

Supporting Planning Processes by the Use of Dynamic Visualisation

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Abstract Large scale and long term decision making processes encounter a huge amount of difficulties. On the one hand, the uncertainty about the future represents a fundamental problem which is innate in long-term planning. On the other hand, the different interests and opinions regarding goals and strategies among the various actors are complex issues to be tackled. In order to build common knowledge and facilitate reasoning among the different actors, the following research proposes a method for sharing information through the use of dynamic maps. By means of the visual localisation of costs and benefits, the participants in the spatial decision processes are led to evaluate methods and objectives for a number of alternative development options. The system has been used in different case studies and has shown its effectiveness in creating awareness of spatial problems and enhancing discussions.

1 Introduction

Planning and decision making on spatial questions is recognised as a complex process which must deal with a large number of variables, interests and actors (Andrienko et al. 2007, 2011). Large scale and long term issues have a deep impact on individual and collective life, so discussing them generates a huge amount of

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elements to be taken in consideration. For these reasons the setting of goals and strategies requires a high level of awareness on the part of decision-makers. To allow knowledge building and achieve an informed decision, literature provides different tools and methods. In particular, many benefits can be gained from the use of spatial data visualisation (Bertin 1981; MacEachren and Taylor 1994; Thomas and Cook 2005), also known as geovisualisation, when applied to support spatial decision making and planning.

Tools for supporting planning and decisional processes, more generally known as Planning Support Systems (PSS), Decision Support Systems (DSS) and Spatial Decision Support Systems (SDSS), try to deal with a multitude of actors, opinions, interests, evaluation criteria and data. These diverse elements lead to a corresponding number of attempts to solve the issues involved, which have produced new research fields and technologies. As a result, PSS, DSS and SDSS represent a large part of scientific studies in spatial issues.

Numerous definitions as well as many concepts and classifications, have been produced, providing different, confusing point of views, especially regarding the classification of PSS, DSS and SDSS. As reported by Geertman and Stillwell (2003) citing Clarke (1990), PSS are conceived for “long-range problems and strategic issues”, while SDSS “are generally designed to support short-term policy-making by isolated individuals and by business organisations”. Also Lima et al. (2003) highlights that PSS are meant to include strategic issues while DSS and SDSS “are in general designed to support more specific or short-term policy-making processes”. The first distinction outlines the two main branches of a family tree of definitions that have been assembled by many authors. In particular, two key classifications can be found for PSS. On the one hand, Geertman and Stillwell (2003), according to Harris (1989) and Batty (1995), refers to PSS as “a subset of geotechnology-related instruments that incorporate a suite of components (theories, data, information, knowledge, methods and tools) that collectively support all of or some parts of a unique planning task”. On the other hand, Klosterman (1997) interprets PSS as an “information framework”, in which technology is not the foremost priority, but rather a means to achieve planning purposes. Our experience confirms Klosterman’s view, showing how this persistent research in building the most complex and realistic model is leading to the construction of scarcely comprehensible scientific axioms which policy makers and the public do not trust (Klosterman 2008, 2012; te Brömmelstroet 2010). This approach leads to models which are no longer an abstraction of reality but a one-to-one scaled map (Borges 1960). At the same time, the difficulty in accurately defining the problems inherent in spatial issues highlights how planning is not fully suitable to being converted into an automatic process (Andrienko et al. 2007), but the individual experience and expertise of the actors involved is essential in the building and assessment of plans.

In this continuous battle between a technology-centered approach and human skills, the application of PSS in real case studies encounters many difficulties (Coculelis 2005; Vonk et al. 2005; Geertman and Stillwell 2009; te Brömmelstroet 2010) especially due to a lack of communication between developers and end-users

such as policy-makers, stakeholders and the public. Furthermore, each case study has specific requirements which can rarely be met by offering a single tool, so much time is spent on investigating existing tools and finding the most appropriate ones to fit the goals of the case study. The choice in technology often requires further customisation, which again takes up more time. For this reason a PSS should be very flexible when studying a problem, allowing for a change of scale, easy customisation, the analysis and evaluation of different goals as well as having a simple interface for the exchanging of information.

