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# Narrowing the Implementation Gap:
## User-Centered Design of New E-Planning Tools

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## ABSTRACT

Developing new digital tools to fit the needs of communicative urban and green area planning requires understanding of the various prospective user groups, the different contexts of use, the planning tasks, and the communicative activities at hand. However, it is not self-evident that user research can be applied in research and innovation projects with limited human and time resources. In this article, a user-centered design (UCD) approach is applied in the development of new collaborative 3D tools for urban and green area planning in a multidisciplinary research team in the GreenTwins project. This research shows how essential it is to select easy-to-learn user research methods, identify the knowledge needs for tool development, and ensure that user insight is transmitted to development. In the GreenTwins project, this was achieved by applying a simple UCD framework (PACT) and engaging the research and development team in the process. Despite the challenges, the results show that the methodology used was beneficial.

## KEYWORDS

3D, Communicative Planning, CPSS, Digital Participation, E-Planning, Green Area Planning, Implementation Gap, PSS, Urban Planning, User Research, User-Centered Design

## INTRODUCTION

The urbanization and densification of cities, along with climate change, have brought the value of green urban infrastructure for ecological, social, and cultural sustainability to the forefront of research. In parallel, the need to develop information systems for green environment and green area planning has been recognized. The role of green information in city information models has lagged behind

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that of the built environment (Münzinger et al., 2022), and there is a lack of tools for co-planning the development and maintenance of green spaces.

Various *planning support systems* (PSSes) have been developed for analytical and collaborative planning purposes, but their implementation in actual planning has been a challenge. The so-called implementation gap between the demands of planning and the supply of tools that support planning tasks was identified years ago (e.g., Te Brömmelstroet & Schrijnen, 2010; Vonk et al., 2005) and remains relevant today. The implementation gap refers to the mismatch between the technology (i.e., digital tools) and the needs and activities of the users. The complexity of planning problems is argued to be a major challenge in developing PSS tools to support planning tasks (Geertman, 2017). This complexity is not only related to planning tasks but also to the broad range of different stakeholders in planning processes and differences between planning organizations. *User-centered design* (UCD), i.e., focusing on end-users' perspectives and increasing dialogue between planners (users) and tool developers, has been proposed as remedies to bridge the implementation gap (Te Brömmelstroet & Schrijnen, 2010) and produce applications that are genuinely useful for planning.

The planning of urban green spaces has its own specific planning questions, such as the continuous change of existing vegetation, the impact of maintenance activities on the environment, and the uncertainties associated with the plans (e.g., how the planned vegetation will succeed in the site and how the environment will affect the vegetation). Additionally, it has been argued that there is a need for the co-creation of the solutions with a wide range of stakeholders, and the importance of engaging citizens and local communities in planning and maintaining green areas has been emphasized (Dos Santos et al., 2021). The communicative planning of urban greening can relate, for example, to questions of preserving green areas in densification projects or enhancing the quality of existing urban areas by adding new plants or greenery.

Recent related research has included novel approaches to the sustainability of cities that suggest, for example, more nature-based solutions and enhancing biodiversity in urban areas (Stroud et al., 2022). Research is also contributing to the need to understand citizens' needs for and experiences of an urban green environment. Recent studies have shown novel methods for analyzing landscape preferences (Schrammeijer et al., 2022) and identifying citizens' ideas and visions to improve green infrastructure (Palliwoda et al., 2022). Public participation (or *geoparticipation*) GIS methods have also been used to obtain the social values of green areas (Rall et al., 2019). Other topics relate, for example, to the health benefits of green environments (Liu et al., 2022) and the perceived well-being effects of nature (Puhakka, 2021).

This article contributes to the existing literature by studying the process of engaging prospective users of a communicative planning support system (CPSS) for urban and green area planning. The novelty of this research is in combining user-centered methodology in a research and innovation project where communicative planning of urban and green areas includes novel 3D PSS tools. This article focuses on a *user-centered process*, in which user insight was gathered and utilized in the early phase of tool development. Another novel aspect of the research is that it is not a single PSS that is being developed but a system consisting of several elements (see Figure 1), whose users include not only planners but also citizens. The practical value of this paper is to help integrate user research into corresponding research and development projects that are limited in terms of human and time resources.

The value of our research also lies in the use of a user-centered approach in two distinctive planning cultures (Helsinki and Tallinn). This research is part of the GreenTwins project (https://www.finestcentre.eu/greentwins), which focuses on a knowledge gap identified in urban digital twins (UDTs): the representation of the environment in UDTs is limited concerning green infrastructure and the natural environment, which are among the most important quality factors of an urban environment. The aim of the GreenTwins project is to develop a layer of green infrastructure in the UDTs of Helsinki (Finland) and Tallinn (Estonia). The GreenTwins project will also produce novel 3D tools for participatory and collaborative urban and green area planning to help cities make more informed and democratic planning decisions.

In this article, we describe how a user-centered approach was applied at the beginning of the GreenTwins project and analyze the usefulness and challenges of the methods applied. At the time of writing this article, the research project is still ongoing, and this article only covers the results of the first year—that is, the early phase of developing the tools. As the research progresses, we intend to publish articles discussing in more detail each of the developed tools and the detailed user needs associated with them. Therefore, this article will focus on the methodology of the user study, ending with the stage where user needs have been identified and translated into user requirements.

In the next section, the GreenTwins tool concepts that constitute a CPSS are presented. After that, the background of this article is presented. In the fourth section, the research problem and questions, as well as the methods that have been used in the action research process, are presented. The fifth section consists of the analytical results of the action research process, and finally, the conclusion assesses how the applied UCD methods helped the multidisciplinary research and development (R&D) team to understand user needs, as well as how the process may narrow the implementation gap.

## GREENTWINS AS A CPSS

A *PSS* is a generic term for digital tools that can assist in planning related tasks in many ways. In addition to computational and analytical tools, the concept includes tools for participation, collaboration, and visualization. Thus, the scope and purpose of the tool can relate to any part of a planning process, at any scale. What characterizes these tools is that they are designed to explore and assess alternative or possible spatial futures or, in other words, facilitate building and assessing future scenarios (Geertman & Stillwell, 2012; Pelzer, 2015).

Recent research has focused on the development of PSSes as analytical tools for data-aided planning decisions in relation to sustainable development issues, such as flood risk assessment (Truu et al., 2021; Webber & Kuller, 2021); climate change risk analysis (Shah & Bhatt, 2021); health impact assessment of plans (Hooper et al., 2021); economic impact assessment of transport solutions (Rittenbruch et al., 2021); and prioritization of nature-based solutions (Sarabi et al., 2022), among others. Another branch of research has emphasized the potential of PSS in fostering more democratic and inclusive planning decisions (Lock et al., 2021; Pelzer, 2015). Pelzer (2015) has argued that instead of being a tool for top-down, rational-comprehensive planning, PSS should facilitate discussion and dialogue among the stakeholders and support socially constructed knowledge creation.

