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# Media Coverage of 3D Visual Tools Used in Urban Participatory Planning

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## ABSTRACT

The opportunities provided by adopting digitally-generated visual tools in urban participatory planning are compelling. These visual tools can promote interactions between authorities and citizens and among citizens. However, the urban participatory practices of these tools are often described from an academic perspective, which leads to a lack of knowledge from the practitioner's outlook. This study investigates practices of 3D visual tools in applied urban projects. The applied projects were recovered from media coverage. The objective is to describe participatory projects and their adopted 3D tools with a contextual and technical lens. The findings demonstrate that 3D visuals are mostly adopted for communication with a realistic representation and limited interaction in the later stage of the project where negotiation margins are insufficient at a small and medium urban scale. A better understanding of applied practices can help to introduce guidelines that support practitioners in designing approaches that benefit from the full potential of 3D visual tools.

## KEYWORDS

3D Visual Tools, 3D Visualizations, Applied Participation, Media Coverage, Online vs. Onsite, Participatory Sciences, Typology, Urban Participatory Planning

## INTRODUCTION

The involvement of citizens, i.e., local experts, in urban development helps to tackle several issues specific to planning by conveying dwellers' judgments, feedback, or wisdom (Arnstein, 1969). However, engaging the population in complex topics during the development of an urban project is challenging (Alawadi & Dooling, 2016; Mostert, 2003), and the use of information and communication technologies (ICT) in participatory approaches does not resolve all issues (Afzalan & Muller, 2018; Brown & Kyttä, 2018; Chassin et al., 2019). The authorities need to determine if the aspects under

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negotiation are accurately understood by the participants, in addition to guaranteeing that their provided feedback is meaningful and related to the urban issue. In this regard, visual communication is often favored, because of its efficiency in conveying information including better memorability and easier understanding of complex issues (Al-Kodmany, 1999; Christmann et al., 2020; de Oliveira & Partidário, 2020; Metze, 2020). For instance, visual tools could promote the immersion of future users (i.e., affected inhabitants) in a soon-to-be-built urban project in order to understand its challenges. Otherwise, this understanding could be laborious, even impossible, due to the several complex aspects of urban design: lengthy timeline, large spatial scale, numerous design parameters, etc.

Since the late 1980s, the technological breakthroughs in the movie and video gaming industry have provided digitally generated 3D visual tools that are increasingly detailed and realistic. This progress promotes, on the one hand, visualizations that are accurate and robust enough to portray urban projects (Chowdhury & Schnabel, 2020; Newell et al., 2021; White et al., 2021), and, on the other hand, a skilled population that is accustomed to experiencing these 3D representations. The recent maturity of these visualizations and their benefits for urban (and landscape) participatory planning has been acknowledged in the scientific literature (Al-Kodmany, 2002; Hayek et al., 2016; Lange, 2011), and numerous prototypes have been implemented to engage the population (Alatalo et al., 2017; Chassin et al., 2018; Onyimbi et al., 2018; Velarde et al., 2017; Yu et al., 2020). These prototypes borrow several features that are well-defined in the scientific literature, such as Public Participatory Geographic Information System (Nummi, 2018; Sieber, 2006), geo-questionnaires (Haklay et al., 2018; Lafrance et al., 2019), and emotional maps (Pánek, 2016). The support of 3D representations in these features that are usually implemented in 2D shows a handful of improvements, such as a better understanding of the complex aspects specific to projects that have a spatial extent (Voinov et al., 2018), the creation of a common language (de Oliveira & Partidário, 2020), or the creation of a visual common understanding of the project shared by all the participants (Land et al., 2013).

Despite the growth in the use of digital technologies, notably with the development of civic technologies that aim to improve interactions between public institutions and the population, authorities seem to show hesitancy and concerns in adopting 3D visuals (Kitchin et al., 2021). This reluctance generates poor opportunities to develop applied practices of digitally generated 3D visual tools in an urban participatory context. As practitioners and scientists, the authors rarely observe projects that endorse these kinds of representations in their development. Even if adopted, authorities (and academics) seem to limit the use of 3D visual tools to a minimal setting, i.e., with a high degree of specificity, limited scalability, or low reproducibility (e.g., Lafrance et al., 2019; Newell et al., 2021; Würstle et al., 2021; Yu et al., 2020). Therefore, in order to evaluate the popular perception of 3D visual tools in participatory planning, this exploratory study aims to identify characteristics, namely the contexts and the practices in which applied digitally generated 3D visuals are endorsed in urban participatory planning. The term *applied* is essential here, because the investigation of this study is conducted on real-case projects that are originally mentioned in paper-based or digital-based media. This uncommon outlook has several benefits, such as the collection of projects influential enough to be mentioned in the media, a different perspective from the state-of-the-art studies that focus only on scientific projects, and the evaluation of projects that are related to the day-to-day work of urban practitioners, which have concerns that may be distant from academic perspectives.

In this media coverage (and additional information inquiry), this study aims to identify the most common characteristics of applied digitally generated 3D visual tools adopted by the authorities from January 2015 to December 2021. Only the urban projects that have a spatial impact on the territory were considered, for instance, the implementation of new highways, the extension of buildings, or the conception of a new tram line. These characteristics are explored in two components: (1) the context in which the visuals are adopted and (2) the technical aspects of the visuals. This classification promotes a state-of-the-art knowledge of the applied practices of digitally generated 3D visual tools in urban participatory planning. An understanding of the misuse, opportunities, and bias of these visualizations in urban planning could lead to creating a better visual design, broadening their use, and ultimately developing better cities. This paper first describes the features that were selected to categorize the different visuals. Next, the approach that was adopted to collect the media articles is described. Then, the findings based on a descriptive interpretation and a feature association analysis are demonstrated. Finally, the findings are discussed, starting with an accurate report of the current situation that will then support the development of prospects to enhance urban planning practices.

## COMPARED ASPECTS AND TYPOLOGY

Participatory approaches have to be shaped according to specific settings in order to be meaningful (Reed, 2008). The nature of these settings is wide-ranging and fluctuates between contextual factors (such as economic, political, social, or linked to the urban project) and technical parameters (e.g., selected medium, visual representation, immersion, device); also, human factors play an active role in the design of the approach (according to the affinity or the experience of the team in charge of designing the approach; Bouzguenda et al., 2020; Bryson et al., 2012; Hrivnák et al., 2021; Ling et al., 2009; Luciano et al., 2018; Sieber, 2006). Digitally generated 3D visual tools as vehicles for the interaction during participatory sessions reflect these various aspects. Three dimensions characterize the design of these visuals: (1) *When?,* which emphasizes the contextual factors; (2) *How?*, which illustrates the technical parameter; and (3) *What?,* which bridges the two parameters together via the urban project itself and its depiction within the visuals (Lovett et al., 2015). Each of these dimensions contributes to challenges that need to be addressed during the design of the visuals: user idiosyncrasies, portrayals, contents, and technologies (Çöltekin et al., 2017).

This preliminary study aims to evaluate the previously mentioned settings through an uncommon approach: media coverage. The use of media articles offers an original perspective to assess current practices of 3D visual tools in urban participatory projects. However, this approach leads to challenges, including the vocabulary and the quality of the information mentioned in the media articles, which strongly vary depending on the media, audience, writers, etc. Therefore, this section describes a precise typology based on the scientific literature, which characterizes the different parameters that will be used to classify the projects.