In time of financial resource constraints and in presence of actors who produce and manage the urban space, often with conflicting goals, it is evident the importance of having tools that can allow to better understand how spatial planning can act within the complex urban dynamics. In this sense, it could be very useful to find visualisation and evaluation tools which are able to manage this complexity at the different scales such as a district inside a city, the whole urban system or a European infrastructural corridor. For these reasons, the following research focuses on implementing planning process by using visualisation in order to stimulate communication and discussion among the actors involved.

Therefore, the goal of this research is to build a method for using an intuitive visual language which should enable communication among decision and policy makers, as well as other kinds of public or private actors for allowing the planning process to be effective in including participation and collaboration as approaches to a sustainable urban development. In accordance with Klosterman's concept of PSS as *information framework* (1997), the purpose of this study is to generate a methodology for organising, managing, relating and communicating data in a visual environment, in order to inform the actors and increase awareness within a planning process. The output of this research is the Interactive Visualisation Tool (InViTo), a visual method for managing spatial data in real-time, based on parametric three-dimensional modelling.

The plan of the chapter is the following. [Section 2](#) contains an overview of the topic. [Section 3](#) describes the methodology developed by the authors. [Section 4](#) describes an application of the methodology in the field of wide area transformations. [Section 5](#) contains the main findings and the evaluation of tool. The conclusion proposes some possible implementation of the research in the field under investigation.

2 Overview

Planning Support Systems require a high flexibility in order to integrate various disciplines and actors, and to be applicable in a large amount of cases, where different characteristics and needs must be met.

In the last two decades, many studies have been carried out in an effort to integrate support systems with other technologies, such as Geographic Information Systems (GIS), Multiple-criteria Decision Analysis (MCDA), Land-Use and

Transport Models (LUTM) and geovisualisation in order to increase their effectiveness in real case studies. More recently, the widespread use of virtual globes, such as Google Earth or Microsoft Virtual Earth, has increased the public curiosity towards the spatial location of data. This new interest has generated a huge amount of web applications but also a diffuse and simplistic approach to geography, even among professionals. Geo-referred data is widely used to locate information, but scarcely exploited to define goals and strategies for cities. Some attempts in this direction arrive from Boston MIT (SENSEable City Laboratory 2012), which proposes the visual analysis of urban areas by recording the spatial movements of personal devices such as mobile phones or bicycles. Even if the visualisation can be very eye-catching, the final purpose of such applications does not enter the real planning processes, remaining an interesting study which does not interact with the applied urban policy-making or strategy definition. With regard to the exploration of data, a good example is the “map tube project” (Centre for Advanced Spatial Analysis 2011). Here a free online resource allows the overlapping and meshing of different maps of the city of London. This initiative of UCL’s Centre for Advanced Spatial Analysis is a Google Maps-based challenge to explore urban clusters within a free public interface. Besides these two famous examples, there is vibrant activity across the globe concerning the combined use of visualisation technologies and geo-based data, especially in interactive environments and customisable interfaces. However, the union between the latest technologies and planning practice does not appear to be particularly vibrant. Among professionals, a deep mistrust of digital support still remains. As reported by Te Brömmelstroet (2010), the main difficulty for the implementation of PSS is a lack of transparency due to which these instruments may be perceived as “sophisticated black boxes”. Further important bottlenecks concern communication issues between models and users, such as “low communication value, lack of user friendliness” and lack of “interaction” (Te Brömmelstroet 2010).

