application fields. In fact, information visualization is increasingly considered as critical component in scientific research, data mining, digital libraries, financial data analysis, manufacturing production control, market studies, and drug discovery (Shneiderman and Bederson 2003).

The growing amount of data collected and produced in modern society contain hidden knowledge that needs to be considered in decision making. Due to the data's

Visual Data Exploration

Fig. 15.2 Visual analytics process adapted from Keim et al. (2008). Connecting the information visualization (*top*) and the data mining (*bottom*) processes

volume and complexity information, visualization can no longer be applied alone. A new research discipline within information visualization was introduced. *Visual analytics* is defined as "the science of analytical reasoning facilitated by interactive visual interfaces" (Thomas and Cook 2005). The goal of visual analytics research is the creation of tools and techniques to enable the user to (a) synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data, (b) detect the expected and discover the unexpected, (c) provide timely, defensible, and understandable assessments, and (d) communicate assessment effectively for action. In contrast to pure information visualization, visual analytics combines interactive visualization with automated data analysis methods to provide scalable interactive decision support.

Figure 15.2 shows an adaptation of Keim's widely accepted process model for visual analytics (Keim et al. 2008). The visual data exploration process from information visualization (upper part), and automated data analysis methods (lower part) are combined to one visual, and interactive analysis process model. The user is directly included in the model by interactive access to the process steps. This generic process model makes visual analytics applicable to a variety of data-oriented research fields such as engineering, financial analysis, public safety and security, environment and climate change, as well as socioeconomic applications and policy analysis, respectively. The scope of visual analytics can also be described in terms of the incorporated information and communication technologies (ICT) key technologies like information visualization, data mining, knowledge discovery or modeling, and simulation (Keim et al. 2008). In its framework program seven, the European

commission (EC) emphasized visualization as a key technology in the objective for ICT for governance and policy modeling (European Commission 2010).

Recently, methodologies on how to design and implement information visualization and visual analytics solutions for data-driven challenges of domain specialists have been presented (Munzner 2009; Sedlmair et al. 2012). Due to their reflection upon practical experiences of hundreds of information visualization and visual analytics research papers, the value of the introduced methodologies is widely recognized. In these methodologies, visualization researchers are guided in how to analyze a specific real-world problem faced by domain experts, how to design visualization systems that support solving this problem, and how to validate the design. Considering information visualization validation, we refer to Lam et al. (2012).

Recent approaches in visual analytics focus on the questions how to simplify the access to the analysis functionality of visual analytics techniques, and on how to present analysis results. This includes the analysis process with its intermediate steps, and the findings derived with the visual analytics techniques (Kosara and Mackinlay 2013).

Information visualization and visual analytics approaches in the policy analysis domain are still surprisingly scarce compared to the number of approaches presented in other analysis-driven fields (Kohlhammer et al. 2012). Still, the policy analysis domain is an ecosystem with a variety of involved stakeholders that intend to collaborate in the best possible way. This outlines policy analysis as an interesting application field for information visualization.

15.2.2 Policy Analysis

Policy analysis as a discipline of the policy sciences was introduced by Laswell and Lernen in their work "The Policy Sciences" in 1951 (Schneider and Janning 2006). It was interpreted as societal problem-solving discipline with the higher goal to support rational decisions in policy making (Blum and Schubert 2009). The main breach of this approach erased from the experience that decisions solely based on rational perspectives (positivism) are not sufficiently considering external factors within real-world scenarios. From this experience, post-positivism approaches evolved (Fischer et al. 2007). With this change of perspectives, the profession of the policy analysts had to be newly interpreted (Howlett and Wellstead 2009).

The knowledge background of policy analysts has to cover different facets ranging from policy science, social science, and economical science, to computer science (Göttrik 2009). The main objective of policy analysts is to provide scientific advice to policy makers during their political decision-making process. This process is also defined as the policy cycle (Blum and Schubert 2009). The policy cycle introduced by Jones (1970) and Anderson (1975) is depicted in Fig. 15.3.

It consists of five succeeding stages: problem identification and agenda setting, policy formulation, policy adoption, policy implementation, and policy evaluation. In the first stage, public problems are identified and the political agenda is set by
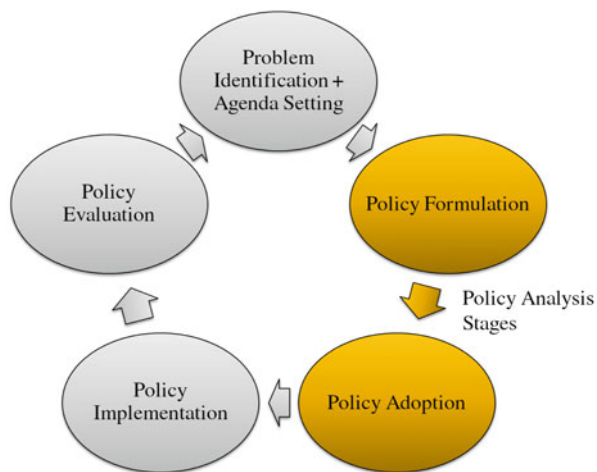
Fig. 15.3 Policy cycle adapted from Jones (1970) and Anderson (1975). Policy analysis is mainly conducted in the policy formulation and the policy adoption stage. While in the policy formulation stage, alternative solutions to a given problem are defined; in the policy adoption stage, one of these solutions (policy options) is selected for implementation. In a broader sense, policy analysis can also be conducted in the other stages of the cycle. However, in this work, we focus on the pre-decision phase before a policy is implemented

prioritizing societal problems. In the second stage, alternative solutions to these problems are explored and evaluated. In the third stage, these policy options are compared, and it is decided which option to choose. In the fourth stage, the selected policy option is implemented through legal process. In the final stage of the cycle, the implemented policy is evaluated with respect to the objectives defined in the first stage of the cycle.

Within the policy cycle, especially the policy formulation phase is supported by the policy analysts' expertise. "Policy formulation clearly is a critical phase of the policy process. Certainly designing the alternatives that decision makers will consider directly influences the ultimate policy choice" (Fischer et al. 2007).

More precisely, policy formulation is about choosing from different types of policy options those that can be used to address particular policy problems. Then, these choices are analyzed in terms of both their technical and political feasibility, with an eye to reducing their number to a small set of alternative courses of action that can be laid out for decision makers at the next stage of the policy process (Howlett et al. 1995).

Despite the expected importance of considering scientific knowledge in the policy formulation phase, a main deficit of policy making is recognized: the *policy paradox* describes the asymmetry between the amount of knowledge generated by scientific experts, and the actual amount of knowledge effectively used in the decision-making process (Shulock 1999). Among others, this paradox evolved from the following obstacles:

Limitations of scientific approaches: The impacts of societal processes are highly complex. The scientific models attempting to simulate reality are seldom precise or accurate. Furthermore, in most cases this uncertainty is not communicated to the user. This fails to raise the awareness of the model's uncertainty and, as a consequence, reduces the credibility of scientific outputs (Hove 2007; Schneider 2008; Göttrik 2009).