### Contextual Factors

Contextual factors (*When?*) are crucial elements in the design of the participatory approach. According to their configuration, they could radically change the medium that is employed during a participatory session or limit the degree of freedom of the participants. Media coverage is a method that is limited to published information. Therefore, reestablishing the entire set of contextual factors could be overwhelming and inaccurate because of missing information. Additionally, the different cultural contexts (such as the publishing country) can strongly affect the way the contextual factors are regarded within the article, and the selected perspective may not always be relevant to other cultural contexts (Zhang et al., 2019). Also, due to the diversity of contextual factors, the assessment of their impacts on digitally generated 3D visuals is challenging. Therefore, this article focuses on three project-dependent parameters that are easily recoverable in the media articles and directly related to the 3D visuals: (1) project stage, (2) project scale, and (3) participation level.

#### *The Stage of the Project*

Any project (urban, non-urban, or from the industry) is subjected to a temporal evolution that regulates two elements: the definition of the project and the room to change the project (Chassin et al., 2019; Midler, 1998). This evolution unfurls in stages that traditionally define the life cycle of urban projects: *initiation*, *diagnosis*, *design* (also known as *plan*), *validation* (which depends on the cultural context), *implementation*, and *maintenance* (adapted from Faliu, 2019; Wates, 2010). The role of the 3D visuals and their representation may vary according to the temporal stage, from a design tool using abstraction in the early stage of a project (enhancing creativity) to a communicative tool portrayed with a high level of realism (enhancing comprehension; Hayek, 2011). Other descriptions of the life cycle of a project are also used in current planning practices such as the urban planning pyramid that describes six phases: (1) dialogue, understanding, commitment, and participation; (2) visioning and creation of ideas; (3) common understanding and goals; (4) planning; (5) building; and (6) maintenance (Oliveira e Costa et al., 2018). However, such granularity is difficult to measure in the information recovered from media coverage. Therefore, an adaptation of the traditional stages was selected, where the initiation and the maintenance phase were excluded. The former phase is excluded because this study focuses on projects launched through an authority's initiative, the ladder is because of its lateness in the life cycle of an urban project, and neither provides participatory opportunities.

### *The Scale of the Project*

Urban projects have a strong impact on the territory. This impact, on the one hand, transforms the urban landscape and, on the other hand, alters the modes of practice of the place (Sebastien, 2016). Each project, by its anchor on the spatial dimension, will not have the same impact on the territory. These projects vary in terms of spatial scale (from the parcel to the agglomeration) and temporal scale (from several years to decades; Arab, 2007). Three types of urban projects are selected in this study: (1) *architectural design*, at a smaller scale, which is related to elements within a parcel or a plot such as buildings or parks; (2) *major metropolitan*, at a medium scale, is associated with a district and can aim at transforming a full neighborhood; and (3) *trans-urban*, at a city scale, focuses on new strategies for the development of an entire city (Chassin et al., 2019). These scales are important for the 3D visuals and their portrayals because these scales result from different cognitive spaces (Montello, 1993), which affect the representation and the exploration of virtual environments (Kettunen et al., 2012).

### *The Level of Participation*

The participation continuum (or ladder), which describes different levels at which citizens can affect decision-making, has been extensively investigated in the scientific literature since its introduction (Arnstein, 1969). This continuum has been applied to different topics and has taken different shapes, such as for children's participation (Hart, 1992), for sustainable agriculture (Pretty, 1995), within the form of the wheel of participation empowerment (Davidson, 1998), or under a spectrum of public participation (International Association of Public Participation, 2018). The last spectrum will be considered in this study. Each of these continuums illustrates the role of the citizens in decision-making under hierarchical levels, from lower rungs, where the population is merely informed about the project or even manipulated, to higher rungs, where the public holds power over the final decision. The International Association of Public Participation (IA2P) spectrum introduces five levels: *inform*, *consult*, *involve*, *collaborate*, and *empower*. Advanced participatory tools, such as participatory mapping, have helped to anchor current approaches within the intermediate levels (Babelon et al., 2021). Based on observations, it seems that, unlike participatory mapping, 3D visual tools are adopted for communication and project promotion, located at the information level. Therefore, the entire continuum of public participation has been considered to categorize the recovered projects. IAP2's spectrum is altered by merging the three higher levels (namely, *involve*, *collaborate*, and *empower*) into the term *involve+*. Two reasons motivated this choice: (1) the scarce information mentioned in the press articles does not allow a fine granularity in the higher levels, and (2) the practices of digitally generated 3D visuals in participatory planning rarely seem to reach the higher levels. Participatory levels are considered only for a specific participatory session that uses the 3D visuals and not for the entire approach.

## Technical Parameters

Visual tools, such as digitally generated 3D visuals, seem valuable and even desirable for participatory planning. These straightforward representations of the environment can help to lower accessibility barriers and improve the inclusivity of the participatory processes, yet their technical challenges and design should not be overlooked (de Oliveira & Partidário, 2020; Metze, 2020). Visual representations have a strong impact on how the population perceives a future project. Therefore, they can facilitate the negotiations around aspects under discussion or help the immersion. However, without technical understanding or specific guidelines, the built project can be significantly different from the one conveyed by the visual representations (Downes & Lange, 2015).

Certain parameters of visualization could be favored by the practitioners from their experiences, knowledge, and skills in dealing with these kinds of visuals. Any choice, intentional or not, tends to impact the perceived experience, conveyed values, validity, interactivity, and legibility of the visuals that are being shared with the population (Bailleul, 2008; Raaphorst et al., 2018). The investigation of the technical parameters aims to identify the most popular visual parameters and their correlation with external components, i.e., the contextual factors. This study mainly focuses on three technical parameters: (1) *format*, which evaluates the selected method to broadcast the 3D visual; (2) *control*, which identifies the degree of freedom provided to the participants for exploring the virtual environment; (3) *portrayal*, which recovers the detail of the portrayed virtual models, and their aesthetic representations.

### The Format

Digitally generated 3D visual tools are broadcast during urban participatory sessions in various formats or mediums. A medium is selected based on technological aspects (analog vs. digital) and type aspects (board, poster, projector screen, etc.; Raaphorst et al., 2018). Different 3D mediums are adopted more frequently than others; for instance, computer-aided design (CAD) drawings rendered in 3D (Wanarat & Nuanwan, 2013), videos (Manyoky et al., 2014; Velarde et al., 2017), and immersive virtual reality (Chowdhury & Schnabel, 2020). These mediums change how the participants experience the future urban project, and based on this experience, participants could refine their opinions or contributions to the participatory approach. Therefore, the selection of a format should be mindfully considered by institutions. For this parameter, a specific typology is not defined, but the format employed in the articles will be reported.

