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Towards satisfying practitioners in using Planning Support Systems

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ABSTRACT

Several Planning Support Systems (PSS) have been developed so far, but their uptake in planning practice remains low. The analysis of the literature shows that one major factors for the limited use of PSS is the mismatch between PSS functionality (as well as the way it is provided through the PSS user interface) and what planners expect. This motivated a deeper research with the objective to analyse the factors preventing a wider use of PSS. In particular, this paper focuses on the usability of PSS. It reports an evaluation study performed to investigate the usability of PSS for some specific tasks: planners were involved in testing the land suitability analysis module of three PSS. The study results confirmed the mismatch between what PSS provide and what planners expect, as well as indicated a poor usability of PSS. Indications for improving the design of PSS that satisfy needs and desires of practitioners are provided.

Keywords

PSS usability, Evaluation, User Test, Human-Centred Design

1. Introduction and Motivation

Planning professionals are faced with complex tasks as they require analysing vast arrays of disparate data for making decisions that endeavour to address the aspirations of cities wishing to be competitive, sustainable and resilient. In order to assist planners in the built environment, who are tasked with shaping the urban fabric of our cities, Planning Support Systems (PSS) have been developed as a decision support tool to assist data-driven land use planning. In this article, PSS are referred to as software tools that use simple or complex mathematical models for analysing and forecasting development of urban or regional land use. Over the last few decades, many PSS have been developed (see the PSS reported at: http://docs.aurin.org.au/projects/planning-support-systems/, accessed on July 10, 2017). Some are commercial products, e.g. Land Change Modeler (http://www.clarklabs.org), CommunityViz [Walker & Daniels 2011], some are available as open software, e.g. UrbanSim [Waddell 2002], CLUMondo [Asselen & Verburg 2013], Online What if? [Pettit et al. 2015]. PSS differ according to several features, for example, the tasks they address (e.g. to assess the impact of land use change, to allocate land uses for more sustainable development), the capabilities they possess (e.g. spatial analysis, map visualisation) and their implementation (e.g. standalone software, module within Geographic Information Systems (GIS), web application) [Pullar & McDonald 1999].

Despite the proliferation of PSS, past research showed that the adoption and use of PSS by planners is limited. A debate on factors that hamper a wide use of PSS in practice has been going on among researchers for several years (see e.g., [Vonk et al. 2005, Vonk & Geertman 2008, Geertman 2017]). Low usability of PSS has been indicated as one of the relevant factors for this [Vonk et al. 2005; Brömmelstroet 2010].

The research presented in this paper aims at providing a contribution to a debate about PSS adoption by investigating primarily on usability of PSS. Indeed, usability is the system quality factor that most affects people that use the system; it is characterised by several sub-attributes, as it will be illustrated in details later in this paper. This paper reports an evaluation study that was performed to analyse the usability of PSS and to better understand practitioners' expectations. The main goal of this study is to get PSS that can be used with satisfaction in planning practice, thus increasing PSS adoption. More specifically, this study provides a significant contribution by systematically highlighting the issue of PSS usability as emerged in a rigorous evaluation study. Indeed, it focuses on a common planning task as performed using three recognised PSS. This work builds upon previous research into the usability of PSS as provided by [Brömmelstroet 2016; Papa et al. 2016] and reinforce the general finding that there still remain issues of PSS usability which underpin their adoption in planning practice.

The evaluation study involved six professional planners as participants of a user test. They were asked to perform a Land Suitability Analysis (LSA) with three PSS. LSA is one of the common activities undertaken by land use planners when performing site selection or strategic planning tasks, as illustrated by the considerable amount of literature on it and the various reported case studies [e.g. Jankowski & Richard 1994; Klosterman 1999; Pettit & Pullar 1999; Pullar & McDonald 1999]. LSA determines the suitability of each land unit for a specific purpose, based on a set of parameters that the planners or actors in the planning process have to set in order to calculate the output. The user test had two main goals: 1) analysing possible usability problems that participants experienced; 2) better understanding planners' mental models and expectations in their interaction with PSS, in order to identify functionality desired by planners and, thus, provide PSS developers with insights for creating systems that satisfy practitioners by properly supporting their activities. Thus, the results of our work strive to improve PSS adoption in planning practice and offer valuable insights from planning practitioners. Most previous studies focus on the usability of PSS in the context of academic exercises [Pettit et al. 2013; Sharma et al. 2011; Waddell 2002].

The structure of this paper is the following. Section 2 discusses related work. The key characteristics of the three PSS evaluated in the user study are described in Section 3. The overall study is reported in Section 4. Section 5 discusses the study findings in relation to indications for designing PSS capable of satisfying planning professionals. Section 6 provides conclusions.

2. Related work

A significant body of literature presenting and discussing PSS applications in specific contexts has been published [e.g. Stillwell et al. 1999; Brail & Klosterman 2001; Hopkins et al. 2004; Brail, 2008; Geertman & Stillwell 2009; Van der Hoeven et al. 2009; Sharma et al. 2011; Geertman et al. 2015].

Although PSS have been available for more than two decades, their adoption by planners is rather low. Indeed, it has been shown that instrumental, human, organisational and institutional factors, such as low instrument quality, low awareness by planners and low diffusion to and within planning organisations, hamper the adoption of PSS [Russo et al. 2017; Brömmelstroet 2013; Williamson & McFarland 2012; Vonk & Geertman 2008; Klosterman & Pettit 2005]. Geertman [2017] recently analysed PSS from four perspectives, namely PSS history, PSS research, PSS education and PSS in practice, and encouraged to differentiate research on PSS in order to improve the body of knowledge and possibly PSS adoption in practice. In line with this suggestion of focusing on specific topics, our research analyses PSS usability, since low usability of PSS has been referred in the literature as one of the most important factors limiting PSS use by practitioners [Brömmelstroet 2010; Vonk et al. 2005]. Moreover, various experts in the field argue that in-depth research on PSS usability is required and that evaluation and improvement of PSS usability should be given a priority [Williamson 2012; Pelizaro et al. 2009; Couclelis 2005].

Usability is the most important software quality factor from the point of view of people who use a software system of any type [Nielsen 1993; Rogers et al. 2013]. In his seminal book on usability, Nielsen proposed a model in which he analysed the *acceptability* of an interactive system by users [Nielsen 1993]. The attributes of system acceptability, beside cost, reliability, compatibility with existing systems, etc., include *usefulness*, an attribute that indicates whether the system allows people to achieve their desired goals easily and with satisfaction. In Nielsen's model, usefulness is actually considered along two sub-dimensions: *utility* and *usability*. The former refers to whether the functionality provided by the system can do what is needed by users, while the latter refers to how well users can use the provided functionality. Specifically, usability is a multi-dimensional quality factor of a system, which can be decomposed in 5 sub-attributes: *learnability*, i.e., the ease of learning the functionality and the behaviour of the system; *efficiency*, i.e., the level of attainable productivity, once the user has learned the system; *memorability*, i.e., the ease of remembering the system functionality, after a period that the user has not interacted with it; *low error rate*, i.e., the capability of the system to support users in making less errors during the use of the system, and in case they make errors, the ease with which the user can recover from the errors; and *user's satisfaction*, i.e., the measure of how much the users like the system.