Isolation, complexity, and ephemerality of political processes: The policy cycles move faster than the research cycles (Schneider 2008; Howlett and Wellstead 2009). Some of the most frequent problems that policy analysts mention are lack of time, resources, and the ignoring of information (Howlett and Wellstead 2009).

Subjectivity of stakeholders: Different facets of subjectivity influence scientific experts and advisors. Human subjectivity is induced by individual, cultural, and religious values (Hove 2007). Economic subjectivity is induced since the advisors and scientific experts may be influenced by their employer (Dobuzinskis et al. 2005). Moreover, political subjectivity may be induced due to an affiliation to political parties (Greven 2008).

Concepts have been introduced to address these problems, which evolve from bringing two contrary systems, politics and science, together. Most of these concepts can be summarized under the term science–policy interface. Janse defines the science–policy interface as "the point at which science and policy meet and act on each other" (Janse 2008). The positive aspects out of this are: (a) rationality and legitimation through knowledge in politics, (b) exploration of policy alternatives with focus on cause and effect, (c) communication between two fields—e.g., research assignment and scientific advice. In order to realize these aspects, the concept of "knowledge brokers" is propagated. Their goal is to mediate between the two systems (Howlett and Wellstead 2009). Still, these concepts contain the risk of subjectivity described above. As a consequence, the propagation of a mere technocratic model has to be replaced by a concept with high interaction possibilities between knowledge and decision makers as mentioned in Göttrik (2009). In our approach, we will lay out how information visualization may support this concept.

15.3 Approach

In this section, we describe our approach of using visual decision support systems as the means to bridge gaps in policy analysis. A first version of this concept can be found in our previous work (Ruppert et al. 2013a). In the following, we characterize the stakeholder involved in the policy-analysis process. Then we provide more detail about the policy-analysis process with its challenges, and provide a concept how to address these challenges. As the last part of this approach, we summarize the advantages of our concept with regards to enhanced policy making.

15.3.1   Characterization of Stakeholders

As described in Sect. 15.2, several stakeholders involved in the policy-making process can be identified.

Policy makers are the final decision makers in the policy-analysis process. They decide which societal problems appear on the political agenda, and by which policy option they are finally tackled. In most cases, policy makers do not have the time and the technical background to execute the policy analysis by themselves. For making profound decisions, they have advisors, namely policy analysts, who conduct the analysis, and provide summaries of the analysis in the form of reports, or presentations. Still, in the agenda setting and problem definition stage, policy makers decide which public problems appear on the political agenda, and how these problems are defined. Requirements for the analysis of policy options are derived from this problem definition. After the analysis process, policy makers finally decide which of the generated policy options will be implemented.

Policy analysts (or policy advisors) are the coordinator of the policy analysis. Their goal is to conceptualize the problem based on the requirements defined by the policy maker. Then, they have to identify information sources, and consult external advisors that assist in analyzing the problem. Finally, the policy analyst provides alternative solutions (policy options) to the policy maker via a report or presentation.

Modeling experts are in most cases external advisors recruited by the policy analyst. They have profound knowledge in modeling techniques. Expertise in the policy domain is not necessarily required from modeling experts. Still, the models have to be adapted to the policy domain, which can be realized by translating the problem to the model domain or by defining technical requirements on the model. The adapted model supports the policy analysis by producing outcomes—e.g., impact of possible actions that are the basis for the generation of policy options.

Domain experts are optional stakeholders in our concept. In many cases, the analytical models have to be fed with domain knowledge and data. If neither the modeling expert nor the policy analyst can provide this information, a domain expert has to be consulted. The domain expert does not necessarily have expertise in policy analysis or modeling techniques but rather contributes as an information provider.

Public stakeholders are not explicitly considered in our concept. Still, they play an increasingly important role in the policy-making process. By realizing an intuitive visual access to complex models for the analysis of policy options, even nonexperts like most citizens may be involved in the policy analysis. This will increase the transparency of the whole policy-making process, improve democracy, and increase the trust in the policy makers. An example of how public stakeholders can be included in the policy analysis is described in the case study of the urban agile policy implementation (urbanAPI) project in Sect. 15.4.3.

A further stakeholder that is not explicitly included in our concept is the role of the *politician*. From our perspective, politicians influence various of the above stakeholders and sometimes even play their roles. For example, the agenda setting and thereby the work of the policy maker is influenced by politicians. Moreover,

they may act as a neutral (or public) stakeholder observing the potential solutions generated through science–policy interfaces. Furthermore, the acquisition of external advisors, the work of the policy analyst, may be influenced by politicians. Due to this heterogeneity, we do not explicitly define the role of the politician in this approach. However, we want to point out their influences.

These different stakeholders need to collaborate in the policy-analysis process to generate policy options that will later be implemented to tackle societal problems. Due to the stakeholders' different backgrounds and knowledge, the collaboration is a challenge to be addressed by science–policy interfaces. In the next section, we show how information visualization technology may be applied as supporting component of science–policy interfaces.

15.3.2 Bridging Knowledge Gaps with Information Visualization

We now sketch how the policy-analysis process is usually conducted. This is based on the literature review presented in Sect. 15.2 and our experience with projects in the field of policy modeling. After characterizing the process, we introduce a method to include visualization into policy analysis to bridge the knowledge gaps between different stakeholders involved.

At the beginning of each policy-analysis process, a public problem is identified that is put on the political agenda. It is mostly described in a more or less abstract way by the policy maker. In order to generate policy options that tackle this problem, policy analysts (policy advisors) are consulted. These policy analysts (a) gather information to provide policy options by themselves, or (b) ask external experts for help in analyzing the problem. Often, these external experts have a scientific background. They provide models that help in isolating the problem, and simulating the potential impact of generated policy options on societal, environmental, and economic aspects. The extracted knowledge provided by scientific experts is summarized by the policy analyst, most likely as a written report, as described in Weimer and Vining (2005). This report is presented to the policy maker textually, or as a presentation. It contains policy options to tackle the defined problem as well as an analysis of the impacts that each of these options inhibit. Based on this knowledge, the policy maker has to decide which option to choose. Alternatively, another iteration of the process can be requested by refining some parts of the problem definition. The upper part of Fig. 15.4 summarizes this process in a simplified way.