### The Controls

The freedom in terms of controls, which allows participants to manipulate or explore a 3D visual actively affects the participants' behavior (Chassin et al., 2021). It has been demonstrated that static vs. interactive or immersive vs. non-immersive representations alter user performance and judgment (Dong et al., 2020; Juřík et al., 2020). Being confronted by user inequities introduced by interactive 3D visual tools (Van der Land et al., 2013; Schroth et al., 2011), institutions face a dilemma about the extent of freedom that should be implemented within the 3D visuals. The interaction functionalities that are implemented in the 3D tools are recovered from the media articles, from non-interaction through navigation and consultation of information to the design of public places.

### The Portrayal

The portrayal of the 3D visuals, as well as their level of realism, greatly affects the cognition of the participants. On the one hand, realistic depictions help with participant orientation and encourage emotional bonding with the project. On the other hand, abstract representations ease the cognitive load conveyed by the visual and tend to focus participant attention on the subject under discussion (Hayek, 2011). Two components constitute the parameter of portrayal: the level of detail (LoD) and the style (i.e., representation).

The *LoD* describes how precise a 3D model is. The definition that classifies LoD into nine levels was adopted, from a simple 3D block to a building that has its interior furniture modeled (Biljecki et al., 2014). This granularity has been aggregated into four main categories to simplify the identification of the detailed levels, which are sometimes hard to differentiate in the recovered 3D visuals: *low* (LoD 0, 1, and 2), which corresponds to simple models with straight wall extrusion, simple roof shape and no vegetation; *medium* (LoD 3, 4, and 5), which may contain a simple balcony, roof structures, and vegetation areas; *high* (LoD 6, 7, and 8), which adds precise vegetation, window opening, textures, and finer structural elements; and *very high* (LoD 9), which is the most accurate model in terms of detail. The role of vegetation is an important factor in the portrayal of urban projects, and occasionally vegetation elements were more detailed than the project representation. In this specific case, the LoD from the project is only considered.

Regarding the *style* or the *visual representation* of the project, three categories were adopted: schematic, realistic, and atmospheric (Raaphorst et al., 2018). The *schematic* style, similar to abstract representations, aims at easing the legibility of the scene. The *realistic* (or *photo-realistic*) representation aspires to mimic reality. The *atmospheric* style, also close to reality, takes advantage of digital filters to smooth the representation and seeks to produce an emotional response.

## RESEARCH APPROACH: MEDIA COVERAGE

The research approach employed in this study (media coverage) mimics the process described for systematic reviews (Kitchenham, 2014). The prospect of these two research methods is similar: collecting all the mentions of a subject under investigation. Typical systematic reviews are articulated around five steps: (1) definition of a strategy to collect the related studies, (2) selection of the relevant studies (first filter), (3) evaluation of the quality of the recovered studies (second filter), (4) labeling of the information present in the studies, and (5) description of the data (Kitchenham, 2014). However, adopting a systematic review approach for collecting media articles that mention the use of digital-generated 3D visuals applied to urban participatory planning is challenging. First, the vocabulary mobilized by these domains is not yet defined, which leads to a profusion of words related to the topic and the development of different corpus between experts. Second, the terminology employed to describe urban participatory planning and 3D visuals is not specific, which implies that a wide range of domains is also using the same terminology. Third, media communication aims to reach a broad, non-expert population. Hence, the stories found in media articles are often abridged and oversimplified. Fourth, the worldwide number of media channels is overwhelming, which makes the identification of relevant articles difficult. Therefore, the procedure for the systematic reviews was adjusted, and a similar approach implemented for the media coverage in this study is presented in Figure 1.

**Figure 1.**
**Description of the steps executed in media coverage**

### Research Strategy: Media Aggregator

Two media aggregators (or databases) are selected to identify and collect the media articles related to digitally generated 3D visuals applied to urban participatory planning, namely Factiva (https://www.dowjones.com/professional/factiva/) and Nexis (https://www.lexisnexis.com/en-us/home.page). The analysis period ranges from 2015 to 2021 and focuses on French-language and English-language media. These two platforms index numerous articles that are published worldwide, which facilitates the exploration of media articles by reducing the number of sources to query without limiting the reach of the data collection. Furthermore, besides having similarities to the approach employed to collect scientific articles with tools such as Scopus (https://www.scopus.com/home.uri) or Web of Science (https://www.webofscience.com/wos/), these tools provide advanced functionalities, which allow more flexibility in the design of the query and the opportunity to conduct progressive filtering methods. However, the adoption of meta-tools implies a challenge and a limit: media channels from several domains are indexed, which leads to severe noise in the data collection; the limited number of media channels that are indexed (e.g., local media are not recorded).

### Database Querying

Before querying the media aggregators, a vocabulary was established, which encompasses the three domains of media coverage: (1) 3D visuals, (2) urban planning, and (3) citizen involvement. Numerous scientific systematic reviews have already been conducted on these domains (e.g., Eilola et al., 2021; Falco & Kleinhans, 2018; Metze, 2020). Therefore, the vocabulary employed in these studies was first adopted, with terms such as (1) *3D*, *visualization*, *virtual globe*, *3D model*, and *digital twin* for the 3D visuals; (2) *planning*, *building*, *design*, and *city* for the urban planning thematic; and (3) *involvement*, *engagement*, *collaboration*, *public*, and *citizens* for the public participation. Queries were challenging to design, and the number of results was often overwhelming and did not perfectly fit with the target. Therefore, the vocabulary of the queries was gradually transformed. The results were also cut down by applying increasingly complex filters. The queries that generated a working number of articles are detailed in Appendix B, along with their filter setups.

### Articles Evaluation: Selection and Identification

The media article headlines returned by the queries were manually scanned. Both media aggregators provide a paginated result layout that shows around 100 headlines per page. These headlines (around 30 words at the longest) can be rapidly identified as relevant or not. The most relevant articles were short-listed and saved. The exported articles were scrutinized in order to identify pertinent aspects of the project, the participatory setup, or the 3D visuals. This step correlates to the *quality assessment* of the systematic review, where the authors determine if all crucial elements for the following analysis are suggested within the articles. If some of these elements were missing (such as a picture of the 3D visual), the lacking data was recovered by browsing information about the urban project on the city website. However, whenever the lacking component was not identified during this exploratory step, the article was dismissed (see Figure 1). Furthermore, the articles were only kept if the use of digitally generated 3D visuals was mentioned in urban projects that have a spatial impact (such as new constructions, new layouts for a park, or extensions of existing structures). The projects related to the redesign of interior spaces were not considered. Moreover, the 3D visuals had to be broadcast to a group of people (public, private, officials, etc.).

### Projects Classification

At this step, all additional information about the project, the participatory setup, and the 3D visuals were already collected. The typology described in this article was used to categorize the articles and projects. The data was gathered in a tabular file, which was then transformed into a CSV file in order to facilitate the comparison of the articles and carry out the analysis. This data is available in Appendix A.

### Description and Analysis

The Python programming language (python.org) was used to analyze and compare the projects' features. Then, Plotly (https://plotly.com/), a graphic library, was adopted to create the different plots. A descriptive comparison was first conducted, then Sankey diagrams were designed to link the different parameters of the urban projects (context) to the ones of the 3D visual tools (technical). Last, statistical tests (chi-square and Fisher's exact test) were estimated using R (r-project.org). This different programming method was used because the implementation of Fisher's exact test in Python does not allow using a contingency table greater than 2 × 2. Chi-square was used if more than 80% of the values of the estimated contingency table were higher than five (Kim, 2017).