Usability is a well-defined concept within the Human-Computer Interaction (HCI) community, which has devoted extensive research to methodologies for designing usable systems and to methods for evaluating system usability. Instead, our analysis of the PSS literature revealed that there is still confusion about terms like usability, usefulness, utility of an interactive system. Today, the most accepted definition of usability by the HCI community is the one provided by the International Organization for Standardization (ISO) [ISO 9241-11, 2010], which decomposes usability along three dimensions: *efficiency* and *effectiveness* of the human-system interaction as well as *satisfaction* of people interacting with the system. In our research, we focus on usability as reported in the previous definition. In other words, rather than analysing which functionality is provided by the PSS, we are interested in analysing how well practitioners can use this functionality. Nowadays, usability is extended by the concept of User Experience (UX), which stresses the satisfaction dimension by emphasising hedonistic aspects of the system as well as the involvement and pleasure of people in using the system [Albert & Tullis 2013]. This means that, in addition to providing usable functionality, today's systems should involve users in pleasant and engaging experiences.

The Human-Centred Design (HCD) methodology recommends that, in order to improve its usability, an interactive system should be evaluated during the design and development phases [ISO 9241-210, 2010]. It is important to remark that performing an effective usability evaluation is not an easy task. In Allen [2008], it is reported that usability evaluations of PSS are rather rare. This is still true, possibly because developers do not see them as part of their standard work process, are not used to perform them and/or do not have the required skills. This is acknowledged not only for PSS but for interactive systems in general [Rosenbaum et al. 2000; Vredenburg et al. 2002; Bak et al. 2008; Ardito et al. 2011; Ardito et al. 2014].

Extensive effort has been made in order to encourage and drive developers in performing PSS evaluations. Recent literature indicates that usability aspects should be considered when evaluating PSS; in particular, in

[Brömmelstroet 2016; Pelzer 2016] some attributes specific for PSS usability are provided. However, no effective guidance on how to carry out usability evaluation of PSS is provided. Within the overall research of which the work presented in this paper is part, a usability evaluation framework has been developed [Russo et al. 2015], whose aim is to serve as a guide for developers in organising and performing an evaluation, such as defining goals, identifying appropriate evaluation techniques, identifying data gathering methods, etc. Among the different methods used to evaluate system usability and UX, the evaluation framework suggests adopting cost-effective methods. Examples of such methods are heuristics evaluation and user test with thinking-aloud protocol [Nielsen 1993]. The latter was the method used in the user test reported in this paper.

The literature shows that PSS evaluations have been conducted within collaborative settings, i.e. workshops in which domain experts (e.g. planners, environmentalists, transport engineers) were also involved [Salter et al. 2009; Arciniegas et al. 2013; Pelzer et al. 2014; 2016]. The analysed PSS were implemented on a touch table, i.e. hardware with a horizontal screen, which can be surrounded by groups of people that perform collaborative tasks. In many cases, domain experts did not interact with the PSS themselves but often the developers of the PSS, acting as intermediaries, carried out actions requested by the stakeholders (e.g. specifying indicators, uploading data and running analysis). The moderators did not only help to operate the PSS but also explained the input and how to interpret the output [Brömmelstroet & Schrijnen 2010; Pelzer 2016]. The focus of these evaluations was primarily the impact that the use of PSS in groups had on social and planning processes, such as communication, shared language, decision-making, consensus (on problem, goals, strategies) [Salter et al. 2009; Brömmelstroet & Schrijnen 2010; Goodspeed 2013; Pelzer et al. 2014; Brömmelstroet 2016; Pelzer 2016]. Promisingly, there are studies beginning to show that, although usability is still a problem which requires further research, it is increasingly improving [Brömmelstroet 2016; Papa et al. 2016].

An approach for improving PSS usability is to closely involve target users in the development process of the software [McIntosh et al. 2011; Van Delden et al. 2011; Pelzer et al. 2016]. This has also been shown by Vonk and Ligtenberg [2010], who tested two PSS prototypes for collaborative sketch planning implemented on a touch table. One prototype was developed by following a traditional system engineering method, while for the second prototype a socio-technical approach was adopted [Ackerman 2000; Sutcliffe 2000], which requires to develop the system in close collaboration with users. In the HCI community, this approach is called "Participatory Design" [Schuler & Namioka 1993]. Thanks to the involvement of users, the socio-technical approach takes into account what users consider really important for them, there is the possibility to discuss with users the appropriate functionality of the system and its implementation according to their view of how the system should work, in order to effectively support their work practice and the way they are used to perform their tasks. When considering participatory design teams, some authors talk about "symmetry of ignorance" [Rittel 1984]; in other words, the usual situation in such teams is that system developers are expert in technology and know less about the application domain, while users and other stakeholders do not know about technology but are expert of the application domain. Thus, in socio-technical development, developers and users complement the weaknesses of each other. In this way, they are able to perform together a better task analysis. Moreover, users' skills and expectations become more explicit during the process, and this results in a better usability of the final system. Indeed, in Vonk and Ligtenberg [2010] it was shown that the traditionally developed PSS was rejected by planners because of their poor functionality and usability, while the other PSS was much more accepted. Despite such studies, only little has changed in the development of PSS so far. Pettit et al. [2014] propose a co-design approach that also emphasises the participation of planners in the PSS design team. However, there is the need for more research on these topics, in order to show developers that the PSS they create have to comply with planners' actual expectations, in order to become more widely used.

Despite such studies, only little has changed in the development of PSS so far. Pettit et al. [2014] propose a co-design approach that also emphasises the participation of planners in the PSS design team. However, there is the need for more research on these topics, in order to show developers that the PSS they create have to comply with planners' actual expectations, in order to become more widely used. This article provides a contribution in this direction by reporting an evaluation study with six professional planners, whose aim was to observe planners working with PSS, in order to identify the main usability problems, and, in particular, to understand what users expect by PSS. This study, which is presented in the following section, was designed according to the framework for PSS evaluation described in Russo et al. [2015]. The framework provides a robust approach for usability evaluation as based on proven methods undertaken through the HCI community [Rogers et al. 2013].