Planning is a process in which people have to interact, communicate, exchange ideas, share information, but also defend their interests and carry out their reasoning. Effective communication is the basis for a well-performed activity in planning practice. Tools derived from complex mathematical formulas which do not employ eloquent images, can not aid this process, but rather help increase the mistrust in technological supports. Many PSS intend to reproduce the behaviour of a complete spatial system, with its inter-relations and connections at the different scales, expressed in various macro-scenarios, as a way to provide different forecasts for a number of planning options. As such, these tools place automatic processing before the whole set of expertise, ideas and opinions which animate the planning debate. The actors may perceive that they are misled by the tools instead of being assisted in building their own reasoning. In order to preserve a priority to human minds, the research field of geovisual analytics aims at supporting spatial problems through the integration of “the power of computational methods with human’s background knowledge, flexible thinking, imagination, and capacity for insight” (Andrienko 2007, 2011). To achieve the enhancement of human capabilities towards building knowledge, interaction with data and interactive interfaces are

recognised as the most effective means, because they allow data exploration and discovery (MacEachren and Taylor 1994; MacEachren et al. 2004).

3 Methodology

The following research proposes a visual method for managing spatial data in real time. This method, called InViTo, is based on Grasshopper, a free plug-in of McNeel's "Rhino", a 3D modeling software most often used in architecture design. Grasshopper generates parametric shapes through the use of different kinds of input such as GIS data, databases, raster and vector files, allowing high compatibility with the largest number of software used by technicians involved in planning processes. InViTo makes use of scripts in Visual Basic language to customise Grasshopper components. The structure of Grasshopper allows the creation of a complex structure of links among different spatial shapes, which InViTo uses to build specific models for each case study. InViTo organises information in order to provide a visual outcome of relationships among spatial objects in real-time. It provides both 2D and 3D outputs such as dynamic maps or volumetric diagrams, which can show the behaviour of single elements or clusters of elements at both micro and macro scale. Data can be presented as an abstract visualisation offering a conceptual view of spatial dynamics, thus allowing users to analyse spatial information in a symbolic way. Nevertheless, photo-realistic representations are also possible, allowing final images to be defined by choosing from a wide range of visual techniques, in order to match the level of expertise of the actors involved in the debate. Moreover, visualisations can be displayed both in Rhino environment, as well as in a virtual globe such as Google Earth. Thanks to the visual interactive framework, which enables users to work with information in real-time, InViTo is a tool conceived as Planning Support System for aiding the actors involved in sharing information and raising awareness of spatial issues. In particular, InViTo aims to provide a number of innovations in approaching planning practice.

First of all, InViTo uses visualisation as the basis for structuring the case study and exploits the properties of visual languages to create a common grammar among the participants to the planning processes.

Secondly, InViTo focuses on the possibility of interacting with data, thereby generating different advantages (Batty 2007). In fact, on the one hand, the opportunity to change input data in a model increases knowledge and awareness on spatial issues and project tasks, allowing actors to have a fruitful "dialogue" with the data displayed. On the other hand, it enhances discussions and debates, supporting users by means of shared images.

Thirdly, InViTo looks for models which are simple and transparent. It avoids the black-box approach and shuns complicated relationships among factors. In fact, these characteristics, which are common among many land use and transport simulation models, have a negative impact on planners' and policy-makers' trust

in information tools. For this reason, InViTo looks for linear connections among spatial elements, as shown in the flowchart structure of Grasshopper. It allows users to access the model and evaluate, validate or customise it.

One further feature of InViTo is its flexibility. Common land-use and transport model are based on rigid frameworks which are difficult to adapt to the unique needs of each case study. These can often be used only for specific applications, such as land-use optimisation or accessibility analysis, and only at particular scales. InViTo, however, allows the production of specific models for each case study by a full customisation, which meets the purposes of application, its scale and planning requirements. Its flexibility also concerns the compatibility with different file formats so that it can employ databases, GIS data, raster and vector files.

Finally InViTo can be applied to the morphological features of spatial elements. Many models are based on the regular subdivision of areas by gridcells, which are used to calculate the values of land transformation. InViTo can work with discrete values of space, but it can also use the real shape of urban spaces, increasing comprehension of the localisation for displayed data.