### Limits of the Media Coverage: From the Scope to the Wow Effect

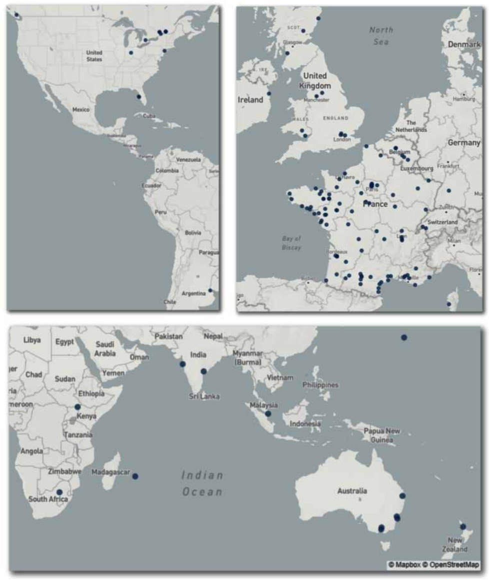
The media coverage approach has numerous benefits, which notably include: the opportunity to reach a worldwide range of media articles (French-language and English-language), and the collection of projects that are applied and adopted by institutions. However, this approach leads to bias that should be considered (Barranco & Wisler, 1999; Earl et al., 2004; McCarthy et al., 1996). First, as mentioned before, the databases list a limited number of stories, which are mainly published on a national or regional scale. However, urban projects are anchored on a local scale, and participatory sessions are applied even on a smaller scale, which is inconsistent with the scope of the media aggregators. For example, a city of a couple of thousand inhabitants that undertakes the renewal of its downtown will not, most of the time, attract the attention of other (larger) cities located hundreds of kilometers away. Therefore, the number of stories mentioning the use of digital visuals in urban participatory planning is expected to be low and incomplete.

Second, Factiva and Nexis aggregate regionally and nationally based media. Therefore, if the story of a local participatory session is published in these media, it often has unusual components (wow effect). Indeed, these components are either related to the technology (digital twin, AR, etc.) or singular contextual factors (such as a strong opposition, the engagement of children, or a strong level of involvement). Therefore, the collected stories are expected to adopt a state-of-the-art approach, i.e., not fully representative of typical urban participatory planning projects. Moreover, opposition groups often politicize the debate by getting media attention. Thus, specific cases mentioning opposition groups and digital visuals could represent a notable number of the collected articles.

## RESULTS

The results presented in this section are based on 132 worldwide media articles published between January 1, 2015, and December 31, 2021. The queries that were conducted on Nexis and Factiva provided more than 30,000 articles that were reduced to 1,300, following the methods mentioned in the previous section. Of these 1,300 short-listed articles, 132 articles fulfilled the required conditions. Surprisingly, 75% of the articles were published in French and 25% in English, in over 15 different countries. Most of the articles were released in France, Canada, the United States, the United Kingdom, and Australia (see Figure 2). Moreover, every continent was represented in this dataset (two from Africa and two from Asia). Each of these articles pictures one urban project using 3D visuals at a specific time; the life cycle of an urban project can see several consecutive 3D representations. Having two articles mentioning the same project at two specific times were rarely encountered; in this atypical situation, the first mention was always kept. The description of the articles through the related parameters is displayed in Appendix A, alongside the metadata. In this result section, the descriptive results of the articles is first shown. Then, in a second subsection, the relationships between the aspects of the urban project, participatory setup, and 3D visuals are investigated.

**Figure 2.**
**Geographic distribution of the articles that have been collected through media coverage**




## From Articles to the Evaluation of the 3D Visual: A Practical Example

To portray the evaluation of the contextual factors and technical parameters, two examples recovered from the press articles will be extensively discussed in this subsection. The objective is to demonstrate the method and assessment as accurately as possible to enhance the reproducibility of this study.

### *Virtual Transect Walk in Rennes, France*

[See Appendix A and the supplementary material for more details]

The story published in 2016 mentions the involvement of the citizens of Rennes, France, through 14 transect walks that aim at helping the population to better appreciate their city and to be able to foresee its future in 2030. Following this broad presentation, the article reports that these transect walks can be conducted in groups during a guided tour, alone, with the help of a guidebook, or virtually thanks to the website called rennes2030 developed by 3DEXPERIENCity (3ds.com). The web application enables users to record georeferenced comments or answer a survey freely. From this document, the identified contextual factors were: (1) the transect walks are spread over the entire city and the name of Rennes 2030 indicates a trans-urban project; (2) the project Rennes 2030 is in its early stage and aims at collecting initial feedback from the population, which demonstrates a diagnosis stage; and (3) these interactive transect walks aspire to collect feedback and insights from the population, which suggests a consultation approach.

The rennes2030 online platform was then investigated. The Web application displays a *digital twin* (the term employed by the provider of the city model) of the city of Rennes, allowing the user to navigate with a birds-eye view through the model at LoD 3. The shapes of the buildings are not too detailed, but a realistic texture from aerial images has been draped on these models. No fog or post-lightning processing has been added. Thus, the style is realistic.

### *Immersion in the New Road Between Troon and Loans, United Kingdom*

[See Appendix A and the supplementary material for more details]

The story was published in 2021 for the city of Troon, United Kingdom. The article presents the design of a new road in consultation with the population. The group that leads the project won a prize for their valuable usage of technology. A 3D video of the road was created to help the residents to understand the project better during its second phase. Besides the video, the 3D model could be visualized from a pedestrian or cyclist perspective with a head-mounted device. Then, the article emphasizes the crucial role of social media and communication. While consulting the website of the project on Sweco (sweco.co.uk/projects/loans-to-troon), it appears that the 3D model was created to aid in conveying the "ideas and ambitions of the project." There was no mention of the use of the video or 3D model in a consultative setup. The project of a road has a large scale but is specific to one structure. Therefore, this road project can be defined as a major metropolitan project. This video was used after the first phase of consultation and was conducted during the design phase of the project. Despite designing the project in consultation with the public, there is no tangible evidence that the video and the project were used in a consultation setting with the population. Thus, the process was defined as passive.

Regarding the 3D model recovered from the project website, the style is realistic, and no interaction is provided within the video and presumably within the immersive VR depiction. The level of detail is systematic, with details such as light poles and trees with their leaves; however, the sides of the road (e.g., sidewalk and grass) seem to be less detailed. Therefore, the LoD was evaluated as 7. The additional buildings were designed schematically (LoD 1). Since they were not part of this project, they were not considered.

