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Use of ICT tools for integration of energy in urban planning projects

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Abstract

Within the European collaboration project SUSREG a number of software tools for sustainable urban planning were applied and tested in the context of real case studies. Three types of ICT tools can be distinguished: Neighbourhood Sustainability Assessment Tools, Rating systems and LCA-LCC Tools. We discuss in more detail the Autodesk Ecotect Analysis tool, as applied in the case study of an old railway area in Burgos, Spain. The second tool is GPR Urban Planning, which was applied to a city expansion plan for the City of Nijmegen, The Netherlands. We conclude that ICT tools are often applied rather late in the planning process which neglects their potential advantages with respect to integral assessment and stakeholder communication.

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Keywords: Information and Communication Tools; urban planning; environmental; sustainable energy, tools state of art; integrated environmental impact assessment.

1. Introduction

1.1. State of the art

Regional and town planning authorities often have the stimulation of sustainable energy and energy efficient building as one of their policy priorities. The actual implementation of this policy, however, is a complex and difficult process with many stakeholders, long lead times and uncertain organizational responsibilities. As a consequence the identified potentials for sustainable energy use or energy efficient building are often realized only to a small extent.

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One of the reasons for this gap between highly ambitious policies and little realization of this ambition is that energy related subjects have not been an important part in the education of urban planning students. Therefore urban planners have less knowledge of the integration of energy efficiency and sustainable energy sources than of other more traditional urban development issues like transportation, spatial layout, etc. In order to address this problem the European project SUSREG was initiated which focuses on capacity building among urban planners with respect to sustainable energy and sustainability in a broader sense. As part of this project the application of dedicated ICT (Information and Communication Technology) tools for sustainable urban planning was addressed.

In this paper we will first give some background information on the SUSREG project. Then we will give an overview of relevant ICT tools and their main application field. Two of these tools are subsequently discussed in more detail as they were applied in regional case studies within the framework of the SUSREG project.

1.2. SUSREG project

To foster realization of sustainable energy policies, the SUSREG (Stimulating Sustainable Regional Development by means of a Structured Process Approach) [1] project aims to stimulate the use of sustainable energy resources and energy efficient methods in urban and regional planning by improving knowledge, skills and attitudes of professional planners at regional authorities, local organizations and national associations. The SUSREG capacity building program has followed a three stage approach:

- Stage 1: Description of good planning examples, practical planning tools and a structured process approach. Focus of the examples and tools has been be on the problem of integrating sustainability ambitions in early phases of planning and on safeguarding these ambitions during the actual implementation of plans.
- Stage 2: Knowledge transfer and on the job training of planners in the regional organizations. While working on their case studies the municipal planners have also been testing the theoretical concepts and tools collected in stage 1.
- Stage 3: Capacity building among members of professional planners associations. The results from the case studies elaborated in stage 2 and the practical experiences from regional planners in the Consortium are used in stage3 as solid practical basis. Theoretical concepts and tools offered in the trainings are derived from the work in stage 1, but with improvements collected from stage 2 experiences. The stage 3 trainings have been organized by ISOCARP, the International Society of City and Regional Planners, in collaboration with the respective national associations.

At this moment the SUSREG project is near finalization. In this paper we would like to share some of the experiences from the project and more specifically the possibilities offered by ICT tools which can facilitate to incorporate energy aspects into urban planning processes.

2. ICT tools used for urban planning and their general characteristics

Depending on the purpose of the urban assessment, currently there are different ICT tools that enable realizing different kind of evaluations. Among these tools mainly the user has the possibility to select between two evaluation tool groups: qualitative and quantitative, which mainly they differ in the calculation methodology and the system of interpretation of results

Qualitative ICT tools usually are associated with Multi Criteria Voluntary Sustainability Evaluation systems (MCVSE). From 1990, with the aim of boosting the term "Green building" or sustainable building, different work teams began to define various MCVSE systems allowing to the end user to evaluate the overall performance (environmental, energy and social) of their building. In addition, due to the need of differentiate over other buildings, the use of MCVSE systems increases such as a new benchmarking system. Therefore, increasing number of MCVSE systems are adapting their scope, extending their evaluation scope from buildings to district (see Table 1). The general structure and working philosophy of all turns out to be similar. Using different calculation systems, each MCVSE determines a score range for each evaluated parameter and once obtained that score, by the sum of points or by a weighting system, the end user gets the final score or rating. By applying this kind of evaluation systems, the user has the possibility to assess different aspects of the district and obtain a final certification or rating. An increasing number of research papers [2,3,4,5,6,7] are discussing about MCVSE systems sensitive aspects such as the direct interrelation between the evaluated parameters, the lack of standardization of a comprehensive set of criteria, and also of the metrics.