To emphasize the set of tools within PSS that support participatory and collaborative planning activities, Kahila-Tani (2015) uses the term *participatory planning support systems* (PPSSes; e.g., Maptionnaire). These tools support large-scale participation focusing on sourcing diverse knowledge from diverse stakeholder groups (Staffans et al., 2020). In GreenTwins, we would like to emphasize the collaborative aspect of planning, which aims to converge knowledge, build shared understanding, and support either consensus building or agonism by enabling the development and promotion of different planning options by citizens (see, e.g., Bäcklund & Mäntysalo, 2010; Munthe-Kaas, 2015). We therefore propose a new concept: the CPSS (see Figure 1), which differs from PSS and PPSS, as it not only supports data-driven and knowledge-informed planning decisions and public participation but facilitates communication and fosters collaboration between actors involved in planning. The concept of an ecosystem is better suited to describe the whole (CPSS), which includes not only the digital tools but also the processes and physical spaces in which the tools are used. Furthermore, the CPSS is a set of many different small tools, rather than one large comprehensive system. In the GreenTwins project, a CPSS is used in multi-stakeholder contexts both in online and offline settings and supports both public and private sector planning, as well as citizens' self-organized planning activities. It advances communication in urban planning processes (communication management), enables the co-creation of urban developments (content management), and supports the management of complex urban processes (process management).

While PSSes aim to support certain planning tasks (e.g., Pelzer, 2015) and PPSSes to enable public participation (Kahila-Tani, 2015), the GreenTwins CPSS aims to support both interdisciplinary collaboration and public participation in the planning process. Thus, the concept of the GreenTwins CPSS is, on the one hand, more specific and, on the other hand, broader than PSS and PPSS. We conceptualize the GreenTwins CPSS as a step toward the development suggested by Geertman (2017), where planning support systems are narrower in purpose and are dedicated to specific planning questions or tasks. Furthermore, these systems transcend the boundaries of technological systems and turn into a research-driven framework for the transition toward smarter urban planning. Figure 1 illustrates the elements of CPSS and their relation to planning practice. The elements brought by GreenTwins to the CPSS are as follows.

### Digital Tools

Virtual Green Planner (VGP) and Urban Tempo (UT). VGP is an application for co-planning urban and green areas built in the Unity game engine. The aim of VGP is to provide an easily usable open-source planning and analysis tool for collaborative planning and active citizens' self-organized plan-making. UT is a virtual reality tool for simulating and visualizing the temporal and seasonal change of urban greenery.

### Urban Digital Twin

The digital plant library adds green information to the UDT. It includes dynamic 3D models of plants to be used in both VGP and UT applications. One of the intentions behind developing the digital plant library is to enable projections of vegetation growth and seasonal change in urban areas. Vegetation growth and seasonal change projections allow users to observe how the visual appearance and ecosystem services of the planned urban green spaces would most likely change over time.

### Physical Space

AvaLinn (Open City, est.) Smart City Planning Hub in the city center of Tallinn is a physical space equipped with state-of-the-art visualization technology for facilitating digitally aided participation and collaboration in planning. This physical space makes it possible to bring together various stakeholders—without concern for their level of digital literacy—into planning discussions and decision-making. Digital tools, in turn, are seen merely as means for building a common understanding of future change in the built environment. The conceptual ideas of these GreenTwins tools already

**Figure 1. GreenTwins tools constitute a communicative planning support system (CPSS)**

existed at the beginning of the project. Indeed, the project received funding based on a competition proposal for further developing and piloting these tools. GreenTwins is one of the projects in the FinEst Piloting Programme (https://www.finestcentre.eu/pilotingprogrammes).

## BACKGROUND

### Implementation Gap in PSS Development

While PSS has different definitions in the research literature, it may refer to any information system supporting activities or processes in land use planning (Te Brömmelstroet, 2010). In the early years of PSS development, the focus was on the technology and the system itself. Despite the various possibilities to use these systems to support planning tasks, they did not become established in planning practice (e.g., Geertman, 2017; Pelzer, 2015). Recently, the focus has shifted from technological development toward the usefulness of the tools (Pelzer, 2015; Te Brömmelstroet & Schrijnen, 2010), and there are several examples of research on UCD of PSS tools (Pelzer, 2015). These case studies include testing different PSS tools with users in various workshop settings in real-life planning situations (Arciniegas et al., 2013; Eikelboom & Janssen, 2013; Jankowski & Nyerges, 2001; Nyerges et al., 2006) and collecting feedback with questionnaires (e.g., Te Brömmelstroet & Schrijnen, 2010). In these examples, users are involved in tool development at the testing phase, meaning that the actual tool is already built.

Previous research has provided a wealth of information on the factors associated with the implementation gap of PSS tools (Geertman, 2017). Vonk and Geertman (2008) classify these factors into three categories: insufficient instrument quality, insufficient diffusion to and in planning practice, and insufficient acceptance by intended users. The poor quality of the PSS tools results from their misfit with planning tasks and politicians' demands, as well as the dichotomy between complex problems and the need for the simplicity of the tools. The diffusion of the tools toward planning practice would require better communication among the developers, users, and experts of the PSS. Apart from that, Vonk and Geertman point out that the lack of strategic decisions to use PSS tools hinders the adoption of the tools in practice. Organizational issues also relate to the lack of cooperation between GIS specialists and planners, as well as discouraging designers from using and experimenting with new tools on their own initiative. New tools are sometimes also considered a risk. A third factor they point out is user acceptance, which is mainly related to the usefulness and usability of PSS, but also to the lack of awareness and experience of the tools among users and to lack of support from the organization.

In the field of human–computer interaction, the usefulness of digital tools is described as a combination of usability and utility. While utility refers to the fit between the functionality of the tools and the users' tasks, usability means the extent to which the user performs the task and achieves the desired result efficiently and effectively (Nielsen, 1993). In the context of PSS, the usefulness is found to be largely dependent on the utility, which can also be described as *task–technology fit* (Pelzer, 2015). Apart from these, there is a large extent of usefulness factors other than the characteristics of the tool—for example, contextual aspects such as political decisions and issues related to the planning process as well the prevailing planning culture (Jiang et al., 2020). Hence, when developing digital tools for urban planning, it is essential to know and understand for whom and for what kind of planning tasks the tools are being developed and in what kind of planning context they will be used.

Lack of dialogue between the tool developers and potential users may be one of the major obstacles in achieving useful solutions (Te Brömmelstroet & Schrijnen, 2010), but focusing on the user perspective does not completely solve the problem. The challenges are not only due to poor user understanding but also to a failure to learn from and improve on the challenges in using the tools (Vonk & Geertman, 2008). This requires an iterative development process as part of a holistic user-centered design that is in close connection with planning practice (e.g., Kahila-Tani, 2015; Vonk &

Geertman, 2008). It is also advised to develop and evaluate PSS tools incrementally, in smaller parts, to deal with complexity and uncertainty (Vonk & Geertman, 2008).

