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Using a touch table to support participatory land use planning

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Abstract: Designing land use plans for areas with multiple stakeholders is becoming an increasingly complex task. This paper presents a method to interactively develop land use plans with multiple stakeholders and conflicting objectives. In this method, spatial information plays a central role. Maps are used to communicate and exchange knowledge among policy-makers and stakeholders. This is done through a series of interconnected workshops, where interaction between stakeholders is prompted through the use of maps, decision support tools and an instrument called the 'touch table'. The touch table is a touch-enabled screen, which is used to support stakeholder collaboration through common visualization and spatial information handling. Three types of workshops with different map use are distinguished: Design (map as design language), Analysis (map as research model) and Negotiation (map as decision agenda).

The main goal of a Design workshop is to identify problems concerning the planning of an area using spatial information to prompt knowledge exchange. Participants are invited to explore and develop land use plans using three reference plans as a defined playing field. With the help of simple drawing tools users can provide feedback digitally and design alternative plans by drawing polygons in free-form mode and subsequently allocating land use classes. In an Analysis workshop, participants are invited to evaluate and adjust any of the reference plans. To create a new plan, the reference plans are used as the canvas, on which participants can 'paint' land use changes. As users 'paint' new land uses on parcels, feedback on suitability is provided dynamically on the touch table.

The main goal of a Negotiation workshop is to reach a land use plan that increases both the objective values of the stakeholders and the total value of a reference plan. Functionality is incorporated into the touch table to help participants suggest land use changes. Multi-Criteria Analysis (MCA) is used to provide feedback on the relative qualities of the plan compared to the reference situation. A multi-user interface allows participants to display on the map the parcels that are both best and worst suited for their own specific interests. Having 'negotiable' parcels shown on the map, users can trade their 'bad' parcels with each other and proceed to paint a new 'negotiated' plan. By making these trades-offs explicit, users are prompted to work as a team in a collaborative environment to reach a plan that is the best possible for all.

We have tested our approach during Design, Analysis and Negotiation workshops with stakeholders of the Bodegraven polder in the Netherlands. Land use must be reallocated in Bodegraven to meet new water level conditions. Surveys conducted revealed the participants' preference for the touch table over printed maps. They liked especially the possibilities to choose and combine background maps, navigate across the area, see what others do and add qualifications to a plan. The touch table increased their awareness of new aspects of the area's problems. Participants thought it can stimulate significantly the discussions and considered it to be most suitable for government representatives.

Keywords: *Participatory planning, multi-user, touch table, land use planning, negotiation*

1. INTRODUCTION

Spatial decision problems with multiple decision-makers are traditionally present in land use planning (whether environmental, urban or regional). Typically this process involves multiple long-term, often conflicting policy objectives. Spatial Decision Support Systems (SDSS) have been developed to support such processes, focusing mainly on individual decision-making. Recent approaches to support group decision-making in land use planning include face-to-face meetings to bring the stakeholders together, involving the use of maps and tools to integrate knowledge. In this context the emergence of conflicts is common among stakeholders, especially at later stages where negotiations take place. Supporting the negotiation process is thus particularly critical. Providing relevant spatial information may stimulate cooperation and improve knowledge exchange among decision-makers. We assume that by increasing the effectiveness of map use in participatory decision-making, the quality of the decision-making process also increases. There is a need to integrate decision support tools with participatory approaches to support conflict solving and to stimulate cooperation among the various parties involved along the decision-making process.

This paper describes a method that incorporates GIS-based tools and a touch table to effective use of spatial information into the decision process for the participatory development of land use plans with conflicting objectives. It reports on tests of our method with stakeholders of the Bodegraven polder during a series of interconnected Design, Analysis and Negotiation workshops. Results of these tests are discussed, with an emphasis on how the touch table was used during the workshops and its potential application as a tool for participatory decision-making. The remainder of the paper is structured as follows: our approach to support participatory land use planning with a touch table is described in Section 2. Section 3 deals with the procedures to support decision-making processes and the use of maps in participatory planning. Section 4 presents our study area and describes the three types of workshops of our approach. Emphasis is given to our proposed support for spatial negotiation with the touch table. Finally, conclusions are presented in Section 5.