It is also important to acknowledge that the evaluation of PSS in the context of group-based exercise is extremely useful with a number of studies highlighted above. However, what is most notable is the paucity of usability evaluation studies undertaken with individual users of PSS. Whilst planning practitioners may spend significant time in collaborative planning exercises with key stakeholders in the planning process it is considered of high value that the planning practitioner also has the ability to use the PSS tools in an individual setting to review data inputs, land use constraints, formulated urban planning scenarios, etc. Thus, in this usability evaluation we take the approach to methodologically isolate the participants (planning professionals) and study their individual usability experiences.

3. A brief overview of the selected PSS

In the evaluation study, six professional planners were required to test the LSA module of three PSS, which was implemented in different ways. In order to identify the three PSS to be used in the test, a comprehensive review of available PSS was carried out which is listed in an online resource (http://docs.aurin.org.au/projects/planning-support-systems/). Nine PSS that were easy to access and to install and allowed performing impact assessment, LSA, land use demand and allocation analysis, were thoroughly inspected. Three PSS that better complied with the goals of the user test were identified. Specifically, the selected PSS had to satisfy the following two conditions:

1. to allow participants to go through the whole workflow process from data input to data output within a reasonable amount of time;
2. to offer a certain level of guidance, so that participants would be able to work without requiring step-by-step instruction during the test.

Condition 1 was taken into account in order to investigate properties that planning experts consider very significant, like PSS transparency (i.e. “the extent to which the underlying models and variables of the PSS are accessible and understandable to users”) and reliability (i.e. “the extent to which the outcomes of the tool are perceived to be valid”) [Pelzer 2015]. Condition (2) was considered because according to the literature [Seewald & Hassenzahl 2004], tasks during user tests do not have to be too easy but possible to solve.

The other six inspected PSS were excluded because they did not fulfil the two conditions. More precisely, their workflow process from data input to output was too long. The consequence was that too much time was required for task completion (contradiction to condition (2)) and it would have been impossible for participants to perform all necessary steps during the user test. As alternative to the latter, only parts of the whole workflow process could have been tested, which however is in contradiction to condition (1).

The evaluation focused on the PSS modules devoted to LSA, which determines the suitability of each land unit (usually at a land parcel level) for a specific purpose and based on a set of parameters. Through the assignment of weights, users can attribute different importance to parameters. All three PSS draw on Spatial Multi-Criteria

Evaluation, a well-supported methodology in decision-making processes that combines multiple datasets with the same spatial extension into one single dataset (output) [Arciniegas et al. 2013]. The output includes a map, also referred to as land suitability layer, which displays the suitability score for each land parcel through colour-coding. LSA functionality differs in the three PSS, requiring different weighting scales or parameter processing. The three PSS are briefly described in the following, illustrating the main operations for performing LSA.

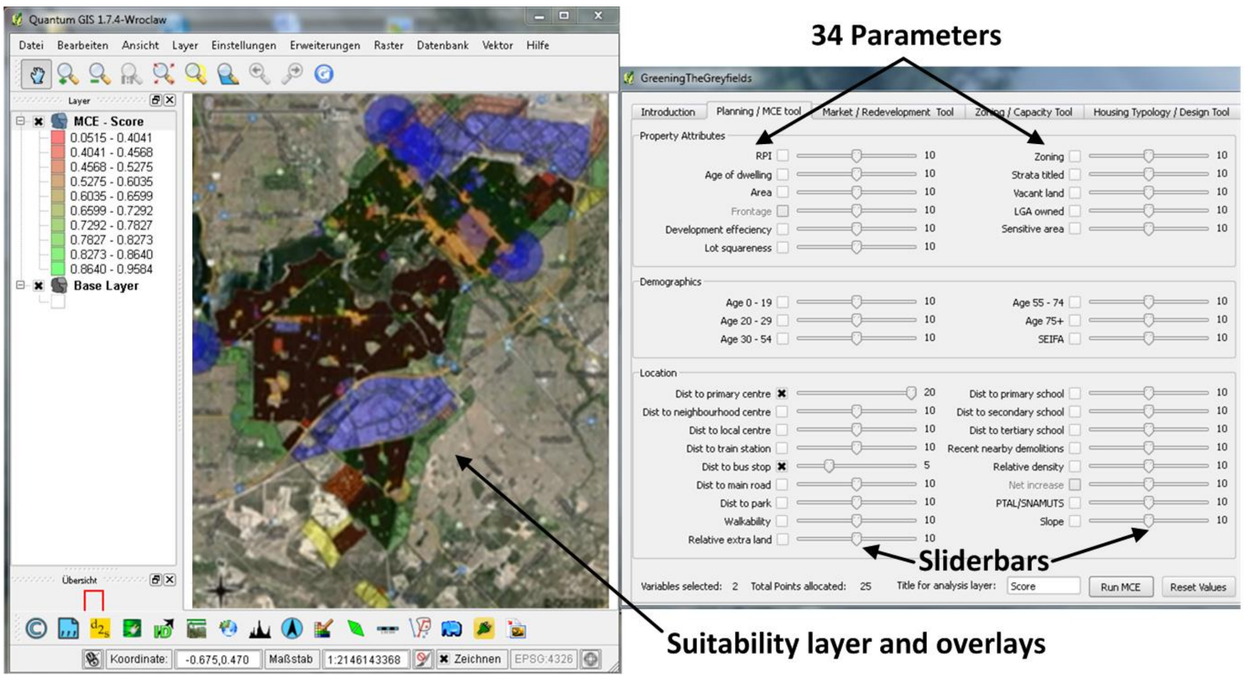

Figure 1. Envision: the 34 parameters provided by the tool and slider bars for selecting their weights (right), and the suitability layer and overlays in QuantumGIS (left).

Envision is a software tool that has been implemented as a plugin in QuantumGIS (GIS software). The objective of the design was to develop a tool that supports sustainable redevelopment of precincts in Australia [Newton & Glackin 2013]. LSA is based on 34 predefined parameters, related to property, demographics and location. The user selects the parameters that he/she wants to consider and assigns to each parameter a weight in the range of 0-20 through *slider bars* (see Figure 1). As an option, through a tick box, the user can choose to display overlays and aerial imageries that provide current zoning information and basemaps. The output, i.e. the suitability layer, is displayed in QuantumGIS. Spatial analysis functionality available in QuantumGIS can be used to further analyse this suitability layer.

The *Online What if?* [Pettit et al., 2015] is an open source, web-based PSS, which actually is the modified version of the well-known standalone PSS What if? [Klosterman 1999]. To perform LSA, the user first has to define

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a series of settings, e.g. developable and convertible land. After that, the user selects the parameters that he/she wants to consider and assigns to each parameter a weight in the range of 0-100 through *spin boxes* (see Figure 2). As a result, land use parcels are classified as *not developable*, *not convertible*, *not suitable*, or *suitable*. In the case of suitable parcels, in the resulting suitability layer a value on a 5-point scale from *low* to *high* is indicated. For exploring the suitability layer, basic navigation functions such as panning and zooming are provided.