## Descriptive Results

### *Contextual Factors*

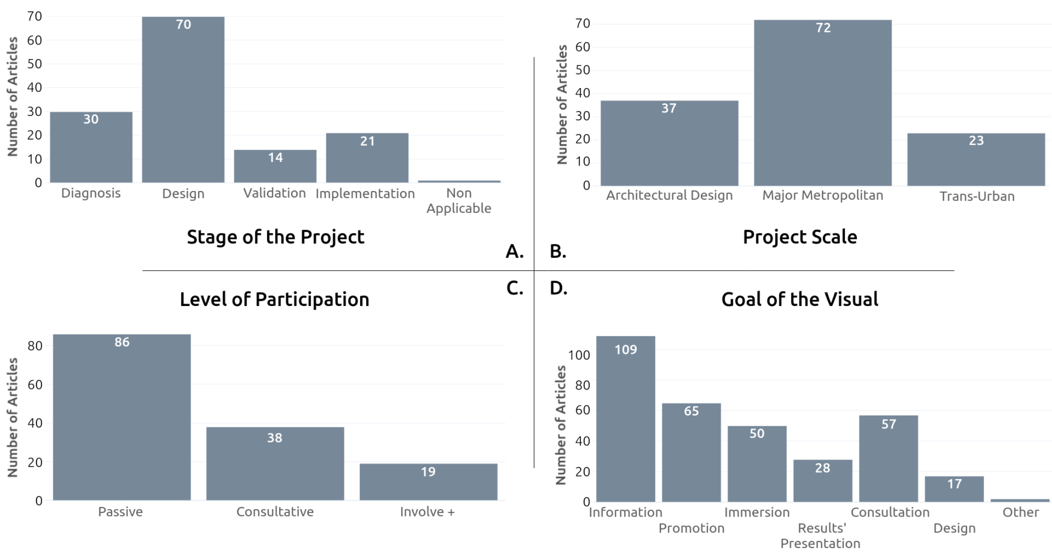
To evaluate the preferred contextual factors in which 3D visuals are adopted in urban participatory planning by authorities, the frequency of the aspects identified in the press articles was analyzed. Four parameters were assessed: (1) stage of the project, (2) project scale, (3) level of participation, and (4) the goal of the visual, which indicates the objectives of the authorities when endorsing and sharing the 3D visual tools (see Figure 3).

Digitally generated 3D visuals appear to be mostly adopted in the design phase of the urban project (49%; see Figure 2A). This phase is highlighted by a shift in the role of the 3D visuals, which shift from a design tool to a communicative tool, where the main goals are about informing and immersing the participant or promoting the project (for 68% of the total goals; see Figure 3D). Moreover, presenting the results of previous interactive sessions or participatory steps adds 8% to the communicative property of the 3D visuals.

The visuals are adopted in a design or consultative setup for only 23% of all the goals identified (see Figure 3D). This low interactivity between the participants and the 3D visuals is highlighted by the level of participation, which remains in the lower rungs, namely *passive* (60%) and *consultative* (26%; see Figure 3C). These two levels show that participants are mostly receivers of information but may provide feedback that is regarded as suggestive and not as a contribution to the negotiation area. In the few examples of interactive participation, the authorities tend to endorse visuals that are shared through serious games (representing around 50%). Therefore, it seems that 3D visuals are mostly used to promote and sell an urban project to the population rather than engaging them in the design of the same project.

The last aspect to be mentioned is the project scale, which shows that digitally generated 3D visuals are adopted in medium and small urban project scales, namely the major metropolitan (55%) and the architectural design (28%; see Figure 3B). The digital visuals portraying trans-urban projects are largely described as *digital twins* (about 70%) that aim, according to the providers, to create a digital copy of a city in order to enhance the efficacy of some processes, such as simulation, citizen involvement or urban development, such as portrayed by the rennes2030 project.

**Figure 3.**
**Distribution of the articles and 3D visuals according to the contextual factors**

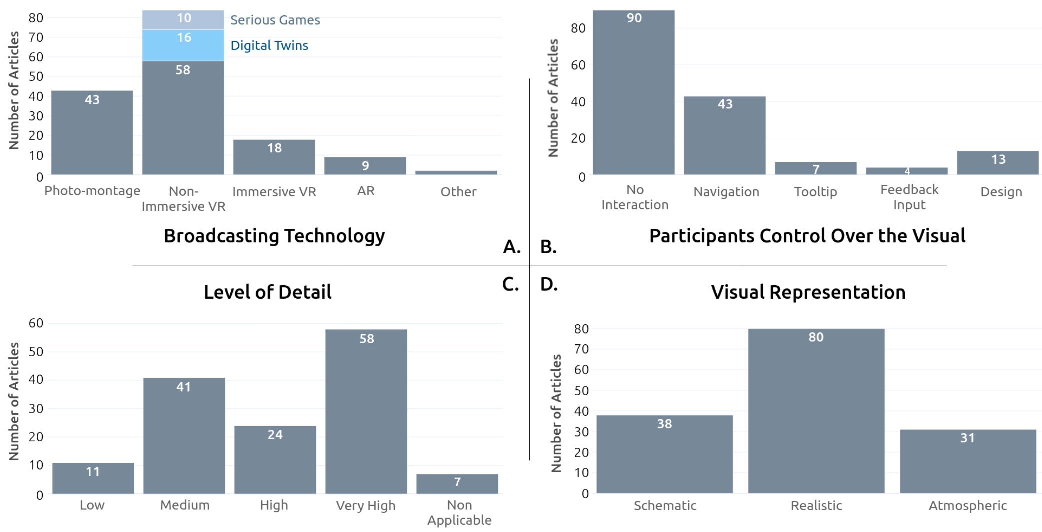



### *Technical Parameters*

To investigate the technical parameters of the 3D visuals that are typically adopted in real urban projects, the prevalence of the visual characteristics was assessed regarding four aspects: (1) the broadcasting technology of the visuals, (2) the freedom that the participant has in controlling the 3D visuals, (3) their level of detail, and (4) their visual representation (see Figure 4). The authorities mainly adopt photomontage or non-immersive VR to create and share the 3D visuals (see Figure 4A). Other technologies such as immersive VR (experienced through cardboard or head-mounted devices), augmented reality (AR), and mixed reality are also used, but to a lesser extent (around 20%), which is notable even though the wow effect bias should be considered (see the section on the limits of the approach and the wow effect). Moreover, the visuals are mostly produced with limited interaction. The results show that 57% of the visuals do not provide any type of interaction (see Figure 3B), which reduces the opportunities to provide feedback from the participants. The preferred formats are static images or video clips that correspond to a practice, which is limited to communication purposes (as seen in the previous section). Basic exploration is also implemented, such as navigation (27%), but it is often restricted to a pre-recorded setup of localizations. This constrained set of perspectives is, on the one hand, convenient for creators of the model, who do not need to design the whole area and can limit their work to the visible spaces, hence limiting the time and cost required to create the 3D visual. On the other hand, limited mobility is also favorable for the authorities, who can impose the points of view through which participants will explore the project. Surprisingly, only rare articles (11%) mention the use of visuals as a medium to gather digital contributions from the participants (see Figure 4B).

The appearance of the 3D visuals shows a preponderance of realism, with 58% of the models having at least a high level of detail (see Figure 4C) and 54% a realistic representation (see Figure 4D). This hyper-realistic representation of the future urban project is in line with current technological advances in 3D that are seen in computer-generated imagery (CGI) and video games. However, this representation crystallizes the image of the project, which therefore offers no prospects to integrate negotiated elements provided by interactive sessions with the population. Moreover, the popularity

**Figure 4.**
**Distribution of the articles and 3D visuals according to the technical parameters**




of realism does not appear to be in line with projects that are conducted during their design phase (see Figure 3A). During this phase, digitally generated 3D visual tools should help to gradually build a legitimate image of the project, from an abstract to a more realistic representation of the project. Therefore, this massive adoption of realistic representation demonstrates the use of 3D visuals at the end of the design phase.