Our approach extends the "classical" policy-analysis process with information visualization technology. As described above, the generation of policy options is enriched by including scientific knowledge, in terms of information extracted from data or scientific models, into the process. This information and the models can in most cases be represented by computational models. However, the complexity of these models impedes the usage of the underlying knowledge for policy analysis. In order to simplify the access to computational models developed by policy analysts,
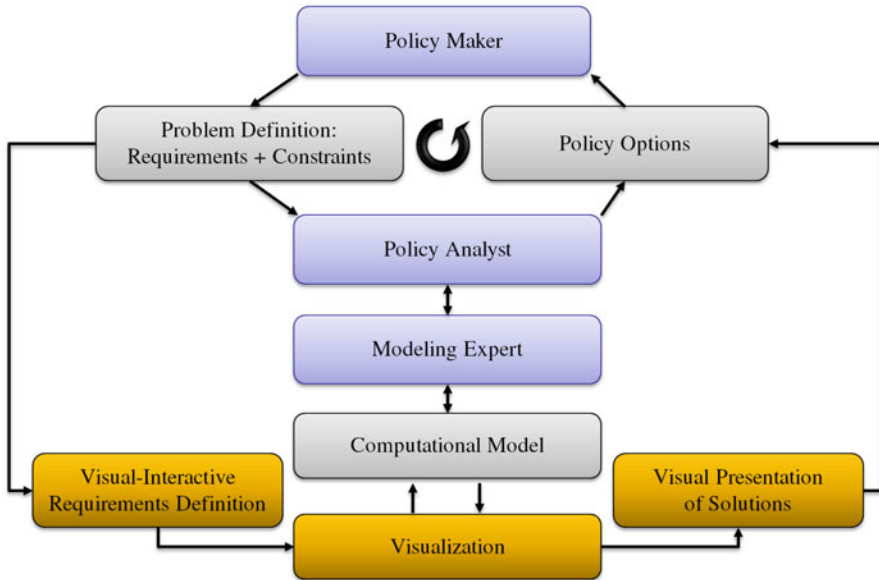
Fig. 15.4 Visual support model for policy analysis. The upper part denotes the policy analysis process which is conducted in the policy formulation stage of the policy cycle (cf. Fig. 15.3). Visualization is introduced into the process in order to support the analysis of policy options

or in most cases external scientific experts, we propose to connect information visualization techniques to these models. In this way, the complexity of the models can be hidden in the computational back end, while only the information necessary for providing user input (e.g., control parameters, etc.) and analyzing the model output (e.g., simulation results, statistical measures, etc.) is displayed on the screen. The most crucial aspect of this concept is that non-IT expert users can visually interact with computational models and execute their own analysis. Hence, the policy analyst and the policy maker can define their requirements and constraints via a visual interface (see Fig. 15.4, left side). They can "experiment" with different settings, and generate alternative model outputs (see Fig. 15.4, right side). As another aspect, due to the similar representation of the model, the different stakeholders can validate the models' utility and usability with visualization technology. For example, the policy maker can detect aspects not covered yet by the model, that the modeling expert might include in an improved model. The communication of results is facilitated, since all stakeholders work with the same visual representation.

To achieve a user-centered system that combines computational models with information visualization capabilities, several steps have to be undertaken. In the following, we propose a possible development cycle based on the concept of Andrews (2008). Before the visualization design process, the policy maker and the policy analyst have to define the societal problem (agenda setting) and identify relevant external experts that may support the decision-making process. We propose to

include visualization experts in the process from the very beginning, since they have to help in conducting the requirement analysis. The steps that follow are:

Phase before design: In this phase, the requirement analysis has to be conducted. That includes the characterization of the (policy) domain, the needs of the users (e.g., policy maker, policy analyst, etc.), and an abstraction of the tasks the users want to achieve (e.g., generation of policy option, impact analysis, etc.). Furthermore, together with the scientific experts, computational models that may help in solving the tasks have to be defined.

Phase during design: In this phase, the information gathered in the previous step have to be summarized and structured. The data exchange interfaces to the computational models have to be specified. Furthermore, an initial design of the visualization tool has to be developed. Therefore, the interaction design, and the visual encodings of the underlying data has to be created.

Phase during implementation: In this phase, the initial design is implemented into software. This software will be implemented in an iterative process together with the user. Intermediate versions of the software will be shown to the users and improved based on the users' feedback regarding initial and upcoming requirements.

Phase after implementation: In the phase after the implementation, the system will be deployed, and tested regarding usability and utility. It will be measured whether the users can solve their tasks with the system, and how easy and intuitive it is adopted by the user.

The method presented here supports the design process whose main purpose is to find the right kind of visualization for the given problem. Note that there is no one-size-fits-all solution for information visualization. There are visualizations that work better as others in certain use cases but fail otherwise. If we generalize this problem to notations—i.e., ways to express information, either visually or textually—we can refer to Green who states, "a notation is never absolutely good, therefore, but only in relation to certain tasks" (Green 1989). Indeed, the question whether general visuals are appropriate for policy analysis is difficult since policy analysis usually involves many tasks (cf. Whitley 1997). However, visualizations tailored to a specific problem can help stakeholders understand its complexity. Gilmore and Green summarize this connection between a visual and the ability of stakeholders to solve a certain problem based on this visual in their match–mismatch hypothesis (Gilmore and Green 1984). They state that every notation (i.e., visualization) highlights certain aspects of a problem while it hides others (Whitley 1997). The match–mismatch problem implies that for every task different kinds of visualizations have to be used. That is also the reason why the case studies presented in Sect. 15.4 differ from each other in terms of visualization methods and why they cannot be generalized. For further readings about design processes in information visualization and visual analytics, we recommend, among others, the approaches by Sedlmair et al. (2012) and Munzner (2009).

15.3.3 Synergy Effects of Applying Information Visualization to Policy Analysis

In order to address the challenges imposed on science–policy interfaces, we proposed the inclusion of information visualization techniques within policy making (see Fig. 15.4). Hereby, information visualization serves as an important component of the science–policy interface itself. The following aspects can be resolved with this integration:

Communication. The communication between science and policy fields will be facilitated. Visualization may serve as a mediator of information between two distinct environments. Through the similar visual appearances of the system, different stakeholders may discuss issues on the same visually presented information basis. Thereby, the interaction of scientists and policy analysts with the policy-making process will be supported.

Complexity: Through the abstraction of user tasks and interactions with scientific models, the complexity of the underlying models may be reduced. With visualization, the complexity of scientific models can be executed on the machine side, while the degrees of freedom in form of parameters for their execution can be intuitively displayed on the screen. Visual interfaces provide the information on the level of detail needed by the respective user role.

Subjectivity: The aspect of subjectivity can be reduced since different stakeholders get access to the same information provided in an "objective" way via information visualization techniques. Hence, the provided information can be discussed among the stakeholders to balance subjective interpretations of the findings.

Validation: The outcomes of the policy-analysis process can be transparently presented to all involved stakeholders including public stakeholders. That way, decisions can be justified since they have been made based on an objective analysis. This can improve the trust in scientific results and political decision making.