4 Case Study

InViTo has been used as PSS, intended as an “information framework” (Klosterman 1997), in different applications. In the COST Action TU1002 on accessibility tools, it has been used to study the accessibility to public transport in urban areas. To achieve this task, its structure has been arranged to reproduce an integrated land use and transport model (LUTM) (Bertolini et al. 2012). In other applications, InViTo has been used to simulate the dynamics of rule-based land use models (Pensa et al. 2011; Marina et al. 2012) in order to assess a number of projects for residential purposes. In these cases, InViTo has been organised to relate different elements, as is usual in spatial models, though by means of a visual and interactive interface as *leitmotif* to approach simulation.

In this chapter, InViTo is presented with another application, which focuses on the visual support to the Analytic Network Process (ANP), a multi-criteria analysis technique for the assessment of alternative project or planning options (Saaty 2001, 2005; Saaty and Vargas 2006).

The ANP is a recent development of the well-known Analytic Hierarchy Process (AHP) (Saaty 1980). It represents a theory of relative measurement on absolute scales of both tangible and intangible criteria, which are based on the judgment of experts, and on existing measurements and statistics needed to make a decision. Recent applications of ANP to urban and territorial problems (Abastante et al. 2012; Abastante and Lami 2012; Abastante et al. 2011; Bottero and Lami 2010; Bottero et al. 2008) show that the theory considers the views of different actors, even with heterogeneous languages and may contribute to the construction and review of alternatives. In this sense it is important to underline that ANP

allows the concept of participation to be developed, by means of focus groups where different actors and decision-makers involved can deal directly with each other.

In this version, InViTo has been used in different workshops and focus groups for studying a number of bottlenecks along the trans-European railway axis (TEN-T) 24 Genoa-Rotterdam, which is part of an Interreg IVB NWE Project called “CoDe24”(CoDe24 2010). The case study here presented is about a German section of corridor 24 between Frankfurt and Mannheim. The research aims at identifying strategies and goals for the area, which has been recognised as one of the most critical for the development of strategies for the Genoa-Rotterdam corridor (Masala 2012).

Through the collaboration between a research team of SiTI, which is a non-profit association between the Politecnico di Torino and Compagnia di San Paolo, and part of the Institut für Raum- und Landschaftsentwicklung (IRL) of ETH Zurich, the problem was structured in three different scenarios, which were discussed in a set of workshops and focus groups at the Value Lab of ETH-Zurich. These events were organised in order to involve both parties of the CoDe24 partnership and experts coming from the two cities of Frankfurt and Mannheim. The Analytic Network Process was used to analyse different areas at different scales, in particular from the urban to the trans-national, in order to assess transport, economic and environmental issues (Lami et al. 2011).

The ANP divides the spatial problems into simple elements and, through a pair comparison survey, asks actors to assign a weight to each element. Like other methods, ANP provides the ranking of alternatives as a final result. In this procedure, InViTo was used to implement discussion during the ANP questionnaire. By means of a visual and interactive representation of each element, ANP provides a visual support to compare the localisation of costs and benefits for each scenario.

4.1 ANP Questionnaire

The assessment procedure within ANP methodology consists of pairwise comparisons. This is essential to establish the relative importance of the different elements, with respect to a certain component of the network. In pairwise comparisons, a ratio scale of 1–9, namely Saaty’s fundamental scale, is used to compare any two elements (Saaty 1980).

The structure of the pair comparison survey is divided into two distinct levels: the cluster, which is principally strategic, and the node (or element), which has a specific and detailed nature. The numerical judgments used in the pairwise comparison matrices are normally derived from a specific focus group made up of decision-makers and stakeholders. This group works together to evaluate the different aspects that characterise the problem with respect to the overall objective. Its main purpose is to reach a consensual decision on the weights and priorities. At the cluster level, the result of this phase is represented by the so-called cluster

With reference to the choice of the best alternative development scenario for the Rhein/Main-Rhein/Neckar area, which one of these two aspects do you think is more beneficial? And to what extent?																		
Economic and Transport Aspects	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Environmental and Social Aspects

Fig. 1 Example of pair comparison between two clusters of elements

matrix, while at the node level, the ensemble of related vectors forms the unweighted supermatrix.