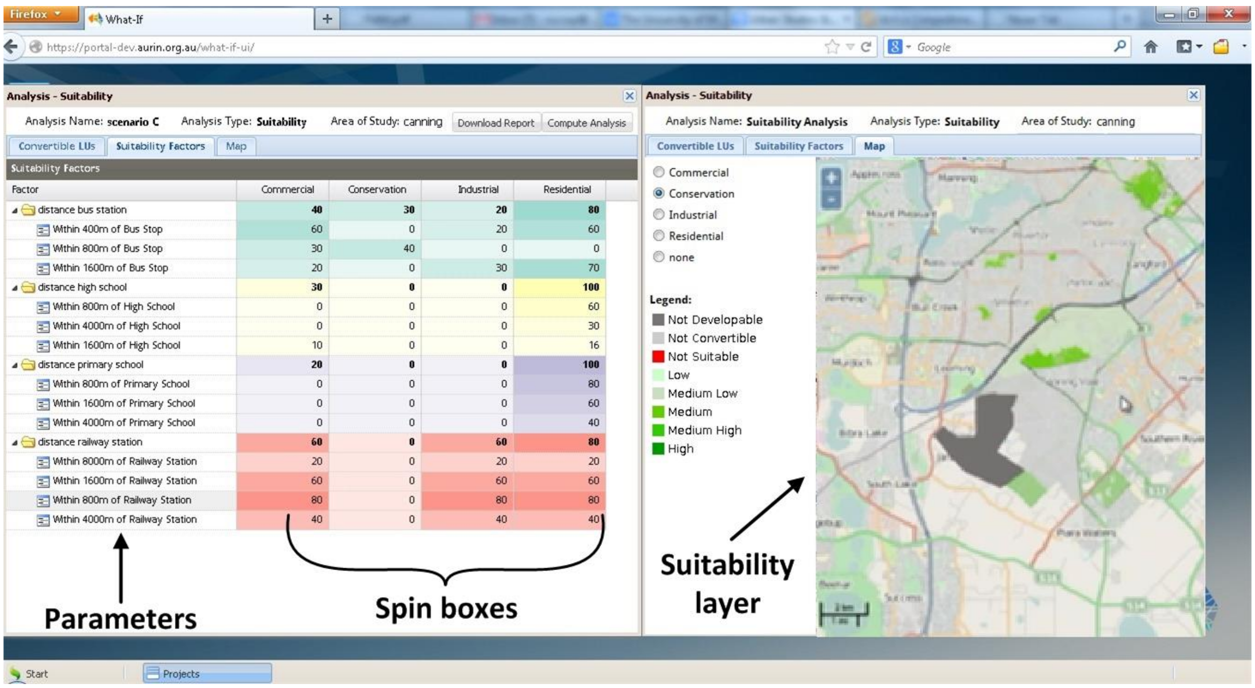

Figure 2. Online What if?: parameters and spin boxes to assign the weights (left) and the suitability layer (right).

CommunityViz (http://placeways.com/communityviz) is a commercial desktop extension of the ESRI ArcGIS (GIS software). The user performing LSA has first to define suitability criteria for each parameter of interest. After that, the user assigns to each parameter a weight in the range of 0-10 through *slider bars*. The suitability layer obtained as output can be analysed through spatial analysis functionality available in ArcGIS (see Figure 3). Hyperlinks in the user interface represent help documentation that explains provided functions.

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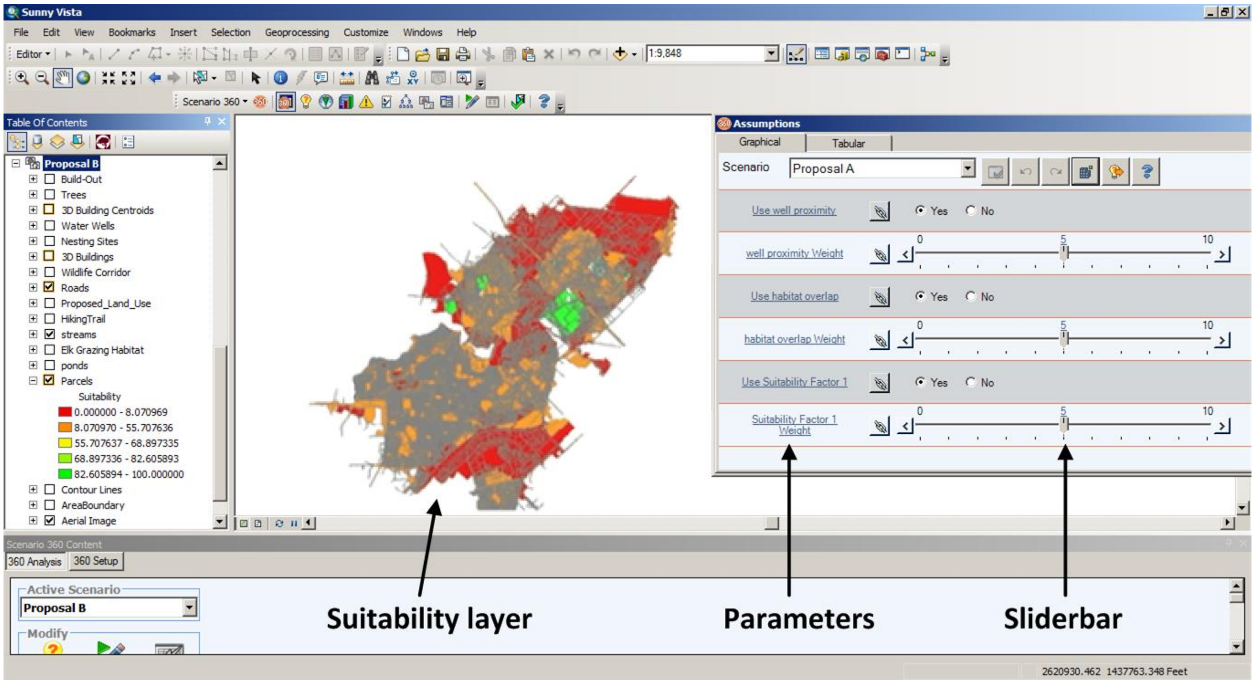

Figure 3. CommunityViz: parameters, slider bars and the suitability layer in ArcGIS.

4. The Evaluation Study

The study was performed according to the evaluation framework outlined in Russo et al. [2015]. The first activity of the framework requires to determine the evaluation goals. Our study had two main goals: 1) to identify usability problems participants encountered, and 2) to better understand participants' mental models and expectations when interacting with the PSS, in order to provide PSS developers with indications for designing more satisfying PSS.