Transparency and reproducibility of results: Public stakeholders (e.g., journalists, interest groups, etc.) can generate analysis results with the same tool and therefore better understand the rational background of political decisions.

15.4 Case Studies

In the following, we present three case studies that have already implemented aspects of our concept within European research projects. The target of each case study is briefly described. Relevant stakeholders are identified, and their roles in the process are characterized. In each approach, scientists have developed a computational model to support policy makers and policy analysts in their decision-making process. To simplify the access to these models, visual interfaces have been designed that have

been developed by information visualization experts. The models and the visual interfaces to them are described. Finally, for each case study, findings are presented that substantiate the benefits of our concept. The three case studies covered the following scenarios:

1. Optimization: the optimization of regional energy plans considering environmental, economical, and social impacts (cf. Sect. 15.4.1).
2. Social simulation: the simulation of the impact of different policy instruments on the adoption of photovoltaic (PV) panels at household level (cf. Sect. 15.4.2).
3. Urban planning: the integration of heterogeneous data sources (simulation results, user input, etc.) in collaborative urban planning scenarios (cf. Sect. 15.4.3).

15.4.1 Optimization

The first case study presented comes from the ePolicy[1] project, whose main aim is to support policy makers in taking transparent, informed, and well-assessed decisions. The ePolicy goal is to develop a decision support system assisting the policy maker in understanding the impact of her decisions on the environment, the economy, and the society. The specific case study of ePolicy is the regional energy plan of the Emilia-Romagna region in Italy, in its part concerning the renewable energy share.

The design of a policy for regional planning is followed, as prescribed by European regulations, by an environmental assessment of the devised plan. Traditionally, the policy maker decides a policy, possibly with allocation of the available funds to chapters, and the plan is submitted to an environmental expert to be assessed. In the Emilia-Romagna region, the assessment is performed by using the so-called coaxial matrices (Cagnoli 2010) that are a development of the Leopold matrix (Leopold 1971). The information contained in the plan is usually very high level and misses many details, so the environmental assessment is usually only qualitative. One of the coaxial matrices links the possible actions that are taken in a plan with their environmental pressures providing information on how much each of the activities impacts on the environment. Current coaxial matrices consider 93 activities that range from building new constructions (buildings, sewers, factories, bridges, yards, etc.) to energy plants (PV, biomasses, coal, etc.) to moving materials (waste, dangerous materials, etc.) to installing infrastructures (pylons, wires, cables, etc.). Activities can have various impacts (or pressures) on the environment: e.g., a thermoelectric power plant emits pollutants or greenhouse gases in the atmosphere, consumes water, etc. The environmental pressures, then, modify the environment, and in particular, some environmental indicators called receptors: the emission of air pollutants changes the receptor quality of the air, while the emission of greenhouse gases impacts on the climate change. A second matrix links environmental pressures with environmental receptors. Both matrices contain qualitative values: the impacts can be high, medium,

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[1] http://www.epolicy-project.eu/.

or low (or null). By considering the plan devised by the policy maker, and elaborating the environmental matrices on a large spreadsheet, the environmental expert is able to point out critical aspects of the plan.

However, even if there are important critical aspects in the plan, the effort for building a new plan, and reassessing it is so high that only small variations can be done. Moreover, although European regulations state that two or more alternative plans should be compared and environmentally assessed, this is rarely done in practice due to the difficulties and costs of designing alternative plans; in some cases, the devised plan is compared to the do-nothing case (the absence of a plan), but devising actual alternative plans and comparing them is usually out of reach.

15.4.1.1   Involved Stakeholders

The involved stakeholders in this research are primarily two. One is a policy analyst, an expert in the energy field. She is responsible for devising the Regional Energy Plan for the Emilia-Romagna region of Italy. Basically, she has the possibility of stating the minimum amount of energy to be produced and constraints limiting the minimum and maximum amount of energy to be produced by each renewable energy source given the regional characteristics and some political choices. As output, the policy analyst could obtain a number of alternative scenarios for the energy plan that can be easily compared.

The second is the domain expert that in this case is an environmental expert whose main task is the configuration of the system. For example, the coaxial matrices are inserted into the system by environmental expert who studies the impact of activities on the environment.

The system being tailored on a specific policy domain needs a modeling expert whose main aim is to (a) define the decisions that should be taken in the regional plan, (b) state the constraints tightening possible combinations of decisions, and (c) specify objective functions defining the evaluation metrics for the policy.

15.4.1.2   Underlying Technologies

In order to overcome the difficulties in current practices, and improve current methodologies, we developed a constraint-based application for performing automatically the environmental assessment of a plan (Gavanelli et al. 2010). In this way, the assessment phase could be performed easily and in a very short time, and the environmental impact of different, alternative plans could be quickly compared.

However, the real challenge was the integration of the two phases: planning and environmental assessment. A unique constraint model to perform both the planning and the environmental assessment was later proposed (Gavanelli et al. 2013).

The constraint model included not only the coaxial matrices needed for environmental assessment but also the cost of each activity, so that a global cost of the plan could be computed. Some of the activities are of primary importance for the given

type of plan: For example, power plants are the main activities considered in an energy plan. On the other hand, power plants require infrastructures to be performed; although these secondary activities are not the main aim of the given plan, they can have an impact on the environment, and should be considered in the assessment. For example, thermoelectric plants require power lines, pipelines (for oil, gas, or steam), cooling systems, roads, etc., while a hydroelectric power plant may require the construction of a dam or other hydraulic works. The construction of such facilities has a significant impact on the wildlife, or on the wellness of people living nearby.

Other aspects taken into consideration in the constraint model are the minimum and maximum amount of each energy source, the required energy production (in terms of both electrical energy and thermal energy), and the amount of energy produced in a year for a given energy source.

The constraint model can be used to generate a single plan, e.g., optimizing an objective function. Examples of objective functions are the minimization of the cost, the maximization of the produced energy, the maximization of some environmental receptor (for example, one can compute the plan that improves most the quality of the air in the region), or a linear combination of these.

In case the policy maker wants to optimize more than one objective function, the constraint model can be used to compute a set of solutions. If two objectives are given, one solution can be the optimum for the first objective, another one for the second objective. Moreover, a series of plans in between can be found that are nondominated, i.e., for which there exists no other plan that improves both objective functions. The set of nondominated points is called the Pareto front. In such a way, it is easy to generate and compare alternative plans. Moreover, the considered alternative plans are not simply the absence of a plan, but they are the result of an optimization, and, in particular, represent plans for which it is impossible to improve one objective without sacrificing another objective.

15.4.1.3 Visual Design

We embedded the global optimizer component into a web interface that takes as input the bounds for each energy source, the objective functions to be optimized, and the number of plans that should be compared (see Fig. 15.5).