2. THE APPROACH: USE OF A TOUCH TABLE IN MAP-BASED WORKSHOPS

The approach combines three elements. First, use of maps and GIS-based MCA tools for knowledge exchange and communication; second, face-to-face workshop meetings; and third, the utilization of an interactive instrument called the touch table. These elements altogether can be viewed as a collaborative environment. Developed at the Mitsubishi Electric Research Labs (MERL) (http://www.merl.com/) and commercialized by Circle Twelve Inc (http://www.circletwelve.com/), the DiamondTouch table™ (touch table) is a large interactive touch screen that allows simultaneous input of up to four users while it recognizes which user is touching it. In this study we use it as the main map interface to visualize and handle spatial information in a multi-user setting (See Figure 1). The rationale behind our choice for it is threefold. First, it is a potential support tool for face-to-face group collaboration because it allows users to maintain eye contact while simultaneously interacting with the display and discussing with each other. Second, it allows users to work with computer-based tools without having a computer get in the way. Third, it provides a common map interface that complements (rather than replaces) printed maps. In addition we included workshop-specific support tools to support participatory decision-making processes. We have developed GIS-based tools for each type of workshop and loaded them on the touch table. The tools are built within ArcGIS 9.3, running on a laptop with Windows XP. Interactive MCA tools were developed with CommunityViz (http://www.communityviz.com/), a set of extensions to ArcGIS for land use planning. Multi-user tools to provide feedback about plans on the touch table were developed with DT Collaborate™ (also from Circle Twelve Inc), an extension to ArcGIS for the DiamondTouch table™. Our method attempts to integrate the touch table and the three workshops into a participatory decision-making process.

Figure 1. The touch table

3. SUPPORTING PARTICIPATORY LAND USE PLANNING PROCESSES

Supporting a decision-making process meaningfully involves dedicated support for each of its stages. A structured decision-making process consists of three major stages: intelligence (identification of problem), design (development of alternatives) and choice (selection) (Simon, 1960), each of which requires different types of support and relates to different usages of information. In land use planning maps are used by decision-makers through each stage of the decision-making process, and can play important roles. Carton and Thissen (2008) distinguish three major frames for map use in policy-making processes and collaborative decision-making. The frames include: design, analysis and negotiation. Table 1 shows an overview of the most important aspects of the frames. In all frames maps are used as the main means to stimulate knowledge exchange and facilitate communication among stakeholders, decision-makers, policy-makers and scientists. Particularly, within the 'negotiation' frame, integrated map-based tools are required to play several roles: tools to make trade-offs of objectives explicit, tools that allow input of multiple users and tools that evaluate plans on-the-fly quantitatively, visually and spatially as decision-makers suggest changes.

Table 1. Overview of most important aspects of the frames on map use, based on Carton & Thissen (2008)

	Design	Analysis	Negotiation
Group or actor	Design expert	Research expert	Stakeholder, expert in decision-making
Actor metaphor	Artist	Scientist	Politician
Emphasis on	Creation and presentation of options	Research and assessment	Interaction, problem framing, trade-offs
Map seen as	Design language	Research model	Decision agenda

Tackling decision problems with multiple objectives with the help of multi-criteria decision analysis (MCDA) has become a widespread practice (Janssen, 2001; Belton and Stewart, 2002). MCDA includes numerous methods and techniques to structure decision problems and support decision-making processes. Spatial decision support systems can be viewed as a major result of the integration of two research areas: Geographic Information Systems (GIS) and MCDA. The GIS-based MCDA integration relates to spatial decision support and has been researched by numerous authors, (e.g., Eastman et al., 1998; Feick and Hall, 2001; Malczewski, 2006) and applied in different domains, notably in land use planning. However, the use of SDSS in participatory land use planning has not always been successful (Uran and Janssen, 2003). GIS are universally accepted tools to handle spatial information for numerous purposes and in many contexts (Geertman and Stillwell, 2003). As such GIS and maps alone have been considered as generic decision support tools. Combining the capabilities of MCDA methods to structure and solve decision problems with the versatility of GIS to handle, analyze and present spatial information can be a potential basis for the development of tools to support decision-making for spatial decision problems. Furthermore, the integration of GIS and MCDA has led to the development of new integrated tools for spatial decision support and has also played an important role in the emergence of two major subfields of GIS science: Spatial Decision Support and Participatory GIS (PGIS) (Malczewski, 2006). Spatial decision support can be associated to individual decision-making, if the decision-makers belong to the same group and have a single goal in common. PGIS belongs to group decision-making as it involves the inclusion and participation of multiple, and often diverse, groups of actors with different goal preferences in the decision-making process (Carver, 2003; Sieber, 2006). PGIS involves typically map-based tools to support group work and collaborative tasks. Particularly, it focuses on the use of GIS-based tools to help the public understand spatial consequences of proposed land use alternatives, evaluate them and create new ones (Jankowski, 2008). PGIS approaches to bring stakeholders together include local approaches (e.g., face-to-face meetings, used in this study) and distributed approaches, such as internet-based online systems.