### *Temporal Evolution*

To investigate the reach of digitally generated 3D visuals in urban participatory planning, the articles were characterized by year of publication (see Figure 5). This distribution aims at assessing the penetration of the 3D visuals per year and also at comparing their use of online vs. onsite formats. An interesting advantage of depicting the recurrence of 3D visuals per year is to be able to evaluate the impact of the COVID-19 pandemic on their use in the urban participatory project.

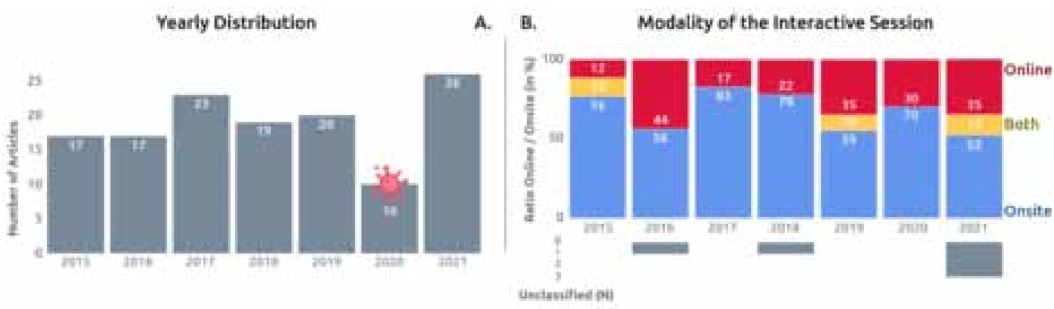
No significant trends were observed on these graphs. The year 2020 is marked by a dramatic drop in the number of publications mentioning the use of 3D visuals (see Figure 5A). This drop was expected with nearly a complete stop of urban participatory planning projects due to the COVID-19 pandemic. The year 2021 shows a return to a more regular situation.

Regarding the relative number of projects having an online/onsite setting, there is evidence to suggest a moderate increase in online projects since 2017 (see Figure 5B). However, the pandemic years (2020 and 2021) do not demonstrate a revision of this trend, which does not demonstrate an adaptation of the participatory practices induced by the exceptionally long duration of the sanitary measures. It seems that the authorities aspire to keep adopting traditional in-person participatory approaches since their improvised experiments with online tools were unsuccessful during the pandemic.

## Association of the Parameters

The previous section shows the frequency of each selected contextual factor and technical parameter. The popularity of some of those characteristics highlights the settings of interactive sessions that are the most likely to be adopted by the authorities in real-case scenarios. This overall picture is valuable to understand better how 3D visuals are currently adopted in urban design projects. However, the

**Figure 5.**
**Yearly distribution of the press articles**




connection between technical and contextual factors is not mentioned within these raw descriptive results. The next figures (see Figures 5–7) show a representation of the combined frequency of the technical and contextual factors using Sankey diagrams. Furthermore, in order to assess the statistical dependence of technical and contextual factors, a chi-square test or a Fisher's exact test value was calculated for each of the associated parameters.

### *Project Stage vs. Technical Parameters*

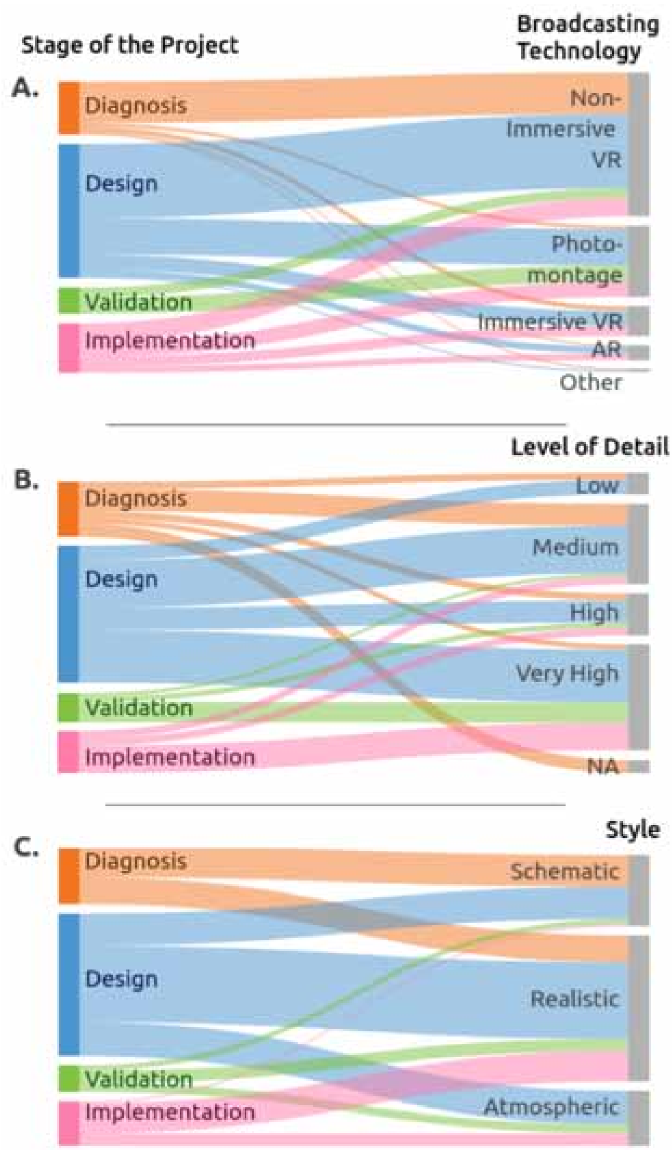
To investigate which technical parameters tend to be adopted depending on the project stage, a Sankey diagram was created (see Figure 6). The results suggest that the early stage of the urban project, i.e., diagnosis, adopts mainly non-immersive VR that offers more flexibility to the practitioners in terms of participatory tasks, interactivity, and representation. Furthermore, this flexibility leads to a less conclusive version of the portrayed project. In contrast, static photomontages are rarely employed (typically used in later stages). The adoption of explorative methods is also shown in the LoD parameter, which demonstrates a high diversity in distribution, including 3D models created with Minecraft (minecraft.net) tagged as *non-categorized level* (NA). Moreover, no post-processed visuals (atmospheric style) are in use at this stage, which limits the consolidation of a static image of the project in the participants' collective imagination.

The design stage is more equally distributed, which is not surprising because this stage is situated between the early and late stages of the project; therefore, it uses different representations with diverse objectives. However, this stage appears to enclose most of the visuals adopting photomontage. A lower level of detail (low and medium) seems to describe most of the collected visuals of the design stage, but extensive use of high and very high level of detail was also observed. This transitive stage adopts each of the styling representations, which is coherent with the range of applications of the design stage. If the urban project is in the early stage, thus, near the diagnosis phase, the abstract representation may be used, and on the contrary, during the late stage of the project, the realistic representation may be more suitable.