Testing ready-made solutions with users can reveal usability problems, but at this stage of development, it is usually too late to make changes to the overall concept of the tool. Iterative processes that enable dialogue between the stakeholders and PSS developers throughout the whole development process have been introduced to overcome this challenge (Te Brömmelstroet & Schrijnen, 2010). Engaging users in the development of digital tools already in the design phase gives them an opportunity to have an impact on the overall concept and features of the system, which may lead to enhanced usefulness. Specifically, co-designing the functionalities and requirements (Rittenbruch et al., 2021) or the model building (Franken-Champlin, 2019) for a PSS together with the users can help to develop a system that meets the needs of different end user groups.

## Research Context: Expanded Urban Planning

The tools developed in the GreenTwins project are based on an in-depth collaborative and participatory planning philosophy. More specifically, we apply the concept of expanded urban planning (EP) developed by Aija Staffans and Liisa Horelli (2014) and Sirkku Wallin (2019) in Finland. Participatory and collaborative practices in urban planning stem from the theoretical approaches of collaboration and participation that reflect on the communicative turn of planning (e.g., Forester, 1999; Healey, 2006; Innes & Booher, 2018). EP approaches the complexity of planning by extending the dimensions of planning both horizontally (overcoming administrative boundaries and integrating urban planning with community development) and vertically (by bringing together different phases of planning processes, implementation of plans, and evaluation of the outcomes).

This approach also takes a stand for human-centered smart city development instead of a top-down technocratic path by emphasizing the role of local people and their self-organized activities in urban settings. In this context, citizens are co-creators of local knowledge, to be utilized in urban planning to create smart communities and livable urban environments (Staffans & Horelli, 2014; Wallin, 2019). Hence, involving local actors in the planning process and valuing their perspectives and the information they provide in urban planning are essential objectives guiding the tool development in the GreenTwins project.

In GreenTwins, the focus is on both urban and green area planning. In this article, green area planning is used for different levels of planning associated with green infrastructure in cities, as it is a common term in Nordic countries. In other counties and contexts, different terms are used (e.g., green space planning, landscape planning, urban green infrastructure planning); the scope of the planning also differs based on the context. In Helsinki and Tallinn, it is part of the institutionalized planning, connected to different levels of municipal planning (e.g., zoning green areas in local master plans, assigning areas for parks and greeneries in detailed local plans). Additionally, specific green area plans are drawn up (e.g., green area strategies, park plans, maintenance plans), and green elements are also designed in street plans. In addition to administrative planning, the green environment in cities is influenced by the actions of active citizens (e.g., urban gardening and place-making). According to the EP framework, GreenTwins also includes these activities, for example, by providing a tool for self-organizing plan-making (i.e., the Virtual Green Planner).

## User-Centered Approach

The gap between the developers and users of the system is well-known in the field of usability and UCD (e.g., Benyon, 2020; Benyon et al., 2005; Nielsen, 1993). Jacob Nielsen (2008), one of the pioneers of usability studies, has argued that the designers of digital tools are usually too advanced in IT skills and lack knowledge of the application domain to be representative of the target audience. Many of the researchers on the GreenTwins project are experts in the field of planning, but some also have special IT skills (i.e., programming and 3D modeling), so we decided to apply UCD methods to help researchers and developers better understand the needs of the wide variety of prospective users.

Understanding the users requires knowing their activities and goals, as well as the physical and social contexts in which the tools are used. Technology can provide opportunities to improve users' activities in a certain context. The PACT model is a framework that aims to find a balance among these different elements of UCD: people, activities, contexts, and technology (PACT; Benyon, 2020; Benyon et al., 2005). In this model, people are the direct and indirect users of the tool or system being developed, and their physical and physiological characteristics (e.g., mental models) should be understood. By activities, Benyon et al. (ibid.) mean the purpose for which users will use the tool or system, as well as the goals they are trying to achieve. Contexts refer to the physical, social, organizational, and cultural settings where the activities are carried out, and technology means providing potentials and constraints to improve the activities in the specific context. The PACT framework was applied to help GreenTwins' multidisciplinary research team to design and conduct a user research process.

In PSS development, user interaction in workshops and collecting user information with questionnaires have been widely utilized to involve users in the testing of the applications (Arciniegas et al., 2013; Eikelboom & Janssen, 2013; Jankowski & Nyerges, 2001; Nyerges et al., 2006; Te Brömmelstroet, 2010). Additionally, direct interaction between end-users and tool developers has been identified as helping developers to understand users' perspectives (Papa et al., 2017; Te Brömmelstroet & Bertolini, 2008). During 2020 and 2021, the COVID-19 pandemic challenged user-centered activities, especially in the planning, preparing, and executing phases (Shah & Jain, 2021). This has also had an impact on the GreenTwins user research methods, which have had to be carried out mainly online. The user-centered process and methods are described in detail in the section on the action research process.

## RESEARCH QUESTIONS, METHODOLOGY, AND DATA

In the GreenTwins project, user-centered methods were applied in a situation in which novel 3D tools (a digital plant library and visualization and co-planning tools) were developed in a short and fast-paced research and development project. Another specific feature of the situation is that there was only one researcher in the research team with expertise in UCD methods. The implementation of user research, therefore, required the application of agile and easily learnable and deployable methods. The objective behind this problem was to narrow the implementation gap and facilitate the uptake of the tools in planning organizations. The main research question was: What kind of a user-centered approach would help a multidisciplinary research team to understand the users of CPSS and their needs?

This research question included two detailed sub-questions:

**RQ 1.1:** How can the established UCD methods be applied to the development of CPSS for urban and green area planning?
**RQ 1.2:** How useful are the applied UCD methods for the multidisciplinary R&D team?

RQ 1.1 is answered by analyzing the collaborative design of the UCD process, identifying knowledge needs, and implementing user research activities. The usefulness of the user research for the CPSS development (RQ 1.2) is examined by asking how well the chosen methods met the knowledge needs, what the role of users in the process was, and how the process was perceived by the research team.

The user research was carried out with the action research approach, working in close collaboration with different stakeholders, both experts in planning the field and citizens. There are many approaches to action research, but, in general, it can be considered as producing change together with the stakeholders (Reason & Bradbury, 2008). The link between action research and practice is strong, and the role of the researcher is to act as a kind of change agent. In this case, the researchers acted as the main developers of the new digital tools and carried out the UCD activities in the project.

In particular, the cooperation in our action research was closely tied to the urban planning organization of the City of Tallinn. Six representatives of the city were part of the research team: Three of them participated in the city Hub development, two in the co-planning application, and one in the plant library. Thus, the impact of the City of Tallinn has been stronger for the tool development than that of Helsinki, representatives from which participated in the project as representative end-users (see the sub-section titled Conducting User Research).