The global optimization component computes the Pareto front of the solutions that optimize the declared objectives. The visualization module provides the computed energy plans in several views. An overview shows the Pareto front through the different objective functions in a scatter plot view. The plans are also compared through bar graphs showing the amount of energy produced by each source. Each of the computed plan can be monitored in a single view providing details about this plan (see Fig. 15.6).

The environmental expert also suggested to add to the interface a set of dashboards: for each plan, they show the three environmental receptors with the best and worst values; in this way, one gets immediately the idea of which environmental aspects are most critical for this plan, and which are improved. For a more detailed description and evaluation of the visual interface, we refer to Ruppert et al. (2013b).

Fig. 15.5 The visual interface for providing the input to the optimization component

Fig. 15.6 The visual interface providing detailed information about a calculated plan

15.4.1.4   Findings

The developed system provides a number of features that enable a better policy-making process. First of all, it enables the policy analyst to compare different scenarios on demand, evaluating their strengths and weaknesses from an environmental and economic perspective.

Second, the domain expert that configures the system can insert and update the coaxial matrices and activity costs. As new technologies evolve, the impact of activities on the environment might change and coaxial matrices as well as costs can be consequently updated.

Finally, the system enables a more transparent decision process empowering a participatory and collaborative approach to public policy making. Citizens and stakeholders can get an explanation and a reason why some choices have been done.

15.4.2   Social Simulation

One further area of research, which has become important for supporting the policy-making process in recent years, is the area of social simulation (Brenner and Werker 2009). Social simulation is a research field that applies computational methods to study issues in the social sciences. One of its main aims thereby is to bridge the gap between the descriptive approach used in the social sciences and the formal approach sometimes used in the computer sciences, by moving the focus on the processes/mechanisms/behaviors that build the social reality (Edmonds et al. 2007). The goal of social simulation is to study this (complex) social reality in order to understand it better—and in case of policy making—to be able to influence and shape this social reality in a better way.

In the EU-funded ePolicy project, a social simulation was used to analyze the impact of different policy instruments on the adoption of PV panels at a household level. The social simulation logically is to be used by policy makers and policy analysts after the planning step on the regional level (also referred to as global level in the project). Once planning goals have been determined, through optimization (e.g., with respect to minimum costs, maximum CO_2 reduction, minimum disruption, etc.) and decisions on how to allocate the budget to policy instruments in order to achieve these goals at the level of the region have been made, it is then necessary to apply the policy instruments.

However, what is an optimal policy at the regional level may not be locally or individually optimal. Thus, some (incentive) mechanism is needed to enforce the policy—one cannot assume that individual agents will adopt the desired behaviors of their own accord. These potential policy instruments could reach from fiscal incentives, via tax incentives and different tariffs to legislation for example. All options have disadvantages, and which is best is not clear and will vary from case to case. In order to be able to assess effects of the different policy instruments on individual households better, a multilevel agent-based model has been developed

that allows policy makers to explore the consequences of different types of policy instrument and thus enable them to make better choices.

In the social simulation (software), agents represent the main actors, the individual households. They are given behavioral rules modeling their likely individual responses to policy instruments (including the effect of influences from other actors, e.g., as a result of collective actions, imitation etc.). The overall response to the simulated policy instruments will be measured to inform policy makers.

15.4.2.1 Stakeholders

In the policy-making process, typically a large number of different stakeholders can be involved with a social simulation, including the mentioned policy makers, policy analysts, domain and modeling experts as well as public stakeholders.

In the social simulator of the ePolicy project in particular, four stakeholder groups thereby have been focused on:

- *Policy analysts* and *policy makers* that use the simulation to derive new information and knowledge about the modeled system (possibly in order to make policy decisions).
- *Domain* and *modeling experts* who are required in order to build the model both in terms of the technical implementation as well as the contribution of domain knowledge required for conceptualizing the simulation model. The domain experts thereby were asked to provide domain knowledge about the behavior of households with respect to PV as well as demographic information of the households to be modeled. The modeling expert's task was to translate this domain knowledge into agent rules and to incorporate the provided demographic household information (mainly data) into the simulation setup.

In this case study, we are mainly looking into the first group, i.e., policy analysts and policy makers and will consider the second group (i.e., domain and modeling experts) as suppliers of tools for them.

15.4.2.2 Underlying Technologies

The term social simulation can have several types of simulation and modeling of which agent-based modeling (ABM) is the most popular one.

An ABM "is a computational method that enables a researcher to create, analyze, and experiment with models composed of agents that interact within an environment (Abdou et al. 2012)."

There are several important elements in this description. First, the model is composed of autonomous and heterogeneous agents. That is, there are many simulated individuals with different properties and decision-making rules. In ePolicy for example, properties include geographic location, PV, and policy instrument knowledge as well as housing and financial situation, and rules include PV prevalence at which the

individual will consider gathering information about PV because they might install panels.

Second, these agents interact within an environment. That is, the individuals are able to perceive the situation in which they find themselves take that situation into account in their decisions and take actions that affect the environment. Continuing the example, the individuals are able to perceive the PV prevalence in their location, which allows them to check their perception of PV and the respective policy instruments.

Finally, ABM is a computational method that simulates interactions over time. Simulations allow "what if" questions to be tested quickly, cheaply, and without the ethical problems of setting up experiments. Provided the key interactions are properly represented in the model, the simulation can explore the consequences of different actions. In the policy context, for example, different policy situations can be explored and better understood. Modeling a system thereby is often understood as a first step to understanding the system to be modeled better.

It is important to recognize, however, that the results of a simulation run will not be suitable for forecasting (Antunes et al. 2008). The model is a simplified representation of the key relationships that exist in the real world. That simplification is what makes the model useful—knowledge about the real world can be captured and its consequences can be understood—but the model will not be detailed enough to support specific claims. In the terminology of Heath et al. (2009), the model is a mediator "used primarily to establish the capability of the conceptual model to represent the system and to then gain some insight into the system's characteristics and behaviors" so as to understand potential implications of different scenarios.

As a result, one of the main problems with respect to the different stakeholders in a social simulation is to help them to understand the advantages and limits of a social simulation and its results in a better way.

That is why, in addition to an easy user interaction with the social simulation in general, it is important to help—by means of visual representation—the developers (domain and modeling experts) to communicate the limitations and assumptions of the simulation (and their impact on the simulation results) to the policy analysts and decision makers.

15.4.2.3 Visual Design

For better understanding what is considered "useful and easy to use" for the potential users of the social simulator, we designed a questionnaire which was given to representatives of potential user groups (including the regional policy makers, as well as PV companies interested in the reaction of households to different incentives fostering the uptake of PV panels).