Table 1. Aspects evaluated by each Rating tool

	Environmental quality	Economic quality	Socio functional quality	Technical quality	Process quality	Transport & movement	Land use and ecology	Pattern and design	Regional priority	Diversity	Environmental quality
DGNB [8]	X	X	X	X	X						X
BREEAM [9]	X		X		X	X	X				X
LEED ND [10]	X				X		X	X			X
HQE2R [11]	X		X					X		X	X
Ecocity [12]	X	X	X		X	X		X			X
SITES [13]	X		X		X			X			X
LCC [14]	X	X	X								X

On the other hand, qualitative systems are based on quantifying and showing the impacts of one or more aspects of a city, applying harmonized calculation methodologies and avoiding weightings and subjective assessment systems. In the event that these kinds of tools show any final scores, this score is accompanied by the calculation result or impact value, reducing the rating system strength and facilitating the necessary information to reach new improvement decisions. According to the evaluated aspects or the system boundary applied, we can distinguish two general groups: Neighborhood Sustainability Assessment (NSA) tools and tools with Life Cycle approach.

NSA tools assess the different sustainability aspects of a district during its operational stage. That is, when the whole district or the assessed aspect is operational. Among these tools, we can mention:

- The tool DPL (Dutch acronym for Duurzaamheid Prestatie voor een Locatie, 'Sustainability-Profile for Districts') " assesses in a clear and transparent way the spatial plan for a district on sustainability, based on the information from the urban plan. It so helps urban designers to creatively improve the sustainable performance of a district"[15]. Compared to other tools for assessing urban sustainability, DPL represents a relative simple and flexible approach. The idea is to use a limited number of indicators based on already collected data (environmental, social and economic), which are often accessible in the municipal registers. If data are not available, the model allows alternative methods for a 'best estimate' on the indicator.
- GPR software assesses and rates the environmental impact, energy performance and design quality of buildings and urban developments. Essential in the GPR methodology, is the dual approach of environmental impact on the one hand and district quality on the other. The key performance indicators are: Energy, Environment (assessing the environmental impact), Health, User quality, and Long term value (assessing the building quality)., which are is divided into several sub-indicators [16]. This gives the opportunity to pin-point topics to be improved, while still keeping an overview of the overall environmental impact.
- TRACE (Tool for Rapid Assessment of City Energy) tool [17] is a decision-support tool designed to help cities quickly identify under-performing sectors, evaluate improvement and cost-saving potential, and prioritize sectors and actions for energy efficiency (EE) intervention. It covers six municipal sectors: passenger transport, municipal buildings, water and waste water, public lighting, solid waste, and power and heat.
- The Transep-DGO tool [18] is an Excel sheet that describes and calculates six teen energy concepts for districts. These energy concepts are classified into five main energy concepts: (Waste heat) district healing with biomass or geothermal, solar Thermal, solar Electric, conventional Healing and hydrogen Storage. Transep-DGO tries to

stimulate the transition towards energy-neutral districts in 2050, by developing a back casting tool which supports municipal decision makers in the early design stages of district development.

- The software DECA [19] supports actors in the field of urban planning during the first stages of planning energy-efficient district concepts. The very heart of the software is a tool for the energy assessment of districts, which uses archetypes and other pre-set configurations to allow for a simple and quick data input mapping all the buildings in the district. Thus it takes the user just a few steps to identify the energy saving potential of various strategies in the areas of building construction, technical building systems, and centralized supply systems.
- The software CitySim [20] is aiming to provide a decision support for urban energy planners and stakeholders to minimize the net use of non-renewable energy sources as well as the associated emissions of greenhouse gases.
- TERMIS is a Real Time Hydraulic and Thermal Modeling and Simulation System [21]. Among its characteristics should be highlighted: the real time component, which significantly improve the operational stage and identify-solve problems
- The WaterCAD [22] tool allows modeling hydraulic schemes, evaluating operation consumptions, and assessing water quality.
- Simulation of Urban Mobility (SUMO) [23] is a free and open traffic simulation suite which allows modelling of intermodal traffic systems including road vehicles, public transport and pedestrians.
- TransModeler [24] is a versatile traffic simulation software applicable to a wide array of traffic planning and modeling tasks. TransModeler can simulate all kinds of road networks, from freeways to downtown areas, and can analyze wide area multimodal networks.
- Ecotect [25] is a tool which, among other applications, assesses aspects of luminance and shading of the whole city. In addition, this tool allows evaluating climate conditions or energy performance of buildings.