A set of questions, underpinning the goals, were also defined, as indicated by the second activity of the PSS evaluation framework, i.e. explore the questions. Specifically, regarding the first goal, some of the identified questions were: Is the user interface easy to navigate? Is the terminology confusing? Is the feedback provided to users clear? In relation to the second goal some of the questions were: Which steps are difficult to understand? What are characteristics that PSS should provide to be accepted by practitioners? Which PSS provides efficient functionality? The complete set of questions are reported in Appendix 1.

The third activity was the choice of the evaluation method. A user test with the thinking-aloud protocol was chosen because it offers a window over the users' mental models, allowing evaluators to detect possible misconceptions about the system and the interface elements that cause them. In addition, it provides useful results even with a small number of users [Nielsen 1993]. It is worth remarking that our study did not aim at the evaluation

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of all usability attributes. In such a case, a larger set of metrics should be considered and more data should be collected, also involving a greater number of participants. As specified by the two goals, we were primarily addressing user satisfaction and aiming at understanding users' expectations. In the following sub-sections, details on the user test, performed according to the fourth, the fifth, and the sixth activity of the evaluation framework, are reported.

4.1 Participants

A total of 21 people from the planning community in the State of Victoria in Australia were contacted, primarily via email, and informed on the purpose of the user test. Of them, 6 people agreed to participate. The participants were professional land use planners (age between 25 and 45 years old, 3 female). One was from a local government and 5 were from the private sector. The local government planner worked for a city council in the south-west of Melbourne, while the other 5 planners were employed in three different consultancy and service companies located in Melbourne. Two of the 5 planners operating in the private sector worked for a consultancy specialised in strategic planning and urban design. The other three worked in globally operating enterprises that provide services in planning, architecture, environment, engineering and other domains. Participants had to meet the following criteria: i) be strategic planners, ii) be familiar with basic GIS functionality such as layer (de)activation, map zooming and panning and iii) have not used the three PSS before.

4.2 Design and Procedure

The evaluation study of the three PSS was carried out following a within-subject design. This means that each participant used all three PSS in sequence but in a different order by considering all permutations of the three PSS (see Table 1), in order to avoid potential learning effects [Graziano & Raulin 2012]. A technical problem prevented Participant 5 from beginning with CommunityViz. Thus, he used the PSS in the order shown in Table 1.

No time restriction was imposed on the duration of the test, which was instead determined by participants' task completion with all three PSS. Ethics clearance was provided by the University of Melbourne: each participant read and signed a consent form.

Table 1. The counterbalanced order in which the participants (P1,…P6) used CommunityViz (CViz), Envision (Env) and Online What if? (OWI).

Participant	1st PSS	2nd PSS	3rd PSS
P1	Env	CViz	OWI
P2	CViz	OWI	Env
P3	OWI	Env	CViz
P4	Env	OWI	CViz
P5	Env	CViz	OWI
P6	OWI	CViz	Env

The evaluation study was carried out in two consecutive days. Three participants per day came to a usability lab at the University of Melbourne. The facilitator firstly informed the participant about the procedure and the task to perform during the test with each PSS. The LSA task was:

Identify an area within the City of Canning (Western Australia) where residential redevelopment might be most suitable based on a set of parameters that you regard as important.

Envision specifically focuses on LSA for precinct redevelopment while CommunityViz and Online What if? support performing generic LSA on a range of planning tasks, including but not limited to redevelopment. The City of Canning is a municipality in the south-east of Western Australia. In the last decades, it has experienced a continuous growth, developing from a district to a city and becoming part of the greater metropolitan area of Western Australia's capital city of Perth. In particular, large population growth motivates the need for residential redevelopment. While Envision and Online What if? already provided a test case on the City of Canning, the facilitator had to prepare a data set of the City of Canning for CommunityViz.

As the participants had never used the three PSS, a short introduction was given to each tool prior to the interaction, providing information required for completing the task that participants could not be aware of. The introduction was longer for CommunityViz and Online What if? than for Envision because the latter does not have a project setup module. According to the thinking-aloud protocol, during the interaction with the PSS, the facilitator intervened to elicit information, to clarify unclear verbal utterances, to provide help if the participants could not continue. As it was expected that some acronyms used in Envision and Online What if? for explaining parameters could be unclear, two lists were provided to the participants that explained the meanings of the acronyms.

After engaging with each PSS, the participants were asked to complete an intermediate questionnaire about their UX which is reported in Appendix 2. At the end, a final questionnaire gathered participants' planning experience, expertise in GIS and educational level (see Appendix 3). Prior to execution of the reported study, a pilot study involving 2 planning students was carried out to check and refine the overall procedure.

4.3 Apparatus

The technical equipment used by the participants in the usability lab included a screen (23 inches widescreen, resolution: 1366 x 768), a keyboard and a mouse. To decrease the level of control and make the participant feel more comfortable, the facilitator followed the session on a laptop next to the participant. During the user test, video, audio and screen recording was conducted. A camera was positioned at the ceiling of the lab (see Figure 4). Later in the study, the recordings helped to analyse user actions during the interaction.

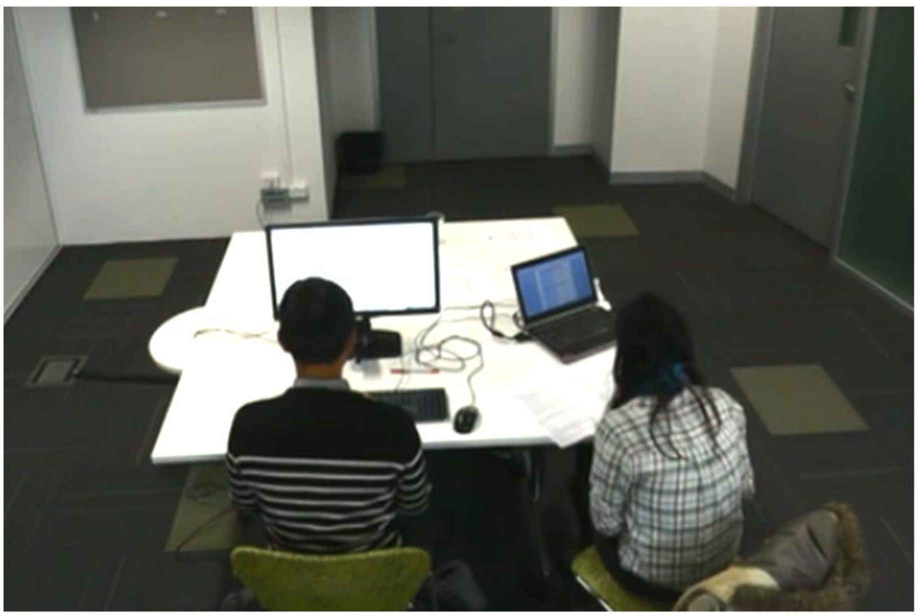

Figure 4. A participant (left) and the facilitator (right) during the test.

