Systematic review protocol:

Review of 3D visualisations supporting communication in urban and landscape planning

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INTRODUCTION

Rationale

3D visualisations and applications have attracted a lot of interest in the fields of landscape and urban planning and architecture with 3D City Models especially gaining prominence as an information management and communication system in many cities in the world (Biljecki, Stoter, Ledoux, Zlatanova, & Çöltekin, 2015; Billger, Thuvander, & Wästberg, 2017). These visualisations with their particular visualisation power compared to conventional 2D plan depictions are envisioned to be beneficial in citizen and stakeholder engagement during planning processes (Herbert & Chen, 2015; Lovett, Appleton, Warren-Kretzschmar, & Von Haaren, 2015).

The technical solutions for 3D visualisations range from tactile models to videos and interactive 3D applications (Alatalo et al., 2017; Lovett et al., 2015). 3D visualisations are developed both within and outside of academia in a variety of disciplines including information and communication technology, urban and environmental planning and education (Billger et al., 2017). Since the technological solutions and the terminology applied to them differ greatly among disciplines and application contexts, it is challenging to build upon the existing knowledge base (Hall, Oldfield, Mullins, Pollard, & Criado-Perez, 2017). To cope with this interdisciplinarity and heterogeneity of the 3D visualisation field during development of new and novel approaches to visualisations would benefit from a systematic synthesis. Furthermore, there is a need for more systematic investigation of the usage and benefits of 3D visualisations (Billger et al., 2017), in particular in communicative urban and landscape planning (Lovett et al., 2015). This systematic review looks into the published scientific literature on case studies where 3D visualisations have been developed and used in participatory and collaborative planning and the level at which they have been evaluated in relation to usability.

Objective of the review

The aim of this systematic literature review is to synthesize recent case studies of 3D visualisations that have been utilized or developed to support participation and collaboration in urban and landscape planning. We examine 3D visualisations that have been developed or used with citizens and stakeholders for planning purposes and identify their shared characteristics and specific link to planning practice. The review is targeted for researchers and planning professionals and will synthesise the state-of-the-art in communicative 3D visualisations for planning that have been reported in research literature. The specific questions to address include:

1. In what kind of contexts have 3D visualisations been applied related to urban and landscape planning?
2. What technological solutions are used for the visualisations and for human-computer interaction?
3. What kind of communicative planning 3D visualisations facilitate and for which kinds of planning purposes are they developed? And finally,
4. How have the users been engaged in evaluating usability of the visualisations?

METHOD

Our systematic review follows established guidelines for conducting and reporting a systematic review (Hall et al., 2017; Moher et al., 2015; Pullin & Knight, 2009; Pullin & Stewart, 2006). Systematic review is common in medical and social sciences as a systematic way to collect research evidence for evaluation and decision-making (Petticrew & Roberts, 2006). Systematic review methodology has also entered the fields of environmental science and the nexus of urban planning and human health and wellbeing (Barros et al., 2019; Labib, Lindley, & Huck, 2020; Moghadam & Rafieian, 2019; Stone, Fernandez, & DeSantiago, 2019). In the field of built environment, systematic reviews have been identified as a way to achieve evidence based practice in planning build environments (Hall et al., 2017). Hall et al. (2017) however state the following as challenges to carry out systematic reviews in the field: the multitude of small studies, which makes synthesis of evidence difficult. In addition, there is a pressure for novel approaches, further contributing to this fragmentation and making it difficult to continually build upon the existing evidence base. Nevertheless, systematic review can be utilized to map out the range of uses of particular planning approaches and technologies and the application contexts.

We document our systematic review protocol below, and have validated it by sharing it among the co-authors.

Study inclusion criteria

Studies in English, Finnish, Swedish and German will be considered. A cut-out year, of which over half of the found items have been published in the largest principal search database, will be used. This cut-out year is 2013 and thus the dataset covers the years from 2013 to mid-2020. The following inclusion criteria will be applied in order to select studies to the review among those captured in the database searches. A study has to:

(1) Employ a 3D visualisation that supports communication in relation to an urban or landscape planning process. At the screening stage we include studies that have been developed for or applied at any level of urban or landscape planning.