Table 2. Summary of aspects evaluated by each Sustainability Assessment Tool

	Energy Buildings	Energy Transportation	Energy Water	Energy Public lighting	Solid waste	Safety	Health	Quality of work and home	Social cohesion	Economic vitality	Future value	Usage value	Urban mobility
DPL [15]	X					X	X	X	X	X	X		
GPR [16]	X		X			X	X				X	X	
TRACE [17]	X	X	X	X	X								
Transep-DGO tool [18]	X												
DECA [19]	X												
CITYSIM [20]	X												
Termis [21]	X									X			
WaterCAD [22]			X										
SUMO [23]													X
Trans Modeler [24]													X
Ecotect [25]	X												

On the other hand, according to the European Commission Communication on Resource Efficiency Opportunities in the Building Sector [26], the life cycle methodology is currently the best framework available to assess the potential impacts of any activity, product or service without geographical, functional or time limits, since it quantifies the impact of the inputs and outputs along its whole life cycle, including the extraction of raw materials, production process, use and end of life stages.

LCA is standardized by ISO 14040 [27] and 14044 [28] standards, and consists of four phases. The first phase is to define the goal and scope of the assessment, which serves as a description of the type of study. The scope of the study determines which processes should be included in the inventory phase of the assessment. In the second phase, the life cycle inventory (LCI) includes information on all of the inputs and outputs associated with a product or service. The third phase is the impact assessment, where the potential contribution of each substance to predefined impact categories is calculated. Once the impact has been calculated, the fourth and final step of the assessment is the interpretation, where the results of the calculations are summarized and discussed. Specifically for the construction sector, new standards, such as EN 15978:2011 [29], already define the different phases of a building life cycle and a number of indicators and methods used to declare the results of the analysis. Due to this effort of standardization, currently there are tools such as Athena [30], Bees [31], Ecoeffect [32], Eco-Quantum [33], Ecosoft [34], Elodie [35], Envest [36], Equer [37], Jomar [38], Legep [39] or Sofias [40], allowing to evaluate the performance of the buildings with life cycle perspective.

Based on this effort or standardization and tool adaptation realized at building level, in recent years, the life cycle methodology is adapting to new evaluation levels, developing new tools that assess different sustainable aspects of the district with lifecycle approach. Among these tools, this article highlights the following two tools (see Table 3). The first tool is NEST [41] (Neighbourhood Evaluation for Sustainable Territories), which is one of the first tools which evaluate a design of a new district with Life Cycle Approach (LCA). The analysis evaluates 4 environmental aspects (infrastructures, buildings, transport and land use) and also evaluate the economic and social aspects. The second tool is UrbiLCA [42], which allows analyzing the energy and environmental impact of a district. In addition, the urban density, geographic location, power distribution, the use of renewable energy, waste collection systems and sustainable mobility are considered by this tool.

However, until now there is not any standardization which facilitate the assessment of this new evaluation level, making difficult the harmonization of the evaluation and the comparison between different results obtained by different tools.

Table 3. Aspects evaluated by each Life Cycle approach tool

	Life Cycle stages								Evaluated aspects		
	Product phase (A1-3)	Transport (A4)	On site processes (A5)	Maintenance (B2)	Replacement (B4)	Operational energy use (B6)	Operational water use (B6)	End of life phase (C1-4)	Environmental	Economic	Social
NEST [41]	X					X	X		X	X	X
URBILCA [42]	X		X			X	X	X	X		

3. Use of ICT tools in the case studies

The advantages and weaknesses of each of the tools defined in the section 2 vary, distinguishing between tools that require a high technical level and very basic tools that estimate very generic values. Although much of the tools provide technically relevant information in improving the sustainable performance of a district, due to the objectives set during the different projects evaluated by SUSREG, mainly two have been the tools used to evaluate different aspects of urban design and urban sustainability.