Besides the obvious requirement that the social simulator must allow to analyze the update of PV by individual households based on different policy instruments, the main result of the questionnaire was that the users want to be able to look at individual subregions (e.g., their electoral region) of the Emilia-Romagna region

Fig. 15.7 Social simulation interface: (**a**) input parameters, (**b**) policy instruments to be chosen, (**c**) geographic representation of photovoltaic adoption, (**d**) output of simulation: costs per policy instrument (*left*), energy produced by photovoltaic panels (*middle*), number of panels installed (*right*)

and want to be able to look at both regional as well as national policy instruments. For these policy instruments, they want to be able to specify funding levels. With respect to the output, in particular adoption rates, the resulting energy production from PV and the costs associated with the adoption (per policy instrument) were of interest to the users. Furthermore, the speed of the simulation was mentioned as one attribute that can influence the utilization of the simulator.

Based on the above described user requirements, the social simulator shown in Fig. 15.7 was developed for the ePolicy project.

The social simulator interface consists of four areas, which will now be explained in more detail. Starting at the top left, as shown in Fig. 15.7a, the first area is composed of two buttons labeled *setup simulation* and *run simulation* as well as several sliders and a drop-down menu for specifying parameters of the simulation.

As indicated by their labels, the first of the purple buttons sets up the simulation with all specified parameters and the different decision entities, whereas the second one can be used to run it. Running the simulation without setting it up beforehand is not possible, thus it is strictly necessary to press the setup button before running the simulation. The parameters that can be specified by the user for the setup include the region to be simulated (via the drop-down menu; as this is a proof-of-concept

prototype currently available only for the Emilia-Romagna and the Bologna region), the initial percentage of people having PV (initial-percentage-of-PV-users slider), the average interest rate for credits in percent (credit-interest-rate slider) as well as the target percentage of people who should have PV (target-PV-percentage slider).

In addition to these parameters, the users can specify which policy instruments should be available to the households being simulated. We thereby distinguish two regional and two national policy instruments all shown in Fig. 15.7b:

1. investment grants
2. contributions to interest rates for loans individuals have to take in order to finance a PV
3. feed-in tariffs, and
4. tax deductions on the PV investment.

For each of these instruments, using the on–off switches, the user can specify whether the instrument shall be considered (on) or not (off position of the switch). Furthermore, for each instrument the user can specify the size of the support by the policy instrument.

On the top right-hand side of the simulation interface, a third area can be seen, which shows the geographic representation (in form of a map) of the PV adoption. Before setup, this map is black. However, once the region the user is interested in has been defined in the setup process (and this setup process has been completed), it changes to a map showing the selected region. In the map, for easier orientation, different red shades are used to reflect population densities (with darker red shades representing higher population densities and lighter shades lower densities). The example map shown in Fig. 15.7c displays the map of the Bologna region. Furthermore, in each area where the previously specified target PV threshold is met, a green dot is shown to indicate this success.

The social simulation can be run by clicking on *run simulation* after the setup of the simulation is completed. A message announcing this setup completion is displayed at the end of the setup process. When the simulation is running, the area at the bottom of the simulator interface shows the results of the simulation in form of three plots displaying outputs of the simulation run over time: costs per policy instrument (left), energy produced by PV panels (middle), number of panels installed (right; cf. Fig. 15.7d). These plots were indicated as desired plots by the policy makers questioned about the interface. The screens show the liabilities the policy instruments have generated in a particular (per instrument)[2], the total number of PV installations over time, and the energy produced by these PV panels in terms of kilowatt hour.

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[2] "Liability generated" that in a given year, also generated future liabilities will be shown. In terms of feed-in tariffs this means that all costs/liabilities resulting from the long-term (e.g., 30 years) feed-in-tariff contracts are completely in the year they were generated in.

15.4.2.4   Findings

During the requirement analysis with the users of the simulation system it became clear that an intuitive visual interface to the simulation model is of high relevance. The users want to "play" with parameters of the computational model to simulate the PV adoption depending on the policy instruments chosen. That way, the simulation becomes more accessible to them compared to a written report that only statically describes the outcomes of the simulation for a number of given parameterizations.

15.4.3   Urban Planning

The EC-funded project urbanAPI[3] is seeking for ICT-enabled tools that support the policy-making process in modern urban planning—hence the project's full name "Interactive Analysis, Simulation and Visualization Tools for Urban Agile Policy Implementation." UrbanAPI supports both sides in the urban policy and governance system: the policy making and practitioner side as well as the stakeholders and the public. UrbanAPI provides a tool set that enables the city planning authorities to effectively use interactive simulation and visualization instruments, and additionally facilitates direct participation of stakeholders and citizens.

The term agile is used to express the interaction with the different stakeholders, in particular the public. Krämer et al. amend the policy cycle from Fig. 15.3 and replace policy adoption with a more general stakeholder engagement phase (Krämer et al. 2013). They propose that all stakeholders—urban planners, decision makers as well as citizens—participate in discussing policies in order to find alternatives and finally achieve consent.

Policy making in the area of urban planning works quite similarly to the general process described in Sect. 15.2.2. The policy cycle describes the process of formulating, implementing, and evaluating policies as it is done nowadays. In the area of urban planning, however, this process has recently started to change. The top-down driven policy-making process is gradually transforming to one that is working bottom up. In Europe, for example, citizens and other stakeholders request to participate in political decisions more and more often. Experience from the past has shown that modern urban planning cannot be done at the municipal administration level alone anymore without risking public discontent. Additionally, stakeholders often have a different view on certain issues. Incorporating their ideas and proposals can improve the policy-making process and finally lead to policies experiencing higher acceptance within the public.

Obviously, involving a large number of stakeholders in the discussion requires provisioning of participation tools that are widely accessible. ICT tools developed in the urbanAPI project are web based and run in a typical Internet browser.

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[3] http://www.urbanapi.eu/.

In the following, we describe the different types of stakeholders in the area of urban planning and their respective needs and requirements. We then present the ICT-enabled tools developed in urbanAPI and their underlying techniques and visual design.

15.4.3.1   Involved Stakeholders

In the context of the urbanAPI project, a thorough process of requirements gathering for ICT-enabled tools as mentioned above was carried out (Kahn and Ludlow 2013), which contributed a lot of information to application development (Dambruch et al. 2013) in the project. The stakeholder's requirements were analyzed and also which types of stakeholders are typically involved or are to be additionally addressed. The term stakeholder refers in this context to individuals or an organization that has a vested interest in the results of urban planning and also the process of policy modeling itself.