During the validation and implementation stage, the timeline of the urban project is greatly reduced and becomes more tangible. The objectives of the visuals within these stages are to settle the project in the collective imagination of the communities/participants. Therefore, more immersion and realism are preferred to engage the population within the future project, notably through the use of immersive technologies in VR or AR, a higher level of detail, and a style depicting realistic 3D scenes.

Fisher's exact test was used to investigate the independence of these two parameters (project stage vs. technical parameters). The tests demonstrate that all the technical parameters (broadcasting technologies, levels of detail, and style) are correlated with the stage of the project and that these relationships are not random. For this statistical test, the values *other* from the broadcasting technologies and *NA* from the level of detail were not considered.

**Figure 6.**
**Diagrams showing the intensity of the connection between the stage of the project and the technical parameters. Panels A, B, and C represent this information in the shape of a Sankey diagram which links the nodes of each parameter together**




## *Project Scale vs. Technical Parameters*

The same technical parameters were investigated with another contextual factor: the project scale. The findings are depicted in Figure 7. Smaller scales, i.e., architectural design projects, seem to be related to more realism within the visuals with a strong proportion of a very high level of detail and post-processed representations (atmospheric style). At this scale, the space, which is affected by an urban project is limited, which leads to moderate 3D scenes that are faster and less restrictive to design, which encourages more complexity (highlighted by ahigh and very high level of detail). Also, a small-scale model consumes less computational power to render properly. Moreover, at this scale, all broadcasting technologies are employed, and an important connection is highlighted for the photomontage. The use of photomontage is not surprising considering it is a visualization of a small area, which is easier to portray than a large environment.

The medium scale urban projects, namely major metropolitan, are portrayed by various kinds of broadcasting technologies adopting diverse styles and levels of detail. Being the most frequent scale mentioned in the articles, a larger diversity is identified in its practice and representation, for instance in significantly adopting augmented reality, photomontage, immersive virtual reality, and non-immersive virtual reality. Furthermore, as with architectural design projects, major metropolitan projects lean toward more realism with, notably with a very high level of detail. Moreover, a medium level of detail was also observed for major metropolitan projects, which can be explained by the variation of scale encountered in these kinds of projects, from revitalizing the downtown of a city to planning a highway through an island.

The trans-urban projects mobilize the largest scale; therefore, their portrayal is challenging due to the number of elements in the model. For this scale, only two broadcasting technologies are observed, where non-immersive VR are adopted in most of the cases. The level of detail is mainly low and medium with a few exceptions. There was no connection between trans-urban project vs. atmospheric representation; this hindrance could be explained by the computational expansivity of the post-processing techniques used to create the atmospheric view. Furthermore, atmospheric representations are essentially adopted for highly detailed scenes, which are scarce at this scale. Moreover, atmospheric representations often apply a fog effect in order to mimic an artistic look. This fog tends to blur the visual, which can be an issue for seeing far elements in the scene that nevertheless may be related to the project.

Regarding the Fisher's exact tests, the scale of the project shows a strong correlation with all the technical parameters again. For this statistical test, the values *other* from the broadcasting technologies and *NA* from the level of detail were not considered.

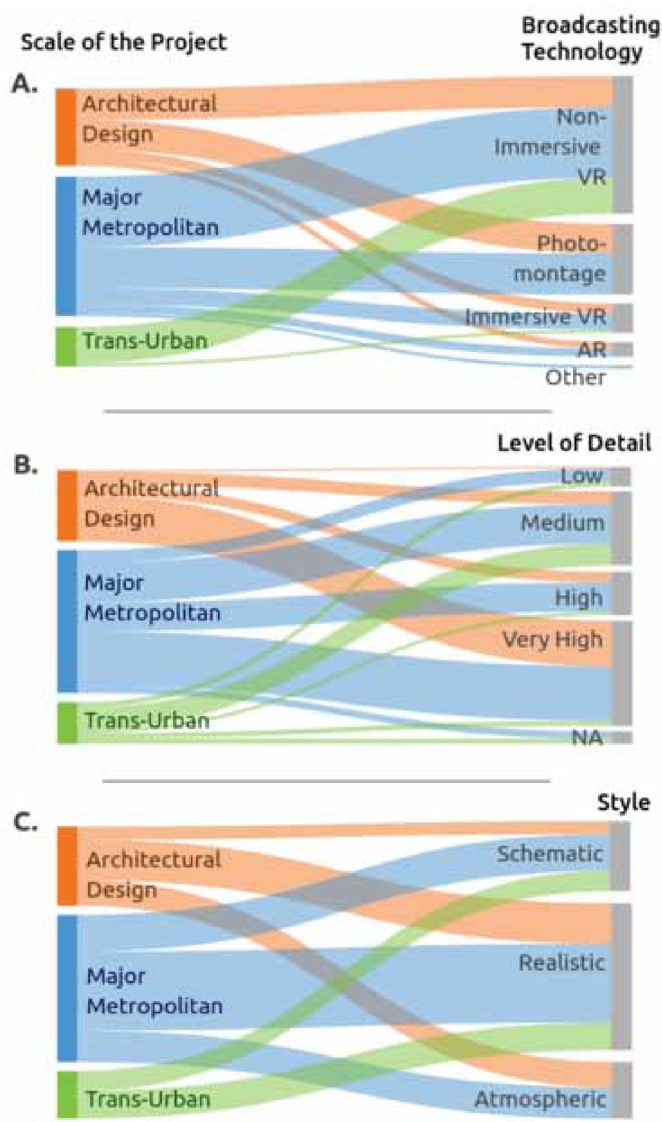
### *Participation Level vs. Technical Parameters*

The last flow diagram shows the relation between the participation level and the technical parameters (see Figure 8). Passive involvement appears to be skewed more toward realism and non-interaction, which is not surprising. Photomontage and immersive VR are prevalent in this passive level, where the visuals have more likely a communicative and immersive role. This passive involvement places participants in an observer position, seemingly in the later stage of the urban project with visuals that accurately represent the future reality, in order to support emotional bonding and engagement with the project. Also, passive involvement tends to use a high or very high level of detail.

The consultative level is characterized by the adoption of the full range of technical possibilities. However, this level of participation seems to be limited to a medium or high level of detail. These two modes of detail appear to represent, on the one hand, a project that is not too accurate, i.e., the project is still unclear and evolving, thus, a fixed image is not conveyed. On the other hand, a project that is less open to future transformation is, thus, more precise and definite. The *involve+* participation mobilizes different technologies to portray the visuals. Nevertheless, non-immersive VR was the most frequently observed one, notably because it supports a flexible implementation. Furthermore, this interactive setup adopts mainly an undefined level of detail (NA), which is constituted by the use of Minecraft (seven projects). This participatory level is also in line with a schematic portrayal, i.e., more abstract, supporting the introduction of salient features which help participants focus on specific aspects under negotiation during the interactive session.

Fisher's exact tests were conducted for the broadcasting technology and the level of detail, and a chi-square test was conducted on the style parameter. No correlation was established between the technical parameters and the participation level. For this statistical test, the values *other* from the broadcasting technologies and *NA* from the level of detail were not considered.