The first tool was Autodesk Ecotect Analysis, which offers a wide range of simulation that can improve performance of existing-new buildings and districts-cities. Ecotect, especially, is designed for architects and planners, offering high-quality images and very interesting graphics and values. In evaluation projects at the district level, this tool allows evaluating aspects such as:

- The potential climate and initial bioclimatic strategies for energy approach.
- Visualize the shadows related to each buildings and view how sunlight moves around within a space.
- When and how long one object stays in shadow, which is very useful to design public spaces such as recreation area, public areas or a bus stop.

The difficulty of this tool is not high. The results are very visual and its representation is very suitable. Many times, the greatest difficulty lies in obtaining the weather data and modelling all areas correctly

The second tool applied during the assessment of the different case studies was GPR Urban Planning (reference, which facilitates to incorporate sustainability targets into urban developments. GPR Urban Planning brings together different specialisms and makes it clear that sustainable urban development is a shared responsibility. The user gets a well-structured insight into the aspects of sustainability as well as the sustainability performance of a new urban plan or the restructuring of an existing area. Based on these selections an urban development is rated on five indicators on a scale of 1 to 10 (very good). The key performance indicators are: Energy, Spatial layout, Health, Quality of use and Future Value. Each indicator is divided into several sub-indicators. When assessed, the performance of the urban plan is rated per indicator. Policy makers and urban planners can determine ambitions for each of the five indicators and thus focus on the topics which are most relevant to a specific situation: in rural areas the spatial planning might be more relevant, whereas in densely populated areas the health aspects may need more attention.

The tool is easy to use and requires no special skills other than a good knowledge of the urban area and the plan that needs to be evaluated.

4. Case studies

4.1. Burgos railway station area (Spain)

The evaluated area is the old train railways, now called "Boulevard" of Burgos. It was a very deprived area, now refurbished at a 60%. During the original urban planning phase (see figure 1) aspects such as volume of buildings, dimensions of streets, green zones and building usage were defined. Urbanization of the roads has been done, as well as new urban and land use planning of the area, including new buildings and infrastructures. Lots of sustainable parameters have been implemented in terms of:

- Transport: bus lane with priority, bicycle lane and less facility for the private vehicles.
- Lighting: new lighting with less consumption and only the necessary light for the area.
- Green areas, safer and wider pedestrian areas for walking.
- Garbage collection (district pneumatic collection)

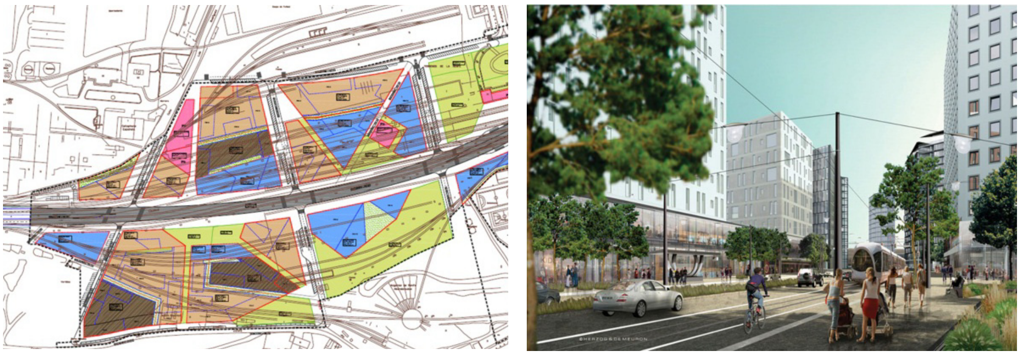

Fig. 1. (a) Original urban plan overview; (b) proposed image of the main street.

However, this urban plan defined by the architects Herzog & De Meuron did not provide any parameters on aspects of energy supply-distribution, renewables use, bioclimatic strategies or environmental limitations. Therefore, with the objective to improve some sustainability concepts and propose new issues, by the application of an quantitative tool, different stakeholders and technicians discussed about this urban plan. In view of the difficulties of the integration of new energy policies in the Burgos region and constant planning restrictions, all work was focused on developing a work of analysis and critical review of the relation between climate, solar incidence and the new geometry proposed by the project. For this, the selected tool was Ecotect. This tool allows you to integrate very easily the geometry of the buildings and through input from the climate file and orientation, the user has information for developing different variants.