(2) Test, pilot or apply in real-life the 3D visualisation with citizens or other stakeholders as a tool for communicative planning. As stakeholders we define e.g. different sectoral administrations, civil society organizations, and people in expert role. We define the concept of communicative planning

broadly and refer to any form of citizen and stakeholder engagement in urban and landscape planning regardless of the planning process phase.

(3) Document in the publication information on the majority of the review topics.

Potential factors affecting interpretation of results

Various planning context characteristics are likely influence the methodological approaches utilized and developed for the participation and collaboration in the empirical studies. We presume these to be related firstly, to the phase of the planning process, planning objectives, emphasis given to the public participation, as well as funders of the study and planning process. Secondly, the case study context, for example, the year in which a case is carried out and reported, the disciplines of the authors, and the data sources, methods and resources used may all show various emphasis in the case development, implementation and reporting.

Information sources

Electronic academic databases and search engines included in the search for relevant cases include:

- Primary sources: ISI Web of Science Core Collection; Scopus; Open grey repository (www.opengrey.eu)
- Secondary source: Google scholar (100 first search results)

We include in the review publications that have been published in and after the cut-out year 2013, on which half of all the found publications in the largest database, Scopus, have been published.

Search terms and strategy

Scoping exercise was performed to test search terms and strings using the ISI Web of Science to iteratively revise the search terms used in the academic literature search. The scoping exercise was performed in the ISI Web of Science, using various keywords. Three groups of combinations of search terms in English presented below (where * denotes a wild card to search for no letter or alternative letter combinations) will be applied to the databases and search engines using title, abstract and keywords or topic search, when applicable (see more details in Appendix A).

The scoping exercise revealed the expected heterogeneity of terminology for denoting 3D visualisations in the scientific literature. While 3D visualisations have been developed for over three decades, their use and development are widespread among different disciplines and, thus, there is a vast array of terminology that refers to 3D based technologies and visualisations. Hence, the search was expanded with the broad variety of terms used to describe urban planning related 3D visualisations in the fields of urban planning, environmental sciences, human and physical geography, human-computer interaction, cultural heritage, laser scanning and photogrammetry, ICT as well in a variety of fields of engineering (Biljecki et al., 2015; Billger et al., 2017) and included:

*("3D geo*visuali*ation" OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D NEAR/3 environment*) OR "virtual geographic* environment*" OR (3D NEAR/3 visuali*ation*) OR (3D NEAR/3 representation*) OR (3D NEAR/3 landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo*visuali*ation*" OR "virtual globe*" OR "virtual landscape*" OR "3D exploration" OR "3D urban model*" OR "3D geomodel*" OR "3D game engine*" OR "urban data visuali*ation" OR "point cloud*" OR "3D scene*" OR "3D urban scene*" OR "digital twin" OR "3D urban space*" OR (3D NEAR/3 reconstruct*) OR "CityGML" OR "CityEngine" OR (3D NEAR/3 geospatial) OR (3D NEAR/3 technolog*) OR (3D NEAR/3 simulation*) OR "3D geo*information" OR "digital earth" OR ("second life" NEAR/3 3D) OR "geo*virtual" OR "3D geodesign")*

To focus the search on urban and landscape planning related applications of 3D technologies, various synonyms of them were included in the search using the AND connector:

*(("landscape" OR "urban" OR "city" OR "environment" OR "land*use" OR "spatial" OR "town" OR "neighb*rhood" OR "green*space*" OR "green*infrastruct*" OR "green*area*" OR "park*") AND ("planning" OR "design*"))*

To find studies, which had a participatory or collaborative approach to planning, the search was refined by adding a third group of search terms using also the AND connector. The term interaction is commonly used in ICT and engineering sciences to denote participation of stakeholders (Law, Roto, Hassenzahl, Vermeeren, & Kort, 2009). However, it alone is a general term and had to be combined with an actor concept to yield relevant results, thus the use of proximity connector (NEAR/x) with the term interaction.