User research is an ongoing and iterative process. In this article, the first part of the action research process, carried out during May–December 2021, is described and subjected to reflection. As is typical of action research, a variety of methods was applied: workshops, online events and meetings, questionnaires, and online discussions. The research process consisted of four phases (see Figure 2): designing the user research, conducting the user research, analyzing user data, and evaluating the user research process. The activities carried out in these phases are described in the following sections.

## Designing the User Research

The first part of the study concerned the design of the user research process. The aim was to define the primary user groups of the new tools, identify their knowledge needs, and select the methods for the user research together with the GreenTwins researchers. Work was organized with online co-working sessions in Microsoft Teams using the visual collaboration tool Miro. A series of five co-working sessions were organized in March–May 2021, attended by between four and nine GreenTwins researchers. The PACT framework (Benyon, 2020; Benyon et al., 2005) was applied to reach a balance between the different aspects of the UCD. Stakeholder mapping (see Figure 4) was done to understand the broad spectrum of different end-user groups. Urban planners, active citizens, and real estate developers were selected as the primary user groups targeted by the user research. The methods and participants are described in the next section.

## Conducting the User Research

By the end of 2021, six stakeholder workshops and eight interviews were organized to collect user data for the development of the GreenTwins tools (see Table 1). Five of the workshops were

**Figure 2. Research process and outputs**

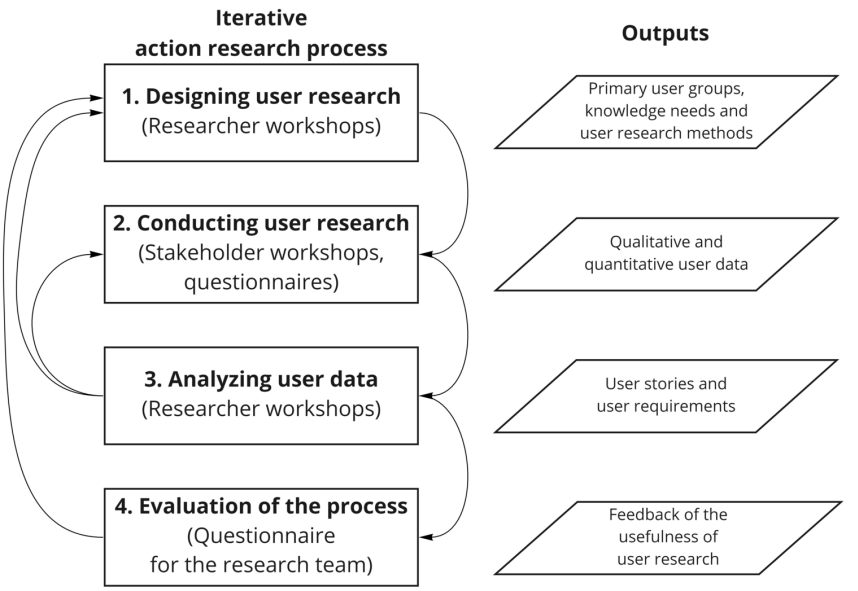


**Table 1. User research activities May–December 2021**

| User research methods (timing) | Target group | Interaction tools | Number of participants | Role of users |
|---|---|---|---|---|
| Online workshops (2) and questionnaire for all GreenTwins tools (May–June 2021) | Urban planners and other experts in the planning field (Helsinki and Tallinn) | Zoom events, online polls with Sli.do, Webropol questionnaire | Two workshop sessions (FIN/EST), 60 participants in total, 19 respondents in questionnaires | informant, dialogue partner |
| Online events (3) and questionnaire for VGP (Oct. 2021) | Active citizens and city planning activists (Helsinki and Tallinn) | Zoom and Facebook live event, online polls with Sli.do, Webropol questionnaire | 3 events (EST/FIN/ ENG), 70 participants in total, 11 respondents in questionnaire | informant, dialogue partner |
| Interviews for the city Hub and VGP (Nov.–Dec. 2021) | Real-estate developers, architecture & planning office (Helsinki and Tallinn) | Zoom online meeting | 8 interviewees | informant |
| Workshop for Tallinn city Hub (Dec. 2021) | urban planners and other users of the Hub (Tallinn) | Face-to-face workshop | 12 participants | co-creator |

Note: VGP, Virtual Green Planner; FIN, Finnish; EST, Estonian; ENG, English.

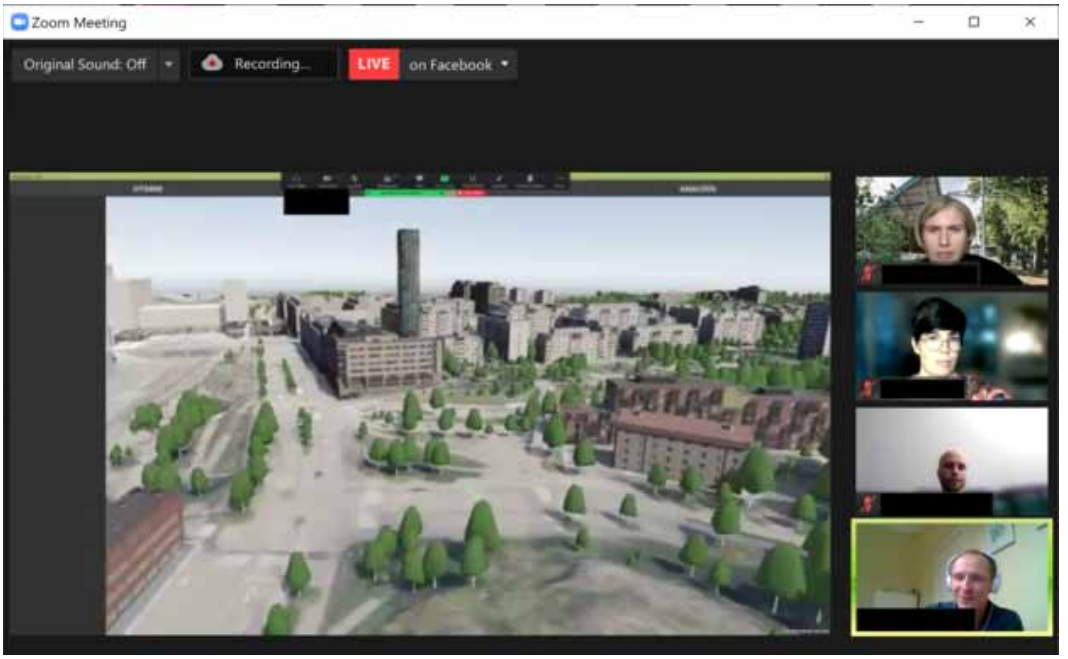
organized online, mainly due to assembly restrictions caused by the COVID-19 pandemic. The first two workshops were organized in May and June 2021 for Finnish (Helsinki) and Estonian (Tallinn) urban planners and other experts working in planning-related fields. The topic was "New tools for smart and collaborative planning of the urban environment," and all the GreenTwins tools (digital plant library, co-planning application VGP, simulation application Urban Tempo, and the Tallinn city Hub) were discussed. The workshops were arranged on the Zoom platform using focus group discussion as a primary research method. Feedback was also collected with online polls via the Sli.do tool during the workshops. In addition, a detailed questionnaire was developed and shared with the workshop participants.