4. THE WORKSHOPS

The Bodegraven polder is the test site of our approach. It is located in the South Holland province in western Netherlands, in the middle of the 'Groene Hart' (Green Heart), the largest national landscape of the country. With an area of 4672 hectares, it is a water-rich region with agriculture, nature and recreation standing out as the primary activities. It consists predominantly of fen meadows, which stand for high natural, cultural and historical values. Currently, several issues are critical in Bodegraven namely, ground subsidence, the physical preservation of the fen meadow landscape, fragmented water management, water quality below the standards of the Water Framework Directive (EU-WFD), and the changing economical position of dairy farming. We selected it as our case study because multiple stakeholders with multiple interests are present and the current land use situation is clearly not sustainable. Changing water levels have created a need to reallocate land use in the region. We organize a series of interconnected workshops for stakeholders, experts and decision-makers, where they can create, assess and negotiate plans in real-time with GIS-based tools and the touch table in a context called 'geocollaboration' (See Maceachren and Brewer, 2004). Our method distinguishes three types of workshops: design, analysis, and negotiation. The nature of our workshops and the tools implemented are associated with how maps are used and the roles they play in decision-making, as shown in

Carton and Thissen (2008). Participants of our workshops in Bodegraven are private stakeholders (such as farming groups and landlords), public stakeholders (involved public actors such as: municipal, provincial and water management authorities, including nature organizations), and researchers.

4.1. Design and Analysis workshops

In a Design workshop maps are used as design language for the exploration and creation of alternative land use plans. Design tasks involve maps as the only type of information and deal with the appraisal of three reference plans, which were created by a landscape architect. Participants are invited to give input on the plans and also 'paint' their own changes on the plans, according to their own views on the decision problem. These tasks are supported by providing the participants with a set of background maps, which are presented digitally on the touch table. Most important maps include: high-resolution current aerial photography, digital elevation model, current topographic map, historical topographic map, administrative borders, estimates of future groundwater levels and yearly land subsidence, historical dikes, current distribution of polder units with water levels, and soil type. Participants are divided into two groups and then invited to provide feedback (strengths and weaknesses) on the three reference plans. One group provides feedback using printed (background) maps and the other group uses the touch table. We developed simple drawing tools for the users to provide feedback digitally on the touch table. Through a multi-user interface they use their fingers to touch on the map and indicate where they see either strong or weak aspects of the plans. Figure 2 shows an example of a produced map on the touch table showing the feedback by participants about one of the three plans overlaid with the plan. A color-coded land use plan consists of three classes: nature (dark green), extensive agriculture (yellow) and intensive agriculture (light green).

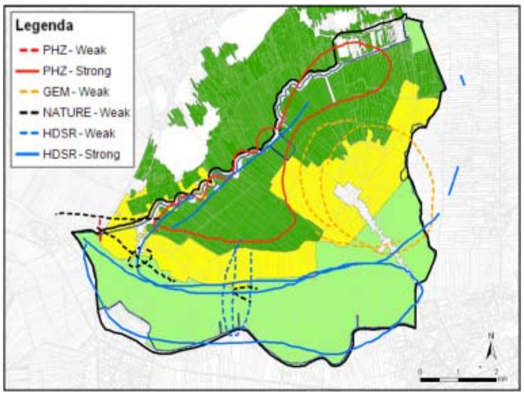

Figure 2: Land use map with feedback by participants using the touch table. Users are distinguished by colors. Solid and dashed lines show strong and weak aspects respectively.

In an Analysis workshop, maps are used as research models to facilitate the researchers' interpretation of results from scientific research. First analysis task consists of measuring the suitability of one of the three reference plans. Participants are asked to try different land use restrictions based on groundwater levels, whose feasibility is dynamically displayed on the touch table (Figure 3, left). They can experiment with different thresholds to test the robustness of one of the plans. In the second task, participants are invited to make changes to that plan. With support tools, they can change existing land uses of parcels by touching on the map where they consider needed. For each user's input, suitability based on groundwater levels, is dynamically calculated and mapped (See Figure 3, right). Estimates of future groundwater levels are used. At the end of the workshop, participants present their results as maps on the touch table.