("participa" OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR ("participa*" NEAR/3 "interacti*") OR ("communit*" NEAR/3 "interacti*") OR ("stakeholder*" NEAR/3 "interacti*") OR ("resident*" NEAR/3 "interacti*") OR ("citizen*" NEAR/3 "interacti*"))*

The field of science categories in WoS and Scopus are used to limit the search results, because the number of initial records that appeared in the search is large. We exclude the following fields of science from the search results: medicine, chemistry and linguistics, and their subfields. The date of coverage will be defined by calculating a cut-out year for the results.

STUDY RECORDS AND DATA

Data management

Titles and abstracts of all the search results will be stored in a Mendeley database and duplicates will be removed using the Mendeley deduplication function as well as the conditional formatting function in Excel, which allows duplicate values to be highlighted separately in each column of the spreadsheet of records. The titles and numbers of articles retrieved, accepted and rejected will be documented in an Excel spreadsheet database. The manuscripts and other found documents will be compiled into one folder, which will be shared and accessible to all the co-authors. After the filtering is completed, the remaining records that are included in the review will be analysed, and analysis results stored in a separate Excel spreadsheet.

Selection process

The records (articles, reports, theses, books, book chapters, conference papers etc. [Plummer et al., 2012]), i.e. publications, are selected through a filtering process (Pullin & Stewart, 2006). In the first instance, the inclusion criteria will be applied on the title only. Records remaining will then be filtered by abstract (or introduction section or equivalent if an abstract is not available) and further, by viewing remaining records at full text content. In cases of doubt, studies will be included to the next phase of the selection process. In case a study and the results are covered in several publications, only one of them will be included in the database and in the analysis.

To check for data quality and consistency of application of the inclusion criteria, three reviewers will be carrying out independently the first two filtering phases of title and abstract on a random subsample of at least 10 % of the records (Pullin & Stewart, 2006). The kappa statistic will be calculated to measure the level of agreement between the reviewers (Cohen, 1960). If kappa should be < 0.5, the reviewers will discuss the discrepancies and clarify the interpretation of the inclusion criteria.

Prior to the filtering, the inclusion criteria will be discussed and agreed upon among the co-authors and a shared understanding of the criteria and their application will be attained. Should the search yield records that vary greatly in their depth of description of the participatory element, the criteria will be adjusted after the initial filtering of 10 % of the records.

Data collection process

The data from the included records will be extracted by all of the co-authors using a spreadsheet matrix. The spreadsheet matrix contains the variables that are extracted, their predefined categories or narrative description and additional notes. The spreadsheet matrix and its categories will be pretested with 10 % of all included records after which the form will be modified if necessary, in order to guarantee repeatability and consistency.

Each co-author will go through the records and extract the data independently from the subset of the records assigned to them. The resulting data will be compiled into one single spreadsheet. The corresponding author, will do a cross-check of the data extraction to ensure the data has been consistently described and the meanings in the data has been similarly interpreted.

Data extraction strategy

We will extract the following information from the publications that meet the inclusion criteria (see entire list of variables in Appendix B):

- **Publication details** such as publication type (journal article, document etc.), year of publication, disciplines of authors
- **Application context** such as number of application sites, level of administrative scale, actors involved in the 3D visualisation development
- **Characteristics of 3D technologies** such as terminology used to denote the 3D visualisation, type of display and development platform
- **Characteristics of the participation and collaboration** such as targeted participants, purpose of 3D visualisation use for planning and mode of participant engagement
- **User engagement in usability evaluations** such as details of the usability evaluations and sampling methods
- **Real-life planning context (if applicable)** such as phase and owner of the planning process

Outcomes and prioritization

The main outcome of the review is to describe and gain general understanding of the variety of the 3D visualisations that aim to improve participation and collaboration in urban and landscape planning. Secondary outcome is to study the link of these visualisations to real-life planning practice and the level at which their usability to communicative planning have been evaluated even if these benefits remain less evaluated in the publication (e.g. in studies concentrating on the technical aspects of the visualisations).