Three online events for citizens in different languages (Finnish, Estonian, and English) were organized in October 2021. A total of 70 people attended the events, either via Zoom (see Figure 3) or Facebook Live. The event showcased and demoed VGP, as well as gathered feedback from participants on the concept of the application. Feedback could be given by discussion during the event, by posting a chat on Zoom or Facebook, by responding to the polls (via Sli.do) during the event, and by answering a questionnaire. In each of the events, there was one invited city planning activist giving a commentary speech in relation to their activism and using digital tools for participation. Additionally, a city planning representative (from Helsinki or Tallinn) was also invited to stimulate the debate about participatory planning.

Two different questionnaires were developed to collect user data in parallel with the stakeholder workshops and events. The first questionnaire included questions related to all GreenTwins tools and targeted urban planners and other experts in related fields. The second questionnaire collected feedback about the concept of VGP and targeted citizens who participated in the online events where VGP was presented. The number of responses remained low for both questionnaires, so there are limitations in using the quantitative data. It is evident that the questionnaire data can only be used to complement the results from the focus group discussions in the online workshops.

In December 2021, a live workshop in the Estonian language was held for urban planners and other strategic experts working in the city of Tallinn. The event concentrated on co-designing the city

**Figure 3. Screenshot from the Estonian online event on October 26, 2021; a demonstration of VGP**




Hub general concept consisting of its strategic purpose, image, and working culture. Based on these collectively designed conceptual categories, the subsequent task was to co-create a spatial layout for the Hub space that would support the conceptual categories and the practical needs of city planners and other city experts that would start to use the Hub.

Additionally, eight semi-structured interviews were conducted with the representatives of Estonian (five interviews) and Finnish (two interviews) development companies and one Finnish architecture office. The informants held key positions in the companies (CEO, COO, development manager, and communication manager) and were approached through personal communication via email and phone. The length of the interviews was approximately 40 min, and the interviews took place on the Zoom platform. During the interviews, researchers introduced the concepts of the city Hub and VGP and asked informants for their opinions about these tools. Additionally, researchers discussed the business and participation models of their respective companies with informants.

## Analyzing User Data

The user data collected in the workshops and with questionnaires were analyzed collaboratively by researchers in online meetings. For this, a total of seven researcher workshops were arranged during the autumn of 2021. From four to nine researchers participated in these workshops. First, a data-driven approach was used to gather all the viewpoints that had been brought up by the participants. Based on these findings, researchers created user stories based on the findings to describe the user needs and activities. Stories were concrete real-world descriptions of what users do or want to do and why. User stories could be used to understand user needs before creating more abstract definitions for the tools (e.g., user requirements; Benyon, 2020).

Additionally, one separate workshop with five researchers was arranged to analyze the planning cultures in the two cities of Tallinn and Helsinki. The results of the planning culture analysis are presented in Table 3. The outcome of the user data analysis is a table including information about the user groups, user stories, and user requirements (examples presented in Table 4). In the next phase, the

list of these user requirements was prioritized together with the research team and the representatives of the City of Tallinn. The aim of the prioritization was to support iterative tool development and to coordinate the requirements for different tools.

### Evaluating the User Research Methods

At the end of the first phase of the user research (in December 2021), feedback was gathered from the research team with a questionnaire. The questionnaire measured the perceived usefulness of the user research methods (stakeholder workshops, questionnaires, interviews), data analysis, and outputs (user stories, user requirements, analysis of the planning cultures) from both a research and practical perspective. There were also questions about how users should be involved in the next phases of tool development.

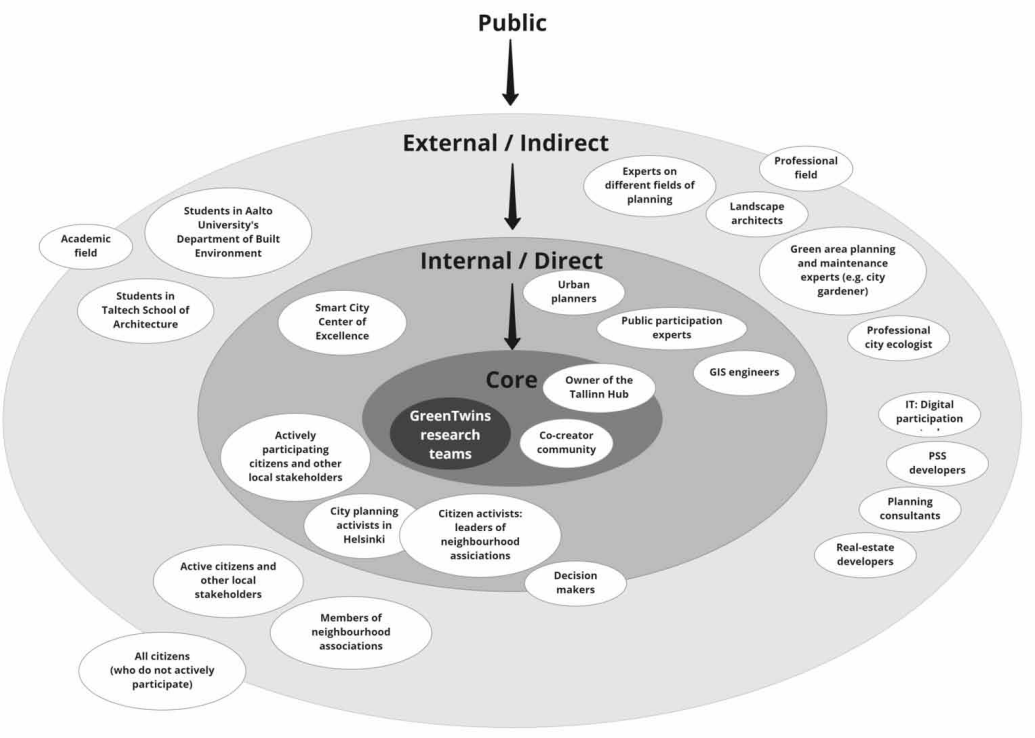
## RESULTS

The aim of the UCD approach applied in the GreenTwins project was to engage users in the development of the new tools and to understand their needs and usage contexts (i.e., differences in local planning cultures) and how technology could answer these needs. In the following sections, the usefulness of the designed and conducted user research is assessed.