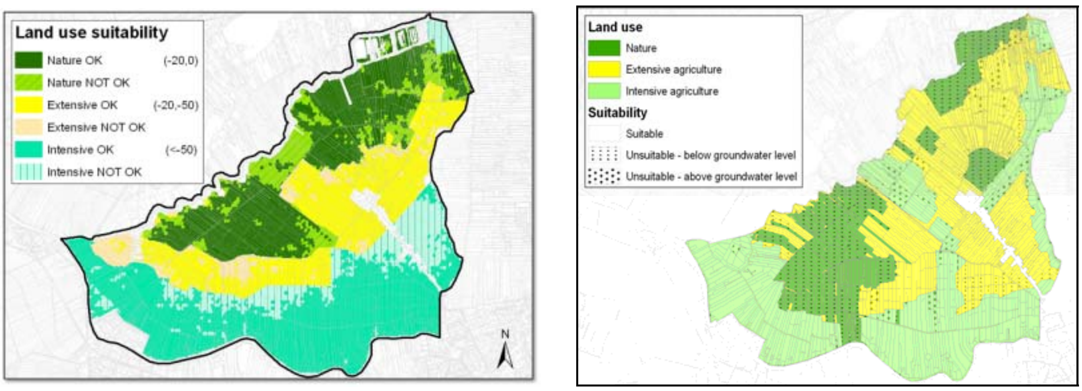

Figure 3: Example of a land use plan designed by the participants using the touch table with dynamic suitability on parcels (right), based on results of testing land use against thresholds (left)

4.2. Negotiation workshop

In a Negotiation workshop maps are used as a decision agenda. Tools focus on supporting negotiation tasks during the 'choice' stage of decision-making. We combine use of maps, evaluation and negotiation tools, and the touch table into a collaborative environment to support negotiations. In this setup, decision-makers can express their preferences and have them simultaneously confronted with others'. Decision-makers are invited to negotiate changes to a reference land use plan. The main goal is to arrive at a new plan that increases both its total value and the objective values of all decision-makers. The setup of the negotiation comprises hardware and software tools. Hardware includes a laptop, the touch table and a separate monitor screen. The software component comprises MCA evaluation tools for dynamic plan evaluation, tools to support land use trade and reallocation, which includes a multi-user interface to make trade-offs explicit on the map and drawing tools to allocate land uses by 'painting' parcels on the map on the touch table. All these software tools were developed with CommunityViz Scenario 360 within ArcGIS.

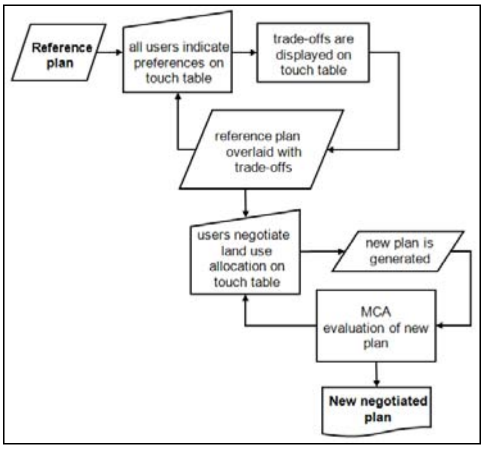

Figure 4. Major steps of the process followed in a Negotiation workshop.

The software tools support the process of collectively changing a reference plan into a new negotiated plan (See Figure 4). The evaluation tool estimates the quality of the plan with MCA. A reference land use plan is used as the starting point of the negotiation process. It is a parcel-based vector map displayed on the touch table, with three color-coded land use classes: nature (dark green), extensive agriculture (yellow), and intensive agriculture (light green). We have defined objectives for Agriculture, Soil and Water, Landscape and Nature, each of which is contributed by criteria. The plan has been assessed previously per individual parcel, both on the basis of each evaluation objective and on a total basis. This is done using weighted linear combination of both criteria scores (for evaluation of each objective) and objective values (for total evaluation). Criteria scores are derived using expert knowledge associated with suitable groundwater levels from tabulated value functions, e.g., higher water levels could permit the preservation of critical nature ecosystems; lower levels are suitable for intensive agriculture; levels in the middle suit better for extensive agriculture and recreation. The objective value for the whole area is determined by spatially aggregating objective values of all parcels on the basis of the parcel area. The total value of the plan for the whole area (complete evaluation) is obtained through spatial aggregation of all total parcel values. Information about quality of the plan, i.e., objective and total values, is available to the users as bar charts on the monitor screen (See Figure 6) and will change dynamically once the land use of a parcel is changed on the touch table. It is assumed that each participant is associated with a land use type according to their interests and backgrounds (e.g., while the representative of the Nature Conservation Groups is interested in a plan that maximizes the value for objective 'Nature' and tries to allocate land use 'Nature', the representative of the Farming Groups is interested in a plan that maximizes the value for objective 'Agriculture' and tries to allocate land use 'intensive agriculture').