4.4 Data collection and analysis techniques

Data collected during the thinking-aloud protocol was triangulated with data from the video recording (including audio), screen recording and questionnaires. The questions were of qualitative nature in order to give participants the opportunity to better describe their experience with the PSS.

The transcriptions of the audio recording data were analysed by the first author of this paper. Participants' actions were coded following a scheme inspired by a list of breakdown indication types proposed by Vermeeren et al. [2002] for detecting usability problems. As it is required in this kind of coding 70% of the results were double-checked for inter-rater reliability by the second author of this paper. The analysts ended up with an agreement of 85% for all reported measures. Discrepancies were solved by discussing different views between the analysts. The audio recording data was also analysed through an open coding approach for gathering information related to the second goal of the study, namely to understand participants' mental models and expectations. For the intermediate questionnaire, each answer was analysed individually and through an open coding approach to reveal both usability problems and information related to the second goal. As such, these results were compared and combined with the ones of the audio data analysis. Double-scoring was conducted on 20% of these data, yielding a value of the inter-rater reliability superior to .85. Also in this case, all differences were solved by discussion.

4.5 Results

All participants were able to complete the task, i.e. identify an area in the output where residential redevelopment might be most suitable based on a set of parameters. However, several problems emerged. In the following, the results are reported according to the two main goals of the usability study.

Goal 1: Usability problems

Usability problems of the PSS were identified by analysing those actions, performed by the user, which revealed difficulties in interacting with the PSS. Specifically, such actions were operationalised as follows: 1) *random actions*, i.e. actions that did not belong to the correct sequence to perform the task or the user randomly clicked on interface objects and moved the mouse on different widgets; 2) *puzzled actions*, i.e. actions that indicated that the user either i) did not know how to perform the task or what action would be needed, or ii) was not sure whether an action was needed or not; 3) *uncomfortable actions*, i.e. actions which the user indicated to be difficult or uncomfortable to execute. Table 2 reports the total number of these actions, performed by the users while interacting with the three PSS.

Table 2. Actions highlighting usability problems in CommunityViz (CViz), Envision (Env) and Online What if? (OWI).

	CViz	Env	OWI
Random actions (*N*)	3	1	14
Puzzled actions (*N*)	4	2	15
Uncomfortable actions (*N*)	2	3	9

Specifically, while interacting with CommunityViz, the participants carried out a total of 3 random actions. Only 1 random action was observed during the interaction with Envision and 14 with Online What if?. CommunityViz prevented participants from performing actions out of the correct sequence and therefore, provided a form of guidance. In fact, a participant said: "*it's all greyed out so far. I can't select anything else here except for that*".

Four puzzled actions were observed during the interaction with CommunityViz, while 2 and 15 puzzled actions were identified with Envision and Online What if?, respectively. "*Should I take it out?"* or *"How do you actually run it?"* are examples of utterances highlighting puzzled actions. The terminology used in Online What if? and Envision user interface appeared to be a cause of puzzled actions. Two users said respectively: "*I do not know what to do, the terms are confusing*" and "*development efficiency … perhaps that's a Western Australia thing, it's not something we usually have in Victoria*". In many situations in which puzzled actions occurred, the intervention of the facilitator was required either because the participants asked for it or to stop actions by the user that prevented task completion (e.g. cancel input data).

Finally, 9 uncomfortable actions were identified during participants' interaction with Online What if?. A smaller number of such actions were recognised for the other two PSS, i.e. 2 for CommunityViz and 3 for Envision. *"It is difficult to use this [spin box]"* or *"inputting all the info is a bit tedious"* are examples of utterances highlighting uncomfortable actions.

Further usability problems emerged by analysing participants' negative behaviour. Participants' utterances revealing negative behaviour were classified into two categories: 1) *uncertain behaviour*, i.e. the user showed uncertainty about an aspect or a content of the interface or he/she did not understand an action effect; 2) *dissatisfied behaviour*, i.e. the user indicated disliking something or the effect of an action was unsatisfactory or frustrating. Frequency and percentage of the participants' negative behaviours are reported in Table 3. Envision appeared the less problematic PSS, followed by CommunityViz and Online What if?. Indeed, participants indicated to be uncertain 18 times with Envision, 28 and 39 times with CommunityViz and Online What if?, respectively. Examples of utterances showing uncertainty were: *"I would just assume that green is good and red is bad"* and *"I don't really understand these widgets"*. For all three PSS, the participants showed uncertainty on how to interpret the weighting scales and suitability scores in the case of CommunityViz and Envision (i.e. how does a weighting of 13 differs from 16 or a suitability score of 2.5 from 2.7) and on what basis suitability classes of the Online What if? are established. Examples of participants' utterances in relation to this are: *"I don't know what the different weightings mean"*, "*the numbers do not mean too much to me at this point*" and "*I don't know what the low, medium, high suitability means in the legend*".

Table 3. Frequency and percentage of the participants' negative behaviours during the interaction with the PSS.

	CViz		Env		OWI	
	f	%	*f*	%	*f*	%
Uncertain	28	76%	18	78%	39	71%
Dissatisfied	9	24%	5	22%	16	29%
Total	37	100%	23	100%	55	100%

Only 5 utterances were related to dissatisfaction during the interaction with Envision. The same behaviour was recognised 9 and 16 times when interacting with CommunityViz and Online What if?, respectively. Examples of utterances indicating dissatisfaction were: *"I do not want to continue with this activity" and "I don't like the scale"*.

Goal 2: Users' mental models and expectations

Users' mental models and expectations were identified through participants' indications for design improvements which were also made unconsciously in order to make the PSS more compliant with their expectations. A total of 33 indications were collected. Only one of these was related to CommunityViz: "*You need to have the assumptions outlined*". Twelve re-design indications addressed Envision and 20 Online What if?.

At different stages of the interaction with Online What if?, the participants emphasised the request for a map display (Online What if? provides a map only at the end for displaying the suitability layer). An example of an utterance was "*I want a map*".

Participants also indicated the importance to have contextual information pertaining to the study area by stating: "*I would start with the big picture*", "*we first look at the existing conditions*" and "*it is good to have them [the overlays] because you can see the context*".

Participants' willingness to zoom-in on items of interest and filter out uninteresting items was revealed by utterances such as *"we've got far too much information in there to start stripping it out"* and *"it would be good to exclude existing residential so that's a bit more targeted and you could just focus on new areas"*.