Risk of bias in individual studies

The review will most likely include literature from various fields of science where the publications focus on different aspects of the 3D visualisations and the reported study cases. This can limit our ability to synthesize the content of the publications and the study outcomes. This may also limit our ability to evaluate the rigor of the participatory aspect of the case studies as technology and engineering science fields do not necessary report in detail the user testing procedures. In the analysis phase of the review we will exclude results of the usability evaluations of those publications where we do not find comprehensive information about the evaluation procedure or where the sample sizes of participants have been very small.

Data synthesis and presentation

The publication characteristics, application contexts and other descriptive variables will be described as frequency distributions or in text form and in graphs and tables. The variable data is analysed through content analysis and or descriptive statistics. The predefined variable categorizations will be identified from the publications using directed content analysis and analysed and reported using descriptive statistics. The remaining variable data is analysed using conventional content analysis deriving the categories from the data. A separate descriptive analysis will be done to the characteristics of the participation aimed at with each 3D visualisation found in the literature. In the analysis we utilize the type of participatory engagement and knowledge needs conceptualized by Staffans, Kahila-Tani, Geertman, Sillanpää, & Horelli, 2020.

Schedule

Table 1. Schedule for the review process.

Task	Accomplished by
Developing the review protocol	May 2020
Data search and selection	June-November 2020
Data extraction and synthesis	December 2020 – April 2021
Submitted manuscript	June 2021

Competing interests

The authors declare that they have no competing interests.

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APPENDICES

Appendix A. Search strings used in each database search

ISI Web of Science search strings			
Search field	**Search string 1**	**Search string 2**	**Search string 3**
Topic	“3D geo*visuali*ation” OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D NEAR/3 environment*) OR "virtual geographic* environment*" OR (3D NEAR/3 visuali*ation*) OR (3D NEAR/3 representation*) OR (3D NEAR/3 landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo*visuali*ation*" OR "virtual globe*" OR "virtual landscape*" OR “3D exploration” OR “3D urban model*” OR “3D geomodel*” OR “3D game engine*” OR “urban data visuali*ation” OR “point cloud*” OR “3D scene*” OR “3D urban scene*” OR “digital twin” OR “3D urban space*” OR (3D NEAR/3 reconstruct*) OR “CityGML” OR “CityEngine” OR (3D NEAR/3 geospatial) OR (3D NEAR/3 technolog*) OR (3D NEAR/3 simulation*) OR “3D geo*information” OR “digital earth” OR ("second life" NEAR/3 3D) OR “geo*virtual” OR “3D geodesign”	*("landscape" OR "urban" OR "city" OR "environment" OR "land*use" OR "spatial" OR "town" OR "neighb*rhood" OR "green*space*" OR "green*infrastruct*" OR "green*area*" OR "park*") AND ("planning" OR "design*")*	*“participa*” OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (“participa*” NEAR/3 "interacti*") OR ("communit*" NEAR/3 "interacti*") OR ("stakeholder*" NEAR/3 "interacti*") OR ("resident*" NEAR/3 "interacti*") OR ("citizen*" NEAR/3 "interacti*")*
Scopus search strings			
Search field	**Search string 1**	**Search string 2**	**Search string 3**
TITLE-ABS-KEY	"3D geo*visuali*ation" OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D W/3 environment*) OR "virtual geographic* environment*" OR (3D W/3 visuali*ation*) OR (3D W/3 representation*) OR (3D W/3 landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo*visuali*ation*" OR "virtual globe*" OR "virtual landscape*" OR "3D exploration" OR "3D urban model*" OR "3D geomodel*" OR "3D game engine*" OR "urban data visuali*ation" OR "point cloud*" OR "3D scene*" OR "3D urban scene*" OR "digital twin" OR "3D urban space*" OR (3D W/3 reconstruct*) OR "CityGML" OR "CityEngine" OR (3D W/3 geospatial) OR (3D W/3 technolog*) OR (3D W/3 simulation*) OR "3D geo*information" OR "digital earth" OR ("second life" W/3 3D) OR "geo*virtual" OR "3D geodesign"	("landscape" OR "urban" OR "city" OR "environment" OR "land*use" OR "spatial" OR "town" OR "neighb*rhood" OR "green*space*" OR "green*infrastruct*" OR "green*area*" OR "park*") AND ("planning" OR "design*")	(“participa*” OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (“participa*” W/3 "interacti*") OR ("communit*" W/3 "interacti*") OR ("stakeholder*" W/3 "interacti*") OR ("resident*" W/3 "interacti*") OR ("citizen*" W/3 "interacti*")