As an example, considering the aforementioned application, the questions that the focus group were asked to solve were similar to the one reported in Fig. 1.






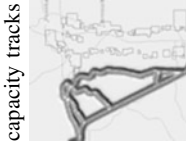
Finally, according to the ANP theory, the cluster matrix is applied to the initial supermatrix as a cluster weight. The result is the weighted supermatrix, which is raised to a limiting power in order to obtain the limit supermatrix, where all columns are identical and each column gives the global priority vector. In the case of this specific application, the spatial problem has been structured into questions concerning the whole area, divided into benefits and costs, where nine elements shared among four clusters are identified. To evaluate the problem, 17 sets of questions have been given to participants who were asked to respond by providing a weight to each question. The pair comparison provided two limit supermatrices, one for each subnetwork of Costs and Benefits. Each column of the limit supermatrices, obtained from either subnetwork, provides the final priority vector of the elements under consideration. Finally, the raw priorities of the alternatives obtained from the limit supermatrices were normalised by cluster and synthesised. These priorities became the input values for the final aggregation and synthesis of the model results.

4.2 Visualisation of ANP Elements

In order to help the actors involved to understand spatial issues, each question of ANP was supported by the visualisation of the symbolic positioning of the expected effects. A map of expected consequences was hereby built for each ANP element (Tables 1 and 2) on the basis of the expertise of researchers in the fields of transport, economics, environment and spatial planning.

The wide scale of the case study corresponds to an approximation in the building of the maps. However, no precise detail is needed because the workshops were intended to aid the reasoning of experts and stakeholders in defining the key

Table 1 Maps used to represent the expected effects of each element under the sub-network “benefits”

Clusters	Maps		
	Scenario 1	Scenario 2	Scenario 3
Economic and transport aspects	<p>Elements</p> <p>Frankfurt and Mannheim</p> 	<p>Railway stations along passenger tracks</p> 	<p>Railway stations along passenger tracks</p> 
	<p>Increase in level of attractiveness due to the improvement in speed/frequency/capacity of passenger transport connections</p> <p>Freight transport railway tracks</p> 	<p>Freight transport railway tracks</p> 	<p>Freight transport railway and high capacity tracks</p> 

(continued)

Table 1 (continued)













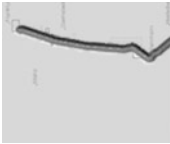
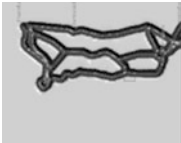




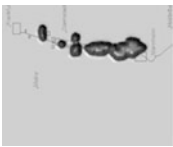

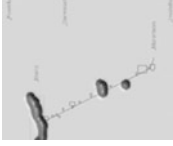
Clusters	Elements	Maps		
		Scenario 1	Scenario 2	Scenario 3
Environmental and urban planning aspects	Reduction in pollution due to the displacement on railway lines of a portion of road traffic	<p>Motorway network</p> 	<p>Motorway network</p> 	<p>Motorway network</p> 
	Optimisation in soil consumption (widespread urbanisation is limited)	<p>Frankfurt and Mannheim</p> 	<p>Brownfield on Mannheim area</p> 	<p>Brownfield on Mannheim area</p> 
	Increase in level of services for the local population	<p>Frankfurt and Mannheim</p> 	<p>Settlements along passenger tracks</p> 	<p>Settlements along passenger tracks</p> 

Table 2 Maps used to represent the expected effects of each element under the sub-network “costs”

Elements		Maps		
		Scenario 1	Scenario 2	Scenario 3
Economic and transport aspects	Missing financial resources and construction costs (initial investments, reclamation costs)			
	Operational cost			

(continued)

Table 2 (continued)

Elements		Maps		
Clusters		Scenario 1	Scenario 2	Scenario 3
Environmental and urban planning aspects	Negative impact (noise, vibrations and visual impact) due to the passage of trains	 <p>Settlements along high speed track</p>	 <p>Settlements along freight track</p>	 <p>Settlements along high capacity track</p>
	Destruction of protected areas between Frankfurt and Mannheim and in the Mannheim region	 <p>Green areas along high speed track</p>	 <p>Green areas along freight track</p>	 <p>Green areas along high capacity track</p>