Participants appreciated the spatial analysis functionality provided in the GIS-based PSS, i.e. CommunityViz and Envision, which was illustrated through utterances such as: *"It provides all the tools and customisation options I would expect"*.

A participant showed hesitance with data input in two ways:

i. the participant stated that she wanted to make sure that she was entering a valid input in Online What if? based on an existing planning policy that was not available during the user test: "*I probably would not do that, unless I knew there was a written report…because that would be a political suicide*".

ii. the participant suggested another data type than required by the three PSS for assigning the weights by uttering *"quite often we just go low, medium and high important"*.

A participant uttered the need for outputs in different formats such as PDF or spreadsheet and their export for being able to use them in planning reports and presentations. This is provided by CommunityViz and Online What if? but not by Envision.

Some participants used the help documentation in CommunityViz accessible through hyperlinks but complained about the difficulties in understanding the suggestions. The help button was not selected in Envision, while Online What if? does not provide any.

5. Discussion and design indications

In the user test, it soon emerged that tedious interaction mechanisms and lack of guidance make PSS cumbersome to use and are likely to overshadow functionality and capabilities of PSS. An example of a tedious interaction mechanism was the *spin boxes* used in Online What if? for selecting a weight to be assigned to a parameter; participants found them more difficult to use and inefficient than the *slider bars* provided by both CommunityViz and Envision. About guidance during the use of the PSS, participants often looked for a help function, which was not available in Online What if? and was not working in Envision. The online help of CommunityViz was not well structured for being easily readable on the web: too much text, which cannot be read quickly, little provision of useful examples. Because PSS are quite complex systems, it is recommended to provide help documentation, possibly fully integrated, which includes examples and short demos of system use. In addition, PSS should offer more interaction mechanisms to guide planners. For example, 'back' and 'next' buttons to move back and forward or greying out items to make them not selectable facilitate user interaction.

Participants remarked that a map display, in which the case study area should be clearly visible, should be provided during the whole workflow process. From discussions with other planners [Russo et al. 2017], we can add that they expect that maps should be dynamically linked to other views such as graphs, charts and tables, in order to provide multiple visualisations of data. The value of using visualisation and feedback techniques, such as *moving over* or *brushing*, in order to support planners in their work, is also reported in [Widjaja et al. 2014]. Providing effective visualisations is not easy. A great body of research about information visualisation is currently available (see e.g. Ward et al. 2015). Several strategies for supporting users to understand big amount of data have been proposed. An example is the visual-information-seeking mantra, summarized as *Overview, Zoom and filter, Details on demand* [Shneiderman 1996]. It requires that a good visualisation should first provide an overview of the set of data, in order to help users making their mental model about the overall data; then, it should provide zoom and filter mechanisms to let users concentrate on a portion of data of interest; finally, it should give details of specific data, when requested by users. PSS developers have to take into account available knowledge about information visualisation methods and tools.

One of the main complaints by participants is that the PSS did not provide enough feedback on how the resulting outputs were generated. In other words, they remarked lack of transparency, and even distrust, in the operations performed by the PSS as already highlighted in previous literature [Brömmelstroet & Schrijnen 2010; Goodspeed 2013; Pelzer 2016] and our study reported in [Russo et al. 2017]. This was primarily related to the weighting scales and suitability scores of CommunityViz and Envision and to the suitability classes of the Online What if?. For example, for the former two PSS, it was not clear how a weighting of 13 differs from 16 or a suitability score of 2.5 differs from 2.7, while for Online What if? Participants did not understand on what basis suitability classes were defined. Thus, explanations about assumptions made by the system, calculation, meaning and interpretation of the outputs should be provided.

PSS can also be *GIS-based*, like CommunityViz and the version of Envision evaluated in this research. GIS typically provides a rich set of geoprocessing and spatial analysis functionality and customisation potential of cartographic elements (e.g. of the colours and classes in a legend considered). The PSS test confirmed that planners' expectation of GIS functionalities differ, also depending on their familiarity with GIS and whether they use and have access to GIS at their workplace. It is worth remarking that most planners are familiar with GIS, thus they expect to have GIS functionality in PSS. Online What if? is the only one of the three tested PSS which is *web-based*. Thus, it is easily accessible and does not require the installation of any software. However, we note a web-based version of Envision is currently being developed.

Planners generally use results of analyses in planning reports and presentations. Thus, PSS should provide outputs in other formats, e.g. PDF or CSV. Users also complained about the slow speed of some PSS operations. It is highly recommended to use appropriate methods and optimisation techniques in order to speed up PSS operations.

Table 4. Characteristics and strengths of PSS for LSA appreciated by the participants.

PSS characteristic	Observed in PSS	Strength
Predefined set of parameters and overlays	Env	- Fewer actions to perform - Easy to learn and use and time saving (efficiency)
Additional functions and settings	CViz, OWI	- Increased adaptability to planning problem - Increased flexibility - Freedom to analyse user defined parameters
GIS-based	CViz, Env	- Geoprocessing functionality (e.g buffering) - Customisation of cartographic elements (e.g. legend) - Data management capabilities (e.g. assignment of metadata)
Web-based	OWI	- Easily accessible on the web, no software installation required

Table 4 shows the characteristics of the three PSS that were most appreciated by the participants either explicitly, because they clearly mentioned them, or implicitly, because they did not generate any problems during the interaction. As we said, we are not interested in comparing the three PSS, but we only want to highlight what planners appreciated and disliked, in order to inform PSS developers about important features of PSS. A *predefined set of parameters and overlays*, as provided in Envision, which is specifically designed for LSA tasks, requires fewer actions by the user in order to perform the required task. This resulted in increased ease of learning of the PSS functionality as well as ease of use and time saving (efficiency). Nevertheless, the participants were only partly happy with the provided set of parameters and overlays. Indeed, it appeared that there is hardly a set of parameters and overlays that is complete and that all planners are satisfied with. Rather, planners choose parameters and overlays based on their work process, their planning problem and context. *Additional functions and settings*, as provided in CommunityViz and Online What if?, especially if they meet planners' requirements, increase the flexibility of the system and allow users to adapt the analysis more closely to the planning problem as occurring in real-world. Thus, developers face a trade-off: to provide specific functionality that limits the actions the user can perform, in order to cause fewer usability problems (as it occurred with Envision), or to provide additional functions and settings (as done by CommunityViz and Online What if?) that allow planners to consider various aspects in the analysis, thus completing planning tasks more comprehensively, which is one of the most important PSS characteristics according to planners.