Open Grey search string	
Search field	**Search string 1**
Not applicable	“3D geo*visuali*ation” OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D NEAR/3 environment*) OR "virtual geographic* environment*" OR (3D NEAR/3 visuali*ation*) OR (3D NEAR/3 representation*) OR (3D NEAR/3 landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo*visuali*ation*" OR "virtual globe*" OR "virtual landscape*" OR “3D exploration” OR “3D urban model*” OR “3D geomodel*” OR “3D game engine*” OR “urban data visuali*ation” OR “point cloud*” OR “3D scene*” OR “3D urban scene*” OR “digital twin” OR “3D urban space*” OR (3D NEAR/3 reconstruct*) OR “CityGML” OR “CityEngine” OR (3D NEAR/3 geospatial) OR (3D NEAR/3 technolog*) OR (3D NEAR/3 simulation*) OR “3D geo*information” OR “digital earth” OR ("second life" NEAR/3 3D) OR “geo*virtual” OR “3D geodesign”) AND (("landscape" OR "urban" OR "city" OR "environment" OR "land*use" OR "spatial" OR "town" OR "neighb*rhood" OR "green*space*" OR "green*infrastruct*" OR "green*area*" OR "park*") AND ("planning" OR "design*")) AND (participa* OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (participa* NEAR/3 "interacti*") OR ("communit*" NEAR/3 "interacti*") OR ("stakeholder*" NEAR/3 "interacti*") OR ("resident*" NEAR/3 "interacti*") OR ("citizen*" NEAR/3 "interacti*")
Google Scholar search string	
Search field	**Search string 1**
Not applicable	3D geovisualisation|geovisualisation|model|landscape AND (urban|land use|spatial|green space) planning|design AND participatory|community|collaborative|public

Appendix B. Variables used in the data extraction and analysis

No.	Variable	Classes	Description	Information source	Adapted literature
	Publication details				
1	Type of publication	Book, book section, conference proceeding, journal article, patent		Publication	
2	Journal name	Description		Publication	
3	Year of publication	Year	Year in which the study was published	Publication	
4	Disciplines of the authors' affiliation	Description, NA		Publication	
5	Funder of the research	Academic, national foundation or program, international foundation or program, public sector (government), third sector (NGO/CBO), private sector, community, NA		Publication	Billger et al., 2017

	Application context				
6	Country	Country	Country or countries in which the application was conducted	Publication	
7	Number of application sites	1-n	Number of application sites reported	Publication	
8	Name of application site(s)	Name of neighbourhood, city, town, region etc.		Publication	
9	Planning sector	Urban planning, land use planning, landscape planning, etc.	Planning and management sector the 3D visualisation application is related to. Urban planning refers to general level built environment planning; urban design refers to more detailed design of built environment; Land use planning refers to planning focused on non-built environments e.g. rural land use; Landscape planning refers to general level planning of landscape or e.g. green spaces; Landscape design refers to detailed design of landscape or green spaces	Publication	
10	Administrative or geographical scale	Block, neighbourhood, city, town, region, national etc. level	At which level of administration or in which geographical area scale the visualisation was used	Publication	
11	Type of visualized situation	Current situation, future scenario, historical reconstruction, hypothetical situation, NA	Objective of the visualisation	Publication	
12	Actor types involved in the 3D visualisation development	Academic, public sector (government), third sector (NGO/CBO), private sector, community, NA		Publication	Billger et al. 2017,
13	End user groups	Description, none	Which end users (e.g. planners, facilitators, citizens) have been identified during the visualisation development, if any	Publication	Rodela et al. 2017; Lovett et al. 2015
14	End user involvement	Yes, no, NA	Have end users been involved in the visualisation development	Publication	