In addition to the stakeholders from Chap. 3, several other stakeholder groups were identified. The main target audience as already mentioned are:

- *Policy analysts*, the typical end users, who will actually operate the software applications to provide information, reports, etc.
- *Domain experts* such as architects, environmentalists, traffic planners, and urban planners
- *Policy makers*, the functional or political beneficiaries of the information generated by the applications for strategic planning
- *Citizen*s as there is a growing demand for public participation

The interests of the users are manifold and distinct in several ways. This is countered by a requirements engineering approach which lead to an exhaustive amount of use cases elaborated together with the four case study cities Bologna (Italy), Ruse (Bulgaria), Vienna (Austria), and Vitoria-Gasteiz (Spain). Three levels of stakeholder involvement have been identified, each is targeted with a specific application.

On the city quarter or neighborhood level, a 3D virtual reality application can be used to visualize alternative planning scenarios and support evaluations by using Internet technology to target to a broader audience, e.g., general public or citizens. By using interactive web technology, it is also possible to gather direct feedback on several topics without additional efforts.

On the citywide level, the public motion explorer provides additional information about the real movement of citizens over the daytime and therefore contributes to the analysis phase, and finally, can also be used in the evaluation phase to asses the impact of measures taken on the behavior.

Finally, on a region-wide level, the urban growth simulation combines several layers of socioeconomic and spatial information to create simulations of the possibilities of future developments which can be used to define indicators and possible hazardous conditions for the evaluation phase.

15.4.3.2 Underlying Techniques

In Gebetsroither (2009) and Krämer and Kehlenbach (2013), the authors show how a state-of-the-art *agent-based simulation model* can be applied to urban change simulation and contribute to urban policy analysis. The simulation includes geo-spatial data as well as socioeconomic data to model the phenomena of urbanization together with some rules to describe a likely human behavior.

The *public motion explorer* application, described in Loibl and Peters-Anders (2012), uses data logged by mobile devices while connected to a radio tower. Basically, modern smart phones have the capability to provide location information based on global positioning system (GPS), but often this functionality is disabled or the information is not logged due to regulations and privacy protection issues. On the other hand, the location and movement information can be derived, if the location of the radio tower to which a device is connected is known, but with a much coarser resolution. There are also some other side effects connected to this approach which have to be identified and corrected by preprocessing and data cleansing to eliminate potential hazards.

With the processed device data the application can provide answers to questions such as "Where are the people from district x at noon?" or "Where do the people in district x at noon come from?"

15.4.3.3 Visual Design

In the context of the urbanAPI project *3D visualization* plays an important role in several aspects. First, a 3D city model is a natural way to visualize changes and alternative designs for a visual impact assessment. The transfer to a virtual digital domain is straightforward, but depending on the data available. For example, if a sophisticated 3D city model is available, an architect can provide a virtual 3D model of a new building project. This building model can then be integrated and a visual impact assessment, such as the analysis how the new building would cast his shadow on other existing buildings, can be done.

Second, enabling the users to leave some feedback directly in the 3D visualization, or at least on the same website, opens up new possibilities in interaction. For example, the users can change a 3D scenario by putting in some custom objects which seem to be appropriate for them. Other options can be the inclusion of textual feedback or filling out some questionnaires about the scenarios.

Finally, the 3D scenario can provide an integrated view of several crosscutting concerns of all applications. For example, the simulation results from the urban growth simulation can be related to the public motion analysis tracks in the 3D city model.

The benefits of such an integrated view is that data can be interpreted in a context that is a more concrete and visually compelling, thus easier to understand by people with non-IT background. It can also be used to amend city planning scenarios and impact assessment for planned actions.

To achieve the aspects above the software design decision was taken to build a web-based portal application (Dambruch et al. 2013) which is based on a concept that uses reusable and customizable components. The components we created are designed to fulfill the requirements and use cases identified in (Kahn and Ludlow 2013), but they are generalized and easily customizable in such a way, that also other use cases can be fulfilled. All components can be arranged visually on the web pages that are created for the evaluation projects. Especially, the adoption of a role-based security concept for the users gives a lot of flexibility to address different target audiences. The policy analysis can therefore tailor the visualization to the level of expertise and, for example, can include additional information. On the other hand, confidentiality of information can be assured. So, it is easy to map the stakeholders into several user groups to which different access rights may be granted. For example, citizens may not be granted to change things, but only to annotate designs for a certain project. Moreover, the portal software provides many components off the shelf such as content management systems or blogs which can be used together with the 3D components to improve the user experience further.

Two of the prominent use cases are an architectural competition scenario and a comparison of design alternatives. In both cases, the stakeholders should have the possibility to place some annotation on an arbitrary point in the 3D scene. Also, the position of the viewer should cover several perspectives, such as viewing the scene as a pedestrian or getting an overview from a helicopter perspective. However, the key advantage of the applications is that the viewer can move interactively by just clicking and moving the mouse or a similar gesture on a touch device to move around in the 3D scene freely.

The next level of interaction is to leave some feedback by directly putting some annotations in the 3D scene. Whenever a user places an annotation, the exact position of the viewer along with the point the user was looking at when placing the annotation is recorded, so that the planner can easily take the point of view of the users. The user has the option to enter simple text in a pop-up window that is put directly into the 3D display, therefore not requiring distractive mouse movements to enter the text. Other components can access the annotations made and present it in a different format, which may be more appropriate, for example, a list view.

The third level is then to modify the 3D scene itself by placing additional or removing existing objects.

In Fig. 15.8, an example for the design comparison use case is given. The page displayed is made up of four components: The two 3D components are prominently placed side by side, each using the same basic 3D city model but with alternative buildings proposed. On the lower left side, a navigation bar with interesting perspectives is given which navigates both 3D views in sync. On the lower right side, a simple vote component is placed, so that stakeholders can select which alternative they like best.
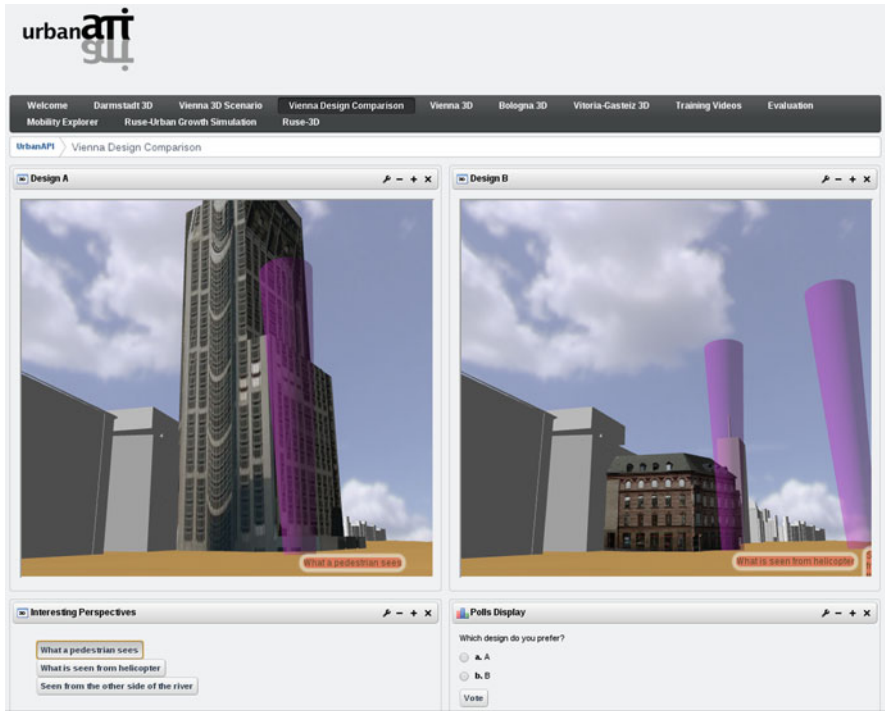
Fig. 15.8 A portal page displaying an A/B comparison of design alternatives