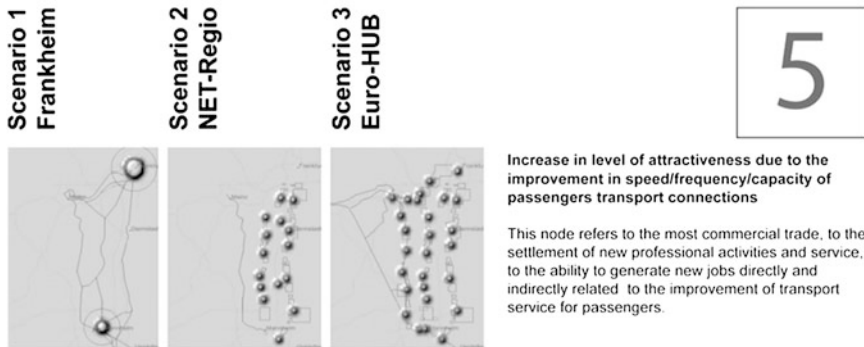


Fig. 2 Example of maps presented to participants for the evaluation of each single question of ANP. Each map represents the expected position of the effect of a specific ANP element depending on the scenario

elements for long term strategies on a very large scale. The maps should therefore give an indication of the effect rather than the actual position of an event.

During the discussion, a set of dynamic maps for each question (Fig. 2) were displayed to participants showing, in real-time, the behaviour of maps if the given weight was 1 or 9 for one element or another. Effectively, participants were guided in understanding where their choice might fall, so as to evaluate step by step the importance of their response.

InViTo was used to build all the visualisations used in this ANP assessment procedure. These visualisations are GIS-based and work with parametric features which have been set to reproduce the ANP scale of evaluation. They have been structured on a three-dimensional mesh where peaks change in height in correspondence to the expected effect, as defined by the weights assigned (Fig. 3).

This means that the mesh changes its shape on the basis of the values given by actors during the pair comparison of ANP elements and clusters. In particular, the interactive interface enables the use of maps to display specific values according to the requests of participants, as well as the identification of the areas with more benefits (coloured in light grey) or costs (painted in black). To allow a better understanding of the visualisations, the three-dimensional meshes are intersected by a slicing plane, which works as a cursor running up and down to visually select the areas included on a specific range of values. This plane (the transparent and white horizontal plane) has the same height in all scenarios so to allow a better comparison between them.

Once the whole set of questions has been answered, the weights resulting for each element are summed up as defined by ANP technique and summarised in two final maps, one for the Benefits and one for the Costs. These two maps overlap in order to compare the localisation and the amount of effects due to the actors' choices (Fig. 4).

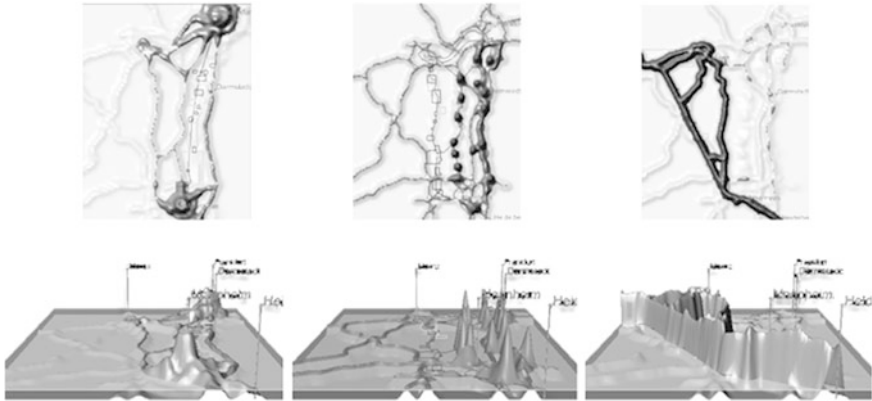


Fig. 3 Maps showing the total amount of the aggregate benefits for the three scenarios