With the multi-user interface, the participants can touch on the touch table to display parcels with either the highest value or lowest value for their objectives, i.e., their 'best' and 'worst' parcels. A user selects a percentage of the total area or an area value for both best and worst parcels for a specific land use that suits his/her own specific interests. The best and worst parcels are internally ranked and then highlighted on the map (See close-up in inset in Figure 5). The other users follow the same procedure so that all possibilities are displayed on the map at the same time. This is done with the purpose of visually identifying 'negotiable' parcels on the map, which are parcels that may suit the objectives of one participant and at the same time may not suit those of the others.

With the drawing tools the users can change land use of target 'negotiable' parcels. They can touch with their fingers on a land use palette to select a land use type and subsequently allocate it to the parcels in question by touching them. The plan starts to change as new land uses are allocated. The evaluation component assesses the quality of the plan as soon as the participants accept the trades and paint the land use changes. Provisional evaluation results are displayed on the separate monitor screen (Figure 6). Each representative is assigned goals in area and quality that match their specific objectives (e.g., the user representing Nature Conservation Groups tries to achieve a high value for objective 'Nature' and a target area value for land use 'Nature').

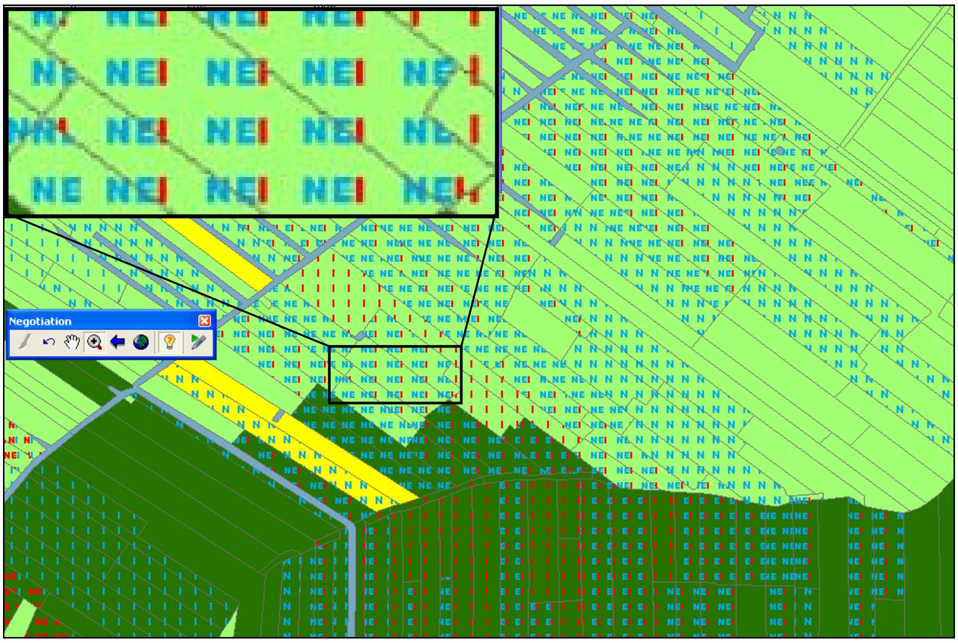

Figure 5. Negotiation Support on land use map: blue characters in zoomed-in inset show best areas for Nature and Extensive agriculture. Red characters show the worst areas for Intensive agriculture.