15.4.3.4 Findings

The traditional policy-making process in the area of urban planning is transforming from a top-down approach to one that works bottom-up. The public's demands have changed and people want to take part in political discourse more and more often. However, at the moment policies are only discussed on a political level and citizens are rather informed than involved. At the same time, there is a gap in the availability of urban planning to anybody outside the city administration.

ICT tools such as the web-based solution of urbanAPI help mitigate this problem. Results of complex calculations such as the public motion analysis and the agent-based urban change simulation are visualized in a way that is understandable by non-IT personnel. The 3D visualization adds attractiveness that increases acceptance of the solution among the citizens. At the same time, the solution allows stakeholders to participate in the discussion by contributing feedback or new ideas. This happens in a controlled environment as the web-based portal application is highly configurable and individual modules can be customized, enabled, or disabled by the urban planners according to the scenario they wish to present and according to the degree of participation they are aiming for.

Within the time frame of the urbanAPI project, the developed tools are regularly evaluated in depth by users from the partner cities of Bologna (Italy), Ruse (Bulgaria), Vienna (Austria), and Vitoria-Gasteiz (Spain). We were able to derive the following results from these evaluations which we consider key for the success of ICT-enabled tools in participatory urban planning.

- The *data quality* has to be reasonably high. The 3D visualization has to be appealing in order to improve acceptance by citizens. This is only possible if it is based on high-quality geo-spatial data like textured 3D building models or high-resolution digital terrain models and aerial images. While many European cities already maintain a 3D city model, at the moment they often miss textures or fine geometrical details which would make the visualization more realistic.
- *Usability* plays an important role for ICT tools that are made available to a large audience. The tools can only gain high acceptance if they can be used easily and without barriers. The user interface has to be clear and understandable. The software should allow stakeholders to participate and contribute without too much effort. Otherwise, the software will not be used and the advantages of participatory urban planning are lost.
- In addition to that, the ICT tools have to be *portable* in order to run on a wide range of systems from desktop PCs to tablets and mobile devices. This improves the acceptance and lowers the barriers, which stakeholders have to take before they can participate in urban planning.

15.4.4   Summary of Case Studies

Figure 15.9 summarizes the presented case studies with a short task description, the applied modeling techniques, the relevant data types, the implemented visualization techniques, and the involved stakeholder. The table shows that the selected case study differ in nearly all of these characteristics. From this, we conclude that for policy analysis a broad range of scenarios exist that need to be tackled with different strategies. We already stated that a one-fits-all-solution from the field of information visualization does not exist. For each problem addressed in a case study, a specific solution needs to be designed in order to support the users in the best possible way. The heterogeneity of case studies in the field of policy analysis even amplifies this fact. Therefore, we strongly recommend to conduct a precise problem characterization and analysis of tasks to be solved with the technologies prior to their implementation. For this, all relevant stakeholders need to be involved. Design study methodologies in the field of information visualization and visual analytics already address this challenge. However, from our point of view these methodologies need to be adapted to the specific characteristics of policy analysis.

	Case Study 1: Optimization	**Case Study 2: Social Simulation**	**Case Study 3: Urban Planning**
Description	define optimal regional energy plan considering conflicting aspects	measure the impact of governmental subsidy strategies on public behavior	eParticipation for urban planning
Modeling Technique(s)	optimization	agent-based simulation	geo-spatial data modeling, agent-based simulation
Data Type	quantitative data	geo-spatial data	geo-spatial data, socio-economic data
Visualization Technique(s)	bar charts	maps, line charts	3D city model
Involved Stakeholders	Policy Analyst Domain Expert Modeling Expert	Policy Analyst Policy Maker Domain Expert Modeling Expert	Policy Analysts Domain Experts Policy Makers Public Stakeholder

Fig. 15.9 Summary of case studies

15.5   Conclusion

In this work, we presented a novel approach to tackle the challenges of the policy paradox. This paradox describes the fact that despite the acknowledged importance of scientific evidence for political decision making, the knowledge gained from scientific disciplines is seldom considered in policy making. In our approach, we proposed a concept that addresses this problem by introducing information visualization technologies to the policy-analysis field. Therefore, we described the disciplines of information visualization and policy analysis. We also identified capabilities provided by information visualization and challenges faced by policy analysis.

Information visualization is defined as "the use of computer-supported interactive, visual representations of abstract data to amplify cognition." Its purpose is the exploration, sensemaking, and communication of knowledge hidden in data. Policy analysis deals with the analysis of societal problems, and alternative policy options to be chosen by policy makers that may serve as solutions to these problems. For the generation of these policy options, scientific advice is proposed. The main challenges of policy analysis lie in an effective exploration, and sensemaking of policy options by the policy analysts, as well as a comprehensible communication of the analysis results to the policy makers who finally decide upon the options to be chosen.

From the capabilities of information visualization on the one hand, and the challenges of policy analysis on the other hand, we identified synergy effects resulting from the combination of these two fields. With this motivation, we proposed a method how to apply information visualization to the field of policy analysis. Therefore, we

identified relevant stakeholders in the policy-making process. We defined possible collaborations between these stakeholders and hurdles that have to be faced. Finally, we sketched a methodology how to structure the development of such science–policy interfaces supported by information visualization.

As a last facet of our contribution, we presented three case studies that have been conducted in two European research projects dedicated to the field of policy modeling. These studies basically implemented the concept described in this approach. In the case studies, technologies from the scientific fields of agent-based simulation, optimization, and geo-spatial data modeling have been applied to the field of policy making in order to generate and analyze policy options for a given societal problem. All case studies provided access to the computational models by information visualization technologies. This enabled even non-IT experts to interact with complex models and generate policy options. Moreover, the visualization tools could be used to communicate and discuss the results derived from the policy analysis. The case studies showed that our provided concept can serve as an approach to further explore the synergy effects between information visualization and policy analysis. We believe that our provided concept stimulates and motivates further research and discussions in this new, interesting, and not yet extensively studied interdisciplinary field.

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