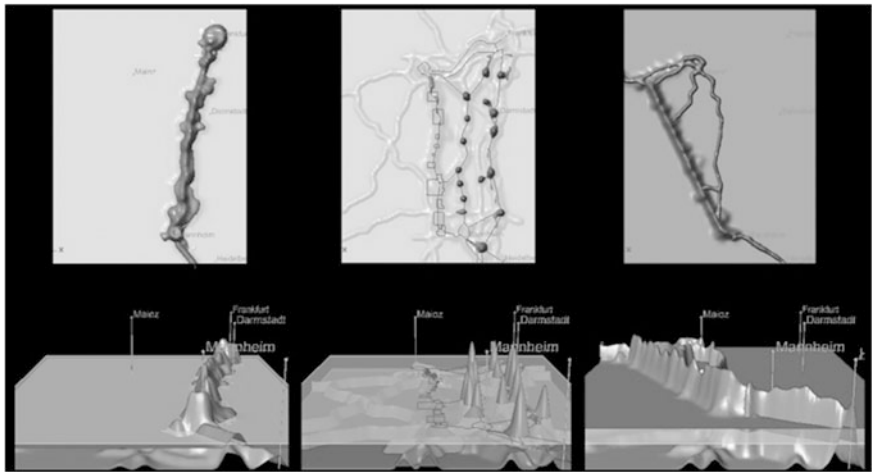


Fig. 4 Overlapping of the total amount of costs (coloured in black) and benefits (coloured in light grey)

The ANP questionnaire provided only one a ranking of scenarios, which showed the second as the best and the third as the worst. The reading of maps confirmed the ANP results and provided a lot of important points for the following discussion. The maps highlighted where and how much benefits overcome costs and vice versa, providing important elements for building reasoning and increasing awareness in participants. The positioning of the effects and their intensity added important contents to the debate so that some people changed their mind.

5 Methodology Evaluation

A survey about visualisation and its use in assessment sessions, distributed among the participants to one of the workshops at Value Lab of ETH Zurich, provided important feedbacks for the improvement of the support system. Although by and large comments were positive and participants satisfied, some participants requested further explanation about the language used by the visualisation. Dynamic maps seemed to be a good way to communicate spatial information, but the high level of abstraction has introduced new rules in the reading of maps. This proved to be a difficult obstacle to overcome especially in the case of participants with technical expertise in GIS management. In fact, the deterministic approach to the use of maps which distinguishes GIS technicians is far removed from the conceptual representation used in this case study. Therefore, a more detailed explanation of visualisation techniques have proven necessary.

In general, InViTo has been recognised by the majority of participants as being very useful in real planning processes while all the participants evaluated it as a useful tool for sharing information, knowledge building and as a support to the discussion.

6 Conclusion and Discussion

The case study described in this chapter presents a new approach to visualisation during the planning process. The goal of facilitating reasoning and awareness has been achieved to the point that many participants in the workshops confirmed InViTo as a being a useful PSS. The integration with ANP was effective in leading participants to build their own reasoning and sharing it with the others.

The visualisation used in this research introduced new languages for reading maps, overcoming the deterministic use and enhancing an abstract approach for clustering and selecting spatial data. InViTo has shown to be highly flexible and capable of being adapted to different case studies at diverse scales along the corridor 24, as well as functioning as a fully transparent interface between ANP technique and users.

The results obtained are encouraging, even if numerous issues remain to be solved. The foremost being that the interface with users is mediated by a technician. The values of weight given by users are input into the model by an operator as well as the movement of the slicing plane. On the one hand this is an advantage to leading the workshop because helps maintain a framework for the discussion. On the other it is a limit because the lack of an individual interface confines the interaction between users and data, therefore limiting the possibility of a comprehensive knowledge of the model. This entails that a graphic interface for direct interaction with the model is needed. First attempts have already been made by introducing the aid of laptops and tablet PCs, although they have not been tested in real decisional sessions.

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