The first analysis focused on discussing whether the volume designed by the architects was adequate. From the energy point of view and solar irradiation the whole volumetric design did not guarantee adequate sun light to all the buildings, as higher volumes with very long shadows sweep the northern part of the area, both buildings and public spaces. The Normative of the General Planning of the city asks for two hours of sun light in the south facade on December 22. But this requirement does not guarantee that all apartments have that minimal sun light as they can be located in the southern facade and not receiving those two hours. Due to the internal distribution of housing, the urban design and building heights, 27% of homes fail to meet this minimum 2 hours of daylight, reducing the life quality of the inhabitant and increasing aspects such as discomfort or energy consumption.

Seeing this problem related mainly to the towers (ground floor + 16 floors) from the main street, the second evaluated aspect was focused on analyzing the influence of the shadows generated by these buildings. The climate of Burgos stands out for its low temperatures in winter (to -15 ° C) and temperatures up to 35 ° C in summer, becoming the shadows in a bioclimatic strategy. Indeed, an adequate assessment of shadows could improve the thermal comfort of urban spaces and decrease thermal demand of the surrounding buildings.

It has been noted that the shadow of the towers sweeps over the entire public space that is located in the northern part of the area, increasing the shadow period by 87% in winter and by 23% in summer. In the cold city of Burgos the sun light of public spaces is essential to enjoy comfort throughout the year and it has been proven that the shadow on them is almost constant in winter. In turn, the great height of the buildings of the main street will significantly reduce the solar gain of buildings that are located in the northern part of the new district. After conducting various studies by Ecotect, technical demonstrate that the reduction of 4 floors of the towers of the main street decrease in 9% the demand for heating buildings on the north side of the new district. If the reduction would be of 9 floors, the heating demand reduction could reach up 15%.

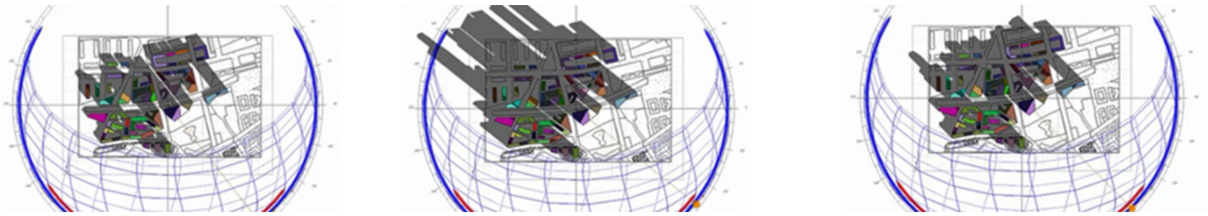

Fig. 2. Solar-shading assessment of the new urban planning

Table 4. Summary of new strategies and weakness of the Burgos case study

New Strategies	Weaknesses
Reduce the height of the north towers in the Boulevard.	Very few sustainable parameters were introduced in terms of energy saving during the original urban planning
Reduce the height of the north towers in the Boulevard.	Difficulty to change the value of the current urban density.
Change the urban pattern, adapting it to the physical environment so they can significantly reduce the energy demand in buildings.	The majority of the solutions planned during the original urban planning (related with the building) have only esthetical purpose.
Adapt the urban pattern to the weather, reducing the buildings energy demand.	Need to learn respect energy and environmental aspects.
Use of renewable energy to cover a higher percentage of energy demand, even covering the 100%.	Difficulty to implement some of the topics chosen on a day-by-day work.
	The politicians in general have problems to admit these criteria for a variety of reasons: short term vision, influence of the owners and the local press, limited time leading the changes…

4.2. Area 'De Grote Boel' in Nijmegen (the Netherlands)

The case study area is part of a larger area designated for expansion of the city of Nijmegen. It is located north of the City Centre, on the north side of the river Waal. The location is within the concession area of a district heating system. The heat for this system is generated by the waste combustion plant in the south-west of Nijmegen (see Figure 3-a). Other new built developments and existing housing areas are to be connected to the system as well. The municipality of Nijmegen has formulated an energy strategy for the city called Power to Nijmegen (see Figure 3-b), whose aim is to reach zero fossil energy usage by 2045.