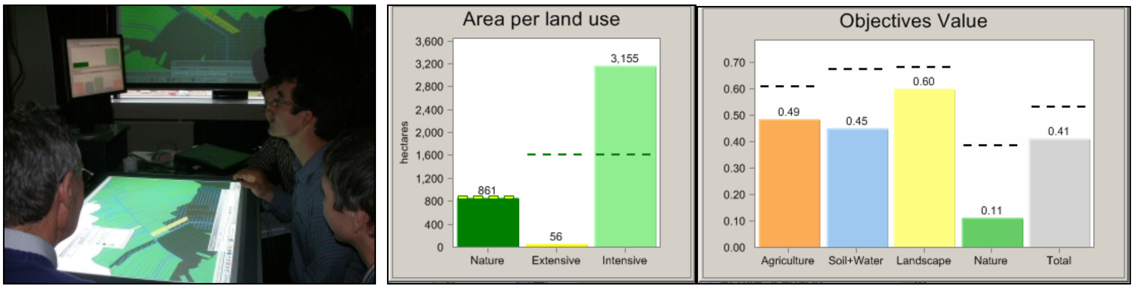

Figure 6. Evaluation information: starting land use areas and objective values for the negotiation exercise. Dashed lines on bars on chart 'Area per land use' (middle) indicate target areas for each land use type. Dashed lines on bars on chart 'Objectives value' (right) indicate theoretical maximum values for each objective and total value of the plan.

Table 2. Tasks and goals of negotiation exercise

Stakeholder	Land use	Goal
Nature organization	Nature	Achieve 860 ha of nature, trying to optimize the value for objective 'Nature'
Agricultural nature organization	Extensive agriculture	Achieve 1600 ha of extensive agriculture, trying to optimize the value for objective 'Landscape'
Farming organization	Intensive agriculture	With 3155 ha of intensive agriculture, land must be given in; try to maintain the value of 'Agriculture' as high as possible, keeping the best parcels and trading the worst ones

We developed a negotiation exercise and tested it in a Negotiation workshop. Participants were members of groups involved in fen meadow research. They were divided into two groups, each of which was provided with a touch table. Each group included three users, each representing a stakeholder and playing a role (See Table 2). We had both groups negotiate separately, but based on the same collective and individual goals. The goals were indicated as target hectares of a certain land use type and in value (quality) optimization, as shown in Table 2. Figure 6 (middle) shows a clear excess of 'intensive agriculture' and hardly any 'extensive agriculture'. The area goal for 'nature' is already achieved but maybe not on the best parcels (See low 'Nature' value in Figure 6, right). The collective value goal was to increase the total value for the whole area (See Figure 6, right, Objective Value 'Total'). The exercise setup allows users to optimize their own objective values and at the same time the whole group to achieve the highest possible total value. We recorded the discussions among users during the negotiations, paying special attention to their negotiation strategies. Records of the discussions reflected two different negotiation strategies, which resulted in two completely different plans (spatially) with similar quality values.

5. CONCLUSIONS AND DISCUSSION

This paper described how the touch table can be used to support participatory decision-making processes. Key to success for application is the perception of usefulness by the participants. We conducted surveys at the end of Design and Analysis workshops, which reflected that the majority of participants preferred the touch table over printed maps. Their reasons included the possibilities to choose and combine background maps, navigate and zoom across the area, see what other participants do and add qualifications to a plan. Printed maps were preferred by very few participants, while the rest showed no preference. When asked about the most suitable type of users of the touch table, they considered government representatives to be most suitable because of their broader scope on decision problems and their interest in overall objectives. Finally, it was also found that the touch table increased their awareness of new aspects of problems in the area. A large proportion of the participants thought that it can stimulate significantly the discussions.

In the Negotiation workshop, we provide users with information about the overall and relative qualities of the plan they are negotiating. This information is used to spatially disclose trade-offs between land use possibilities and problems and supports participants to find a compromise plan using the touch table. Interestingly, it was noticed that the participants made more use of the negotiation support provided on the touch table, in comparison to the summarized quality information provided on the screen, which was used much less. Despite technical limitations such as maximum number of users and land use classes, the support offered for a Negotiation workshop was accepted by the participants. At present, the exercise is set up on the basis of land use areas and plan quality. It would be interesting to include spatial aspects, such as connectivity (e.g., for hydrological connection of nature), clustering, vicinity and topological rules into these definitions and have the plan evaluated on these conditions. Further research should be done about how to incorporate these aspects into our method without overcomplicating it. The next step is to test the negotiation exercise with both public and private stakeholders in a Negotiation workshop and see whether they are still willing to negotiate within our framework with real interests at stake. This is expected to be more difficult because unlike public stakeholders, private stakeholders may have a more limited scope for negotiation and more direct stakes. While the participants enjoyed the workshops and found our approach useful, we will develop formal ways to test effectiveness in map use.

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