15	Emphasised novelty of the publication	Novel technical solution with description of a simple user testing; User experience study with little/no reference to principles of participatory planning; Participatory planning study with robust use of participatory planning theories and testing, and less focus on novelty of technical solution; or a mix of these emphases	Does the publication focus on reporting novelty in the technical solution, user experience and usability, participatory planning implications of the visualisation or a mix of these. To what extent the technical solution, user experience and participatory approach to planning are documented and discussed in the publication?	Publication	
16	Case type	Testing, piloting, real-life planning related process	At what stage of development the visualisation is applied, e.g. as a test in a laboratory or street setting, as a pilot study (with targeted participants in a real-life-like setting), in real-life planning related process	Publication	Billger et al. 2017
17	Characteristics of the 3D visualisation test users	Description, NA	What kind of test users were involved in using the 3D visualisation?	Publication	
18	Number of test users involved in the exercise	1-n, NA	Numbers of participants involved in the exercise(s)	Publication	
	Characteristics of the 3D technology				
19	3D visualisation terminology utilized	Description	Naming of or concepts to denote the 3D visualisation	Publication	
20	Platform utilized for viewing and interaction	Description, NA	Reported system for viewing and interaction	Publication	Julin et al. 2018
21	Name of the development platform	Description, NA	Reported system for data processing and development	Publication	Julin et al. 2018
22	Types of source data used in 3D visualisation and/or for its development	Description, NA	Which data sources were utilized to develop the 3D visualisation, or were part of the visualisation	Publication	
23	Type of display	Description, NA	Display for viewing the 3D visualisation	Publication	

24	Level of realism in the 3D visualisation	Non-realistic, realistic-looking, photorealistic, mixed, NA	Non-realistic refers to limited visual representation in terms of textures (e.g., a simple volume for a house, contour lines as ground surface); realistic-looking refers to realistic representation without reality-based visual (e.g. photograph-derived texture) data; photorealistic: refers to reality-based visual textures (photograph-derived textures); mixed: refers to visualisations in which different levels of realism are combined	Publication, figure(s) showing the visualisation	Hayek 2011; Gordon et al. 2011
25	Type of final presentation	Real-time 3D, 3D renderings, NA	Is the visualisation presented with a real-time 3D technology allowing real-time and interactive rendering of 3D images or is it presented as pre-rendered static images or videos (3D renderings)	Publication, figure(s) showing the visualisation	
26	Hardware to access the 3D visualisation	Online, special hardware, non-special hardware, mix, NA	How do the users access the visualisation? Does the access require special hardware or is it accessible via web-based solution thus making it possible for users to participate in their own time and with their own device?	Publication	
27	Functions for participants to use in the visualisation interface	Description, NA	What functions are provided for participants to use in the interface, such as commenting, analysing scenarios, ground level navigation, gaming	Publication	
	Characteristics of the participation and collaboration exercise				
28	Targeted participants	Citizens, expert stakeholders, both, NA	Is the 3D visualisation developed to involve citizens or expert stakeholders in the planning process?	Publication	