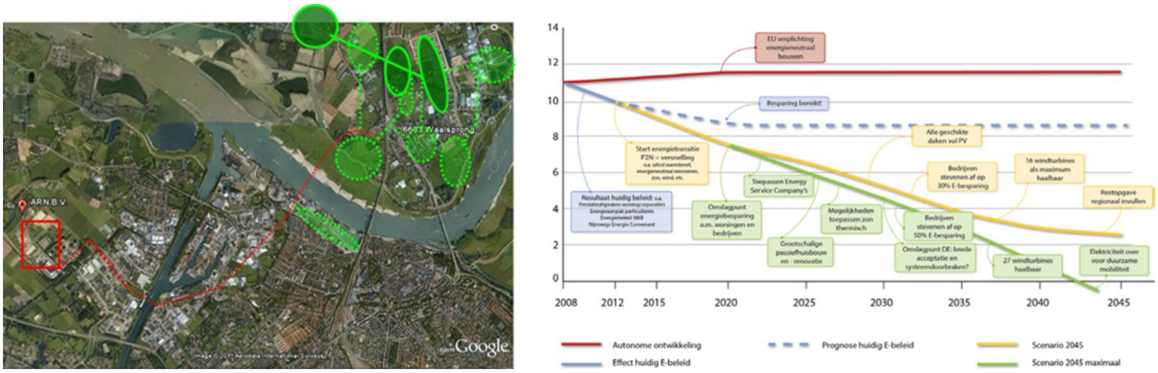

Fig. 3. (a) Green circles are areas designed to connect to district heating; red box is the location of the waste combustion plant; (b) energy policy municipality of Nijmegen

During the case study the original urban plans for the area Grote Boel were evaluated with GPR Urban Planning. Originally, the planning focused on landscape development. Green areas were planned at the edges of the new development and heating will be supplied by district heating. After evaluated the case study with GPR tool, the results show that the focus on landscape development pays off with highest performance on the theme 'Quality of use'.

Due to the economic crisis the demand for new houses reduced significantly, thus causing a delay in the development process for the Grote Boel. But this also offered the opportunity to assess the plan again with GPR Urban Planning and evaluate different scenarios for this development:

- integration of sustainable energy,
- livability and flexibility of plan,
- placement of green spaces and,
- traffic structure optimized for bicycles.

The result of the evaluation of those scenarios was an adapted plan with stronger emphasis on bicycle use, better balance in green spaces and a higher chance of success for implementation of the development as planned. Sustainable energy has been integrated more in the urban design. The enhanced focus on sustainable development in the project attracted developers with new building concepts, like GB4All who will build 60 dwellings in a nearly zero energy concept and convinced the traditional developers like Heijmans Bouwbedrijf to also market 0-energy houses in the Grote Boel development.

The visualization of the performance of the area has also resulted in an amelioration of the cooperation between experts (energy experts in urban planning). It gave the opportunity to establish the similarity of issues to be resolved in other town developments, leading to a closer cooperation with the neighbouring town of Arnhem.

5. Conclusions

Based on the experiences in the case studies, it can be concluded that ICT tools are often introduced rather late during the planning process. And when introduced, the tool is used to evaluate the performance with regard to very specific aspects. When used during the project initiation phase, even when the design or use of the area is not yet clear, the tools can be used more to their full potential in the process to formulate the project's ambitions. A major benefit of the use of integral planning tools is that measures are weighted not only in comparison with comparable measures, but also against other aspects of planning.

What also has been learned during the execution of the case studies is that by visualizing the sustainability performance scores by means of an ICT tool during the design of an area, the development plan does not benefit only on the technical aspects. A strong additional benefit is that early use of ICT tools gives the planners the means to communicate with stakeholders about the sustainable performance, right from the start of the project. This can be very valuable for example for finding investors for the project or during discussions with stakeholders about difficult subjects. In general we observe that the tools can be very useful for the facilitation of participation processes.

The Grote Boel case shows, that, if sufficient time to analyse plans is available, improvements in the plan can be made that have a much farther reaching impact than the improvement of a score on a ITC-tool would suggest.

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