### Identifying the User Groups

Selecting and defining the user groups of a system is a central task in the UCD approach (e.g., Benyon et al., 2005; Nielsen, 1993). Stakeholder mapping (see Figure 4) revealed the variety of

**Figure 4. Stakeholder groups of the GreenTwins CPSS**



user groups identified by the researchers at the beginning of the project. The challenge was to deal with the complexity of users and the diverse needs of the wider group of citizens. When developing tools for the wider public, defining the primary user groups may be challenging due to the diversity of potential users. Engaging a variety of different user groups helps to tackle this challenge, but in a short R&D project, the resource and time frame for engaging users is limited, and prioritizations have to be made.

In this case, the challenge was balancing the expectations of our primary user groups (urban planners, active citizens, and real-estate developers) and the needs of the wider public. Based on our user research, the active citizens have experience participating in planning processes, while we cannot expect this from the wider public. They may also have expertise in planning-related areas and expect more advanced features (e.g., green factor analysis, impact analyses) in tools for co-planning. The advanced features easily result in a complex user interface, which does not meet the needs of novice users (i.e., citizens with no previous experience in participation or planning) for a simple and intuitive user interface. Another challenge considered by the researchers was the "dual role" of citizens, as they often represent residents and experts in a particular field simultaneously. This is especially the case with city planning activists, who often have some professional background in planning. Indeed, the CPSS users often represent several groups at the same time, which can make it difficult to clearly define their goals.

Additionally, Urban planners, one of the primary user groups of the CPSS, are becoming increasingly heterogeneous as the tasks and professional backgrounds of planners diversify. In the context of urban planning, there are many different types of planners with different job descriptions, job roles, and personal mindsets. Othengrafen and Levin-Keitel (2019) have identified six different types of planners in their study of German urban planning, with different tasks and roles. It is evident that planners cannot be grouped in one "urban planner" user group and their activities as "planning," because the tasks they perform constitute "a colourful bouquet of activities between plan-making and moderating exchange" (p. 115). The GreenTwins user research reflected the wide range of planners. Their roles varied from detailed local planning to strategic planning, landscape design of green areas, and maintenance planning, among others. The variety of perspectives produced a large number of different needs and aspirations in the user study.

## Using the PACT Model to Identify Knowledge Needs

The user research methodology and process were designed in close collaboration with the GreenTwins research team. Due to the multidisciplinarity of our team, the researchers did not initially have a shared understanding of how to conduct user research. To overcome this challenge, the PACT model (Benyon, 2020; Benyon et al., 2005) was used as a framework for identifying the knowledge needs for user research in the first phase of the project. This model appeared to be easy to learn and apply without prior knowledge. Our team was able to produce the knowledge needs for the user research (see Table 2) in one co-design session.

## Using the Concept of Planning Culture

While the planning practices are largely dependent on the local cultural context (Othengrafen, 2010), the development of the GreenTwins project needed to reflect the planning cultures of both Helsinki and Tallinn. Othengrafen's concept of planning culture was used as a tool to help identify and structure the factors that influence the local contexts where the tools will be used (see Table 3). Based on the analysis, cultural differences may have an impact on the demand and use of planning support tools. For example, the different roles of active citizens and citizens' self-organization may have an impact on the use of the co-planning application. In Finland, there seems to be a need for this tool for citizens' self-organizing plan-making (alternative plans), although integrating citizen-driven plan-making into the formal planning process is a challenge. In the case of Estonia,

**Table 2. The PACT model was used to identify the knowledge needs for the user research**

| Element of PACT | Identified knowledge needs |
|---|---|
| People: The direct and indirect users of the tool or system that is being developed and their physical and physiological characteristics (e.g., mental models) | Primary end-user groups of the GreenTwins CPSS and their characteristics (e.g., IT and collaboration skills, professional backgrounds, job roles)<br>Understanding the "double roles" of expert citizens (i.e., local inhabitants with expert knowledge in a planning-related field)<br>Attitudes towards participation, urban planning, digital tools, and green environment<br>Motivation to engage citizens and participate in planning<br>Ability to recognize visualized plants<br>User research methods: stakeholder workshops, focus group discussions, questionnaires |
| Activities: The purpose for which users will use the tool or system and the goals they are trying to achieve | Current and future methods to engage citizens (e.g., passive or active participation, commenting plans, making alternative plans)<br>Role of green environment in planning communication<br>Preferred tools for and methods of participation<br>City planning activism<br>Ways of using digital plants<br>User research methods: stakeholder workshops, focus group discussions, questionnaires, interviews, user testing of the tools |
| Contexts: The physical, social, and organizational settings where the activities are carried out | Differences in local planning cultures in Helsinki and Tallinn (e.g., challenges in participation, the role of citizens and citizen activism, societal factors, legislation)<br>Characteristics of the case areas (e.g., physical environment, planning situation, planning projects' phase and level of planning, the value of the place for citizens, third sector organizations)<br>User research methods: stakeholder workshops, focus group discussions, questionnaires, literature review, interviews |
| Technology: The potentials and constraints of technology to improve the activities in the context | Digital tools currently in use in planning organizations<br>Enabling technologies (current and future, e.g., game engines, VR technology, digital twins, communication platforms)<br>Similar existing tools for co-planning and visualization in 3D (e.g., SpaceMaker, Urban Menus, interactive city models)<br>Existing solutions for digital modeling of plants<br>Ways to communicate assumptions behind projections of vegetation growth to the users<br>Technological boundaries (e.g., level of details vs. computer performance)<br>Technology research methods: benchmarking of similar tools, technology review |

the main value of the co-planning application is seen in quick site analysis and visualization of the concept in a facilitated discussion.

Another aspect is the level of participation in each city. In Estonia, the level of participation is currently only in the informing and consulting phase (Ilves, 2022). In Finland, public participation is already more interactive, relying on communication and fact-based discussion (Nummi, 2020). This is also reflected in what aspects of the tools the city representatives value. The Tallinn representatives emphasized informing the citizens, while in Finland, communicative and analytical methods that support discussion were highlighted. For the tools, this meant that interactive functionalities (e.g., commenting, discussion, and co-planning) were not equally important for the cities.