Additional functions and settings also require more input data that might not be available for the investigation area. In many countries, there is a move towards open government data, including Australia, which is assisting in overcoming some of the data access barriers in order to run such PSS. However, even with the shift towards open data, the needed data may still not be available in the required form or might not have ever been collected so is not available to support desired additional functions and settings. On this basis, the geographical context is an important consideration and PSS developers should be aware that planners' requirements and data availability might differ depending on the regions and countries in which planners work. Thus, functionality might, in turn, be adapted to the geographical area the PSS is used for. Similar to the functionality, also the terminology should be the one of the region and country where the PSS is used. In fact, the participants' confusion about the terminology used by the PSS might emerge from i) developers not knowing well the terms used in planning and ii) differences of planning terminology in various geographical areas.

The above concerns about the users' need of terminology specific for some geographical areas highlights that the slogan "one size fits all" does not apply to PSS, as it happens with many systems in other contexts [Cabitza et al. 2014]. Users of the same interactive system are often diverse, being characterised by specific cultures, goals, tasks and context of activities. Different users may need different interfaces that provide them adequate support. People experience many difficulties when interacting with a system that has been designed without taking into account their cultural background, their reasoning strategies, the way they carry out tasks in daily practices, the languages and notations they are familiar with. They do not want to be constrained by formalisms unfamiliar to their culture. In the evaluation study, it clearly emerged that PSS terminology and functionality did not actually satisfy most participants. Indeed, terminology and task to be performed vary depending on countries and even regions where the PSS are used. For example, due to high urbanisation in city centres, residential density analyses might be more important for planning organisations in city councils than in regional councils. People wish to use software tools that are easily accessible and usable, but which can also be tailored to their needs, tasks and habits. A solution may come from current research on End-User Development (EUD), whose aim is to create systems that support people to tailor software according to their own needs and preferences (see e.g. Costabile et al. 2007; Diaz et al. 2015). Fischer points out that EUD is a *necessity* and not a *luxury* because, beside people being very diverse, systems modelling some particular "world" are never complete [Fischer 2010]. Indeed, new requirements emerge over time because either the world changes or skilled domain professionals change their work practices. Thus, developers should consider methodologies created by EUD specialists and apply them for creating future PSS [Costabile et al. 2007; Cabitza et al. 2014].

Most usability problems found during the PSS test could have easily been avoided if PSS were developed according to the Human-Centred Design (HCD) process, which prescribes to focus on user aspects and to perform usability evaluation of early prototypes of the user interface [ISO 9241, 2010]. In HCD, identification of user requirements is a crucial phase. The focus on users has not only the potential for preventing serious mistakes when designing innovative systems, but it also allows addressing what is actually needed by final users. Moreover, the system is developed through an iterative design-implementation-evaluation cycle, during which system prototypes of increasing complexity are created and evaluated by using one or more of the many evaluation methods developed by the Human Computer Interaction (HCI) research [ISO 9241, 2010]. Designing PSS through a HCD process may appear as a naïve recommendation. Unfortunately, after more than 30 years since HCD has been proposed [Norman & Draper 1986], software practitioners still neglect basic HCD principles and methods as demonstrated by various studies [e.g. Rosenbaum et al. 2000; Vredenburg et al. 2002; Bak et al. 2008], performed even in recent years [Ardito et al. 2014].

6. CONCLUSIONS AND FUTURE WORK

Despite the potential of PSS as tools for supporting planning professionals in making decisions both in the context of operational and strategic planning tasks, their uptake in planning practice is still very low. Though in recent studies there has been some indications that PSS are increasingly being used [Papa et al. 2016]. However, it is important to note that this is occuring in the context of accessibility related tasks across both land use and transport planning and in the context of Europe. The evaluation study reported in this paper involved six planning actors interacting with three PSS. This small sample of participants is enough to identify usability problems in such a user test setting [Nielsen & Landauer 1993]. The study showed PSS usability is still relatively poor and confirms the mismatch between the PSS functionality and what practitioners expect [Vonk 2006; Williamson 2012]. The mismatch was demonstrated in that the planners participating in the user test voiced the desire for other functionality and interaction mechanisms than those provided by the three tested PSS. This mismatch affected all parts of the PSS and their workflow processes, including the help documentation, data visualisation, information gathering, analysis functionality, general capabilities such as efficiency of operations.

From the discussion of the study results, indications emerged for designing PSS that better meet users' needs. A main indication is to closely involve users in the PSS development. The low PSS usability identified in this study suggests that the developers did not satisfactorily investigate and consider planners' requirements during the design process. A comprehensive study investigating design processes adopted by PSS developers should be the object of further work, which would potentially explain the low usability of PSS. Most results of this study are not limited to PSS specifically for LSA but can be transferred to PSS in general. Nonetheless, evaluation studies should be performed on PSS other than those specifically for LSA to gain an actual overview of PSS usability. With these possible next steps of research this article stimulates and encourages further work towards fostering improved usability and widespread adoption of PSS.

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Appendices

A1. Research questions

Goal	Question	Sub-question
Identify usability problems participants encountered	What were the most relevant participants' experiences (positive/negative) during task execution with the PSS? At which point of the test execution did these experiences mainly occur? Which actions/steps caused problems?	Was the user interface easy to navigate? Was the terminology confusing? Was the feedback provided to users clear? Are links and buttons clearly visible? Were appropriate icons provided?
Better understand participants' mental models and expectations when interacting with the PSS, in order to provide PSS developers with indications for designing more satisfying PSS.	To what extent was the PSS functionality satisfactory? Did the provided functionality make sense to the participants? Did the participants understand the outcome? Did the outcome meet participants' expectations?	Did the participant know what he/she was actually doing by changing the weighting? Which PSS functionality allowed the participants to perform the task efficiently? Which PSS functionality was well accepted by the participants?

A2. UX questionnaire

What were your most relevant experiences while engaging with the PSS?	
At which point of the test execution did these experiences mainly occur?	
To what extent are the PSS features and functions satisfactory for identifying land suitable for redevelopment?	

List the 3 most positive aspects	i.
	ii.
	iii.
List the 3 most negative aspects	i.
	ii.
	iii.

A3. Expertise questionnaire

Participants' background and expertise

What is your job function?							
In what sector do you usually work?	Local Gov't		State Gov't		Federal Gov't		
	Private Sector		Other (please specify):				
In which state is your work location situated?	VIC	NSW	SA	TAS	QLD	WA	NT
What was the motivation for participating in this test?	I have been given the task by the management						
	The management stated to require participants and I volunteered						
	We discussed and selected the participant in the group according to workload and appropriateness						
	Other (please specify):						

Experience

How long have you been working in planning practice?					
On a scale of 1-5, with 1 being novice and 5 being expert, …	**1**	**2**	**3**	**4**	**5**
… how would you rate your expertise in planning practice?					
… how would you rate your expertise level on GIS?					
… how would you rate your expertise level on PSS?					

Education

What have you studied? What is your background?	

General

Gender (m/f)	
Do you have any visual impairment? (If yes, please describe the constraints)	