29	Mode of participant engagement	Participation, collaboration, informing, NA	Which of the mode of participant engagement is the visualisation used for? Participation addresses wide audience and can be based on one-way communication; collaboration happens in groups and is based on two-way/many to many communication. Informing refers to cases where the visualisation is only used for informing participants	Publication	Staffans et al. 2020
30	Knowledge needs gathered for planning purposes	Diverging, converging, NA	Diverging refers to when diverse information is collected but not discussed together and converging refers to when the knowledge claims of individuals are tested in a collective setting	Publication	Staffans et al. 2020
31	Purpose of using the 3D visualisation for participation or collaboration	Description	For what purpose(s) the 3D visualisation was developed to engage with participants?	Publication	
32	Form of the collected data	Description, NA	In which forms data from the participants has been collected for planning purposes during the exercise	Publication	
33	Medium of communication in the exercises	Non-digital medium, digital external platform, internal 3D visualisation interface, NA	In what medium is communication between people facilitated in relation to the 3D visualisation	Publication	
34	Level of communication	One-way, two-way, many-to-many, mixed, none, NA	What type of communication between people the visualisation allows, e.g. commenting (one-way), discussing (two-way or many-to-many among all participants)	Publication	
35	Level of facilitation	Self-directed, facilitated, NA	Level of facilitation in the exercise	Publication	
	User engagement in usability evaluation of the 3D visualisation				
36	Usability evaluation of the 3D visualisation	Yes, No, NA	Was the usability of the 3D visualisation evaluated or not	Publication	Billger et al., Çöltekin et al. 2016

37	Evaluation method of usability	Description, NA	Which methods were used to collect information to evaluate the usability of the 3D visualisation	Publication	Billger et al.
38	Selection of test users (sampling type)	Random sampling, purposive sampling, convenience sampling, volunteered participation, planning guideline based selection, mix, NA	What was the sampling method for test user selection	Publication	
	Characteristics of the real-life planning context (if applicable)				
39	Phase of the planning process	Description, NA	Phase(s) of the planning process where the visualisation was applied	Publication	
40	Owner of the planning process	Academic, public sector (government), third sector (NGO/CBO), private sector, community, combined effort, NA	What is the main actor(s) and owner(s) of the planning process	Publication	
	Additional notes				
41	Notes	Description			

References: Billger, M., Thuvander, L., Wästberg, B.S., 2017. In search of visualisation challenges: The development and implementation of visualisation tools for supporting dialogue in urban planning processes. Environ. Plan. B Urban Anal. City Sci. 44, 1012–1035. https://doi.org/10.1177/0265813516657341; Çöltekin, A., Lokka, I., Zahner, M., Halounova, L. 2016. On the usability and usefulness of 3D (geo) visualisations--A focus on virtual reality environments. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives. Gordon, E., Schirra, S., Hollander, J., 2011. Immersive planning: A conceptual model for designing public participation with new technologies. Environ. Plan. B Plan. Des. 38, 505–519. https://doi.org/10.1068/b37013; Hayek, U.W., 2011. Which is the Appropriate 3D Visualisation Type for Participatory Landscape Planning Workshops? A Portfolio of Their Effectiveness. Environ. Plan. B Plan. Des. 38, 921–939. https://doi.org/10.1068/b36113; Lovett, A., Appleton, K., Warren-Kretzschmar, B., Von Haaren, C., 2015. Using 3D visualisation methods in landscape planning: An evaluation of options and practical issues. Landsc. Urban Plan. 142, 85–94. https://doi.org/10.1016/j.landurbplan.2015.02.021; Rodela, R., Bregt, A.K., Ligtenberg, A., Pérez-Soba, M., Verweij, P., 2017. The social side of spatial decision support systems: Investigating knowledge integration and learning. Environ. Sci. Policy 76, 177–184. https://doi.org/10.1016/J.ENVSCI.2017.06.015; Staffans, A., Kahila-Tani, M., Geertman, S., Sillanpää, P., Horelli, L., 2020. Communication-Oriented and Process-Sensitive Planning Support. Int. J. E-Planning Res. 9, 1–20. https://doi.org/10.4018/ijepr.2020040101