**Table 3. Particularities of planning culture in Helsinki and Tallinn relevant for GreenTwins tools**

| Element of planning culture | Helsinki | Tallinn |
|---|---|---|
| Planning artifacts: Products and results of planning | In Finland, there is an ongoing digital transformation towards machine-readable and interoperable (i.e., information model-based) planning data. A national information system for built environment data is being developed (Ministry of the Environment, 2022). Current practices still rely on a strong document-based tradition, and formal plans are in PDF format (Ramboll Finland & Ubigu, 2018). | In Estonia, there are legal requirements for the production of digital machine-readable planning information (Riigi Teataja, 2019). A national planning database is being developed for sharing digital plan data (Ministry of Finance in Estonia, 2022). As in Finland, the planning documents are usually shared in PDF format. |
| Planning context: Cognitive frames and norms | Public participation is well-established in planning. Simultaneously, planning practice is dominated by a comprehensive-rationalist paradigm and comprehensive expert assessment (Bäcklund & Mäntysalo, 2010). Planners emphasize fact-based discussion and the feasibility of planning proposals. | Participation is seen as an essential part of urban planning. Participatory practices are strongly consensus oriented. Local government represents the public or stays a neutral intermediary (Ilves, 2022; Metspalu, 2019). |
| Planning context: Actors and their interactions | Public planners and experts have power in negotiations, and the role of the citizen is relatively narrow (Othengrafen, 2012). Legislation leads to a one-way consultation process, with participation too late in the process. | Private developers have strong power in planning. There is no interaction between participants in the planning process. Public discussions are prone to conflicts, and processes create opposition and a negative climate (Ilves, 2022). |
| Planning context: Planning system | Public participation has been required by law since 2000 (Finlex, 1999), although participatory practices already existed in the 1980s. | Public participation has been required by law since 1995 (Riigi Teataja, 1995, 2002). |
| Planning context: Local strategies | Helsinki has significant land ownership and extensive urban planning resources (Staffans, 2004). The city has been growing strongly, and the Master Plan 2016 continues this trend. | The relatively strong power of private developers is noteworthy, and the importance of green environments is emphasized, as Tallinn has been selected as the Green Capital 2023. |
| Societal context: Underlying and unconscious societal beliefs, perceptions, and values | Finnish participation paradox: People trust the public sector but feel that they cannot have an impact (OECD, 2021). The political agenda increasingly emphasizes citizen participation and responsibility for society's resources (Finnish Government, 2019). | Citizens' trust in public authorities is relatively weak (Beilmann et al., 2021). |
| Digitalization: Possibilities and constraints | Digital participation tools are widely in use in planning processes. The city of Helsinki is actively developing new tools for public participation. The city information model (semantic and visual) is shared as open data. | Digital participation tools are in use in planning processes. A state-wide urban information model has been published. |

Note: The elements of planning culture follow Othengrafen's (2010, 2012) concept of planning culture, complemented by two elements: strategies and choices in the local planning culture and the potential and constraints of digitalization.

## Co-Developing User Stories and User Requirements

User data (i.e., workshop discussions and questionnaire data) were analyzed collaboratively together with the GreenTwins researchers in online meetings with a qualitative analysis approach. First, the results were organized thematically and then used to create user stories for each GreenTwins tool. User stories are abstracted conceptual scenarios describing the features of the system from the user's point of view (Benyon, 2020). In our case, the format of the stories followed the pattern of: "As a

[role], I can [capability], so that [benefit].” For example, a user story could be: “As a planner, I can view different alternative plans, so that I can see the variety of suggestions made by local people.” User stories are different from user requirements in that they also express the motivation or needs of users in addition to the activity. In this process, user stories were essential for communicating the results of the user research between researchers. A story was a tool to understand why a user would want to do something with the tools or need some information.

A total of 61 user stories were produced. User stories played an important role in defining user requirements. Requirements were formulated based on the stories, and a link to the original story was maintained so that it was possible to go back from the user requirement to the user story and further to the original user data. In total, 280 user requirements were generated. The user requirements were developed by first assessing how the user’s need would be met in the co-planning or visualization application. The requirements for the applications were then reviewed by the research team considering the required features of the dynamic plant library to implement them. Examples of user stories and related requirements are presented in Table 4. The analytic and systematic quality of the requirements generation process is questionable as creative thinking was an essential part of the process. To increase the validity of the requirements, they were assessed with both the research team and the stakeholders from Tallinn.

## Evaluating the Process

In general, the research team considered the user research process useful, except for one person who considered that it was implemented too late in the development process. The reason behind this is

**Table 4. Example user stories and requirements generated for the GreenTwins tools and the digital plant library**

| User story | Requirements |
|---|---|
| As a city ecologist or citizen activist, I want to see how much meadow area is available for pollinators, to be able to evaluate the impact on biodiversity. | Co-planning tool: The user wants to see how much meadow area is available for pollinators<br>Digital plant library: Data of green areas and biome types of pilot areas should be collected, and meadow biomes classified |
| As a citizen activist, I want help in choosing vegetation that is suitable for the area’s soil and environmental conditions, when making an alternative plan to be able to design a feasible suggestion. | Co-planning tool: The user wants to know which kind of vegetation is suitable for the area’s soil and environmental conditions<br>Visualization tool: The user is able to see if the plant species chosen for a plan will grow well in the environment<br>Digital plant library: The species and biome data should contain information on species’ and biomes’ environmental adaptations (e.g., preference for dry or moist soil, and sun or shadow) |
| As a landscape architect/urban planner/citizen activist, I want to see tree growth in the area I have planned, so that I can see how much shade the trees will provide over the years and when they reach their full size. | Co-planning tool: The user can get information that helps to understand the urban space in a new way (e.g., view-lines, temporal changes, different view angles)<br>Visualization tool: The user can see tree growth in the planned area to be able to assess how much shade the trees will provide over the years and at full size. The user is able to assess whether the planned trees will fit the place (e.g., narrow street) over the years and at full size<br>Digital plant library: Plants grow into new forms (that are derived from their younger forms) annually or per decade following their species-specific growth curves |
| As a planner orcitizen activist, I want to see how a green area plan will affect the microclimate over the years in a warming climate, to be able to assess the impact of the plan for the livability of the urban space. | Co-planning and visualization tools: The user can understand how a planned green area will affect microclimate over the years in a warming climate.<br>Digital plant library: Effects of plant growth and microclimate impacts need to be projected |

that the GreenTwins project was funded through a competition, and at the competition stage, a plan for the project content and a description of the initial concepts for the tools to be developed had already been drawn up. The PACT model was considered functional for defining knowledge needs. The researchers found the collaborative development of knowledge is important. The results showed that the framework was functional both for introducing UCD to the team and for understanding what issues should be considered in the user research. This made it easier to identify the knowledge needs and formulate the questions for the user research (see Table 2).

Despite the difficulties in defining the user groups in detail, it was agreed that stakeholder mapping was important. Selecting the primary user groups did direct the UCD activities (e.g., inviting citizen activists to the online sessions and interviewing developers), and thus, discussing the user groups was an important phase of the research design. Both user stories and user requirements were considered useful by the research team. However, the usefulness of the requirements was prior to the stories, as the requirements were considered easier to apply in the development of the tools. Nevertheless, the user stories were an important intermediary step in the data analysis and helped to shape the requirements.

The researchers felt that analyzing the local planning cultures of the cities through Othengrafen's (2014) concept of planning culture was complicated. The factors that emerged through the concept of planning culture were, in this case, quite broad, as shown in Table 3, and the discussion perhaps drifted into overly general issues in relation to the information needs at hand. The feedback from the research team revealed that the concept of planning culture was felt to be too complex for utilization in the data analysis. Specifically, the researchers felt that the data collected were not sufficient to analyze the planning culture.

## DISCUSSION

### Dealing With Complexity, Diversity, and Ambiguity

The complexity of planning has been recognized as one of the factors behind the implementation gap (e.g., Geertman, 2017; Pelzer, 2015; Vonk & Geertman, 2008). Conducting user research in the context of participatory planning shows that, apart from the complexity of planning, the diversity and ambiguity of user groups are also obvious challenges in a project with limited resources for user research. Indeed, user research can never give representative information about the real world. This is not even the objective, which is rather to adequately understand users and their needs. Systematic user research and testing help to understand which users' needs the tools are really serving and who is excluded. In GreenTwins, it is obvious that selecting urban planners, active citizens, and developers as primary user groups exclude many groups of citizens from the study. Therefore, it is crucial to involve more citizen groups at a later stage in the development process. This may be more feasible once functional prototypes exist and can be tested in real planning cases.

Previous research has pointed out the dichotomy between complex planning tasks and the need for simplistic tools (Vonk & Geertman, 2008). The claim is justified, but the conclusion of simplicity as a goal may lead to a dead end. Following Geertman's (2017) ideas, we believe that complexity should be addressed through dedicated tools that support solving smaller tasks. In GreenTwins, the visualization tool is dedicated to the visual analysis of landscape changes in urban planning, and the co-planning tool is developed to make alternative plans through quick game-based 3D sketching. In the co-planning tool, different user interfaces can also be offered to different user groups. For planning experts, there is evidently a need to develop smart analytics, so the aim for them should be in developing digital tools that fit their tasks and the planning processes to answer certain planning questions. This might require more complex features and the use of professional language in the user interface. Meeting the needs of those citizens who are unfamiliar with urban planning requires a different user interface, content in their own language, and easy-to-learn functionalities. On the

other hand, based on this research, active citizens are willing to use more advanced tools to analyze the green environment.

### Mismatch Between Information Needs and Methods

The weakness of our UCD approach was the slight mismatch between information needs and methods and synchronizing the user research process and tool development. To design the system architecture of the digital plant library, detailed knowledge of the user needs (e.g., how detailed the digital plants should be and how they should be visualized) would have been needed in earlier stages of the process. Simultaneously, the development of the prototypes was lagging, and the user testing of the tools was therefore not conducted at this phase of the project. It is also evident that the user research resulted in an extensive list of user requirements, and only a part of those can be implemented during the GreenTwins project.

An understanding of the planning tasks and practices is also needed at an early stage. Close collaboration with planning practice has been emphasized in previous research (e.g., Franken-Champlin, 2019; Kahila-Tani, 2015; Vonk & Geertman, 2008), and following that path in this user research process, the planners were engaged in the process as dialogue partners in the workshops and as co-designers of the Tallinn city planning Hub. However, these methods did not provide enough detailed information about the needs of the planners for digital tool development. The daily routines of planners can be better understood through empirical research (Othengrafen & Levin-Keitel, 2019). In the next phases, our aim is to complement user research with on-site observation and real-life planning pilots.

### Structured Frameworks Help to Map Out Results

Clear analytical frameworks can help to apply UCD in a multidisciplinary research team. Based on the results, the PACT model was helpful for identifying the knowledge needs, but the concept of planning culture was considered too complex for use at this phase of user research. However, utilizing the concept of planning culture as an analytical framework may help to identify and clarify the underlying beliefs that would otherwise be left out. However, in a research and innovation project like GreenTwins, it may not be necessary to carry out a systematic analysis of the planning culture. Although an in-depth analysis of planning culture would be interesting from a research point of view, a partial picture may give adequate insight into the nature of planning culture in relation to tool development. In the GreenTwins case, the most relevant aspects of the planning culture were the differences in participatory practices, the relationship between citizens' self-organizing activities and institutional planning, and the current status of the digitalization of planning artifacts.

### Challenges in User Research Methodology

The output of the user research is obviously dependent on the methods. In this study, the COVID-19 pandemic inhibited UCD activities and directed our methods toward online participation (online workshops and questionnaires). The discussions in the online workshops were limited and emphasized participants' previous experiences of the field and similar tools, leaving out information about the users themselves and their actual activities. The fault of the questionnaires was the low number of respondents, which resulted in data not being representative of different user groups. However, the questionnaires can be reused in the next phases to collect more comprehensive data. The self-selection of participants remains a challenge: the participants represent very active citizens and a group of highly motivated planners.

Previous research recommends co-development and close dialogue with prospective users to narrow the implementation gap of the PSS (Franken-Champlin, 2019; Rittenbruch et al., 2021; Te Brömmelstroet & Bertolini, 2008; Te Brömmelstroet & Schrijnen, 2010). In this user research, the

users were acting as co-developers only for the city Hub. In the development of digital tools, users acted as informants (interviews) and dialogue partners (workshops and focus group discussions). It can therefore be said that our user research process was user-centered but did not involve users in a co-creation sense.

## CONCLUSION

Easy-to-learn and easy-to-implement methods for user research and engagement are needed when developing novel digital tools in an R&D project with limited human and time resources. A feasible process requires a clear analytical framework for identifying the knowledge needs for user research, as well as collaboration between the researchers and developers in organizing user research activities and analyzing the user data. The action research approach applied in the GreenTwins project was successful in identifying the knowledge needs using the PACT model and co-developing user insight with the help of user stories, despite the slight mismatch due to the launching phase of the approach.

Synchronizing user research activities with concept and tool development is crucial for a short R&D project. Balancing the project's predefined features with new user requirements demands the freedom to redirect development. To ensure the impact of user research in a R&D project, it is necessary to use methods that allow user insight to be conveyed to tool developers, so that the motivational factors behind user activities are communicated to tool developers. In the GreenTwins project, this was helped by user stories that describe not only the user's actions but also their goals. Another important aspect was that the researchers and developers were involved in conducting the user research themselves and discussing the process with the users. They were also involved in the analysis of the user data collected.

Following previous research, narrowing the implementation gap (i.e., the mismatch between technology and demands of users) of the PSS tools requires, inter alia, focusing on good quality tools, acceptance of the users, and transition to practice. In this first part of the GreenTwins project, we have succeeded in building the R&D team's understanding of user needs, in particular by discussing with potential end-users and co-analyzing the user data. According to our estimate, thus far in the GreenTwins project, the challenges linked to the implementation gap have been addressed partly. This UCD process does not yet guarantee the acceptability and quality of the tools, but it is the first step in that direction. The information gathered and the user requirements developed from it can, if properly applied, enable the development of tools that meet user needs.

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