**Figure 7.**
**Diagrams showing the intensity of the correlation between the scale of the project and the technical parameters. A, B, and C represent this information in the shape of a Sankey diagram which links the nodes of each parameter together**

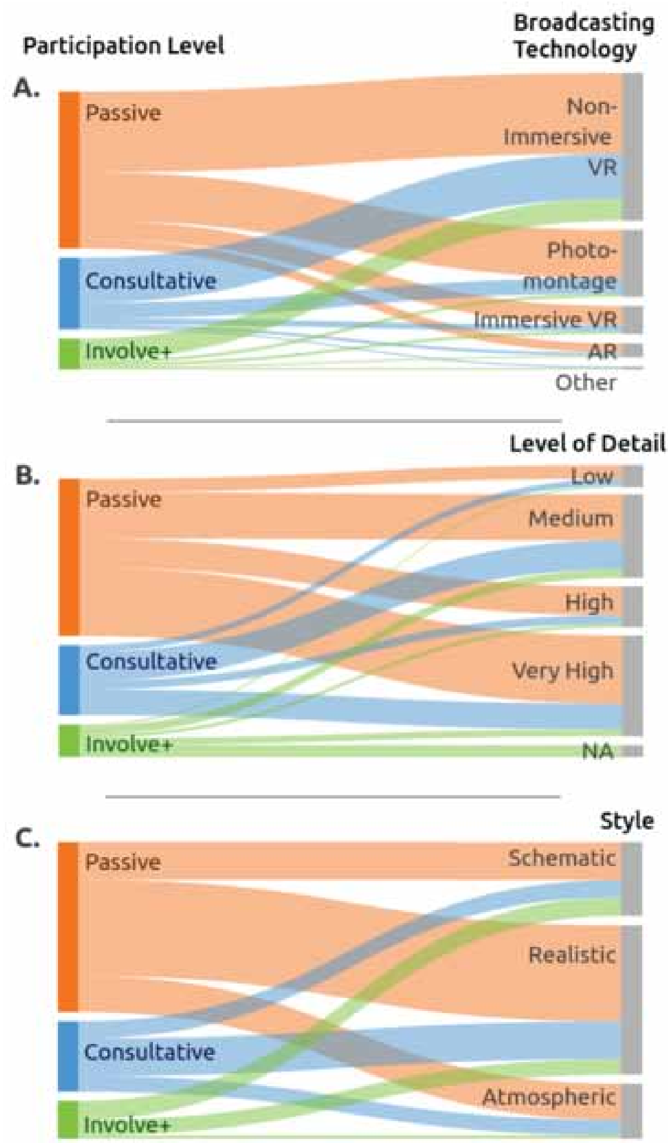



## DISCUSSION

### Current Practices of 3D Visual Tools in Urban Participatory Planning

This study demonstrates an apparent preeminence of certain characteristics of digitally generated 3D visual tools adopted in urban participatory planning. The results illustrate that these tools are mainly adopted in major metropolitan projects (at a medium scale), during the later phases of the project's design (where numerous aspects of the urban project appear to have already been defined), which leads to the passive involvement of the population with the 3D medium. This passive level of participation seems, however, to be bound to the specific usage of 3D visual tools; it indeed appears (from the articles) that most of the approaches designed by the authorities mobilize the population in

**Figure 8.**
**Diagrams showing the intensity of the connection between the levels of participation and the technical parameters. A, B, and C represent this information in the shape of a Sankey diagram which links the nodes of each parameter together**




a consultative context. The technical parameters resulting from these contextual categories illustrate more realism and details (in line with the later phase of the project) combined with limited opportunities to manipulate the 3D visuals (in line with the passive context of involvement). These findings are valuable because they provide a better understanding of the typical settings of 3D visual tools that are currently adopted by the authorities in urban participatory approaches. This snapshot of today's practices in participatory planning demonstrates a limited diversity of uses despite the high potential of 3D visual tools acknowledged in the scientific literature (Jacquinod & Bonaccorsi, 2019). This lack of opportunities seems to highlight a hesitancy of the institutions to adopt these visuals, which may be caused by poor knowledge of the benefits of these mediums, lack of abilities to implement them due to their inexperience with the 3D medium, reluctance to change their current practices, or the cost of implementation (Heldal, 2007; Houghton et al., 2014). Furthermore, 3D visual tools are complex to implement efficiently due to several challenges to address through their design (Chassin et al., 2019; Billger et al., 2016).

Furthermore, clear and expected relations have been established between contextual and technical parameters. For instance, the described findings showed the use of rendered, accurate and detailed 3D visuals broadcast through video or photomontage toward the later stages of urban projects. Realism facilitates communication, intuitive representation, and the creation of emotions that can help to promote a positive image of the future project (Hayek, 2011; Lovett et al., 2015; Voinov et al., 2018), notably by using a signifier that conveys an interpretation (e.g., the depiction of a child playing that points out the safety of the space; Raaphorst et al., 2017). Conversely, visuals appear to often be designed with less detail when the urban scale of the project is large. 3D still requires high computational power to render, which tends to limit the size of the environment that is virtually represented. Also, the participation level *involve+* seems to adopt more schematic representations that help to develop opinions and new ideas (Hayek, 2011) and focus the attention of the participant on their tasks, notably by limiting the cognitive load conveyed by the 3D (Judge & Harrie, 2020; Skulmowski & Rey, 2020). These findings of adopting abstract representation in the early stage and realistic in the later stage of the project are in line with the idea of matching the level of detail to the planning phase (Kibria et al., 2009).

One of the most striking findings of this study is the final number of articles mentioning the use of 3D visuals, a relatively low number considering the extensive search that has been conducted. This low number demonstrates poor visibility of the 3D visual tools in participatory planning, at least in the media. The simplicity and flexibility of sharing these visual tools online could have been valuable during the COVID-19 pandemic. However, the findings did not demonstrate a dramatic rise during or after this exceptional period. Moreover, the conduction of different observations and discussions with practitioners has highlighted an increase in negative feelings toward the use of online settings, which could suggest poor applicability of 3D visual tools in urban participatory planning. One example is the low number of participants attending these online sessions, which demonstrates a failure of these online methods. Nevertheless, the online sessions designed during this period appear to mimic in-person, more typical interactive sessions, and thus, are not designed for an online medium, which leads to a gap. This simulation of in-person settings cannot work online. The interactive session should be shaped according to the characteristics of the medium adopted.

## The Case of Digital Twins and Serious Games

Several articles (12%) mention the use of 3D visuals via the implementation of a digital twin (Deng et al., 2021) or, more accurately, a city model (Wright & Davidson, 2020). This technology is used in the context of urban participatory planning with two objectives: (1) being able to communicate about future urban projects by sharing information and visualizing 3D models, and (2) consulting the public on specific issues. These solutions that represent a digital, identical image of the city appear to be a new opportunity for the institutions to share and promote future projects or explain their development strategies to the population while being able to collect feedback on these elements through virtual georeferenced comments shared by the population. Another benefit of these large virtual environments is the representation of the entire city and the availability of a set of participatory functionalities; therefore, these platforms could be reused over time, limiting the need to create 3D models and a platform from scratch for each project, thus limiting their cost. However, these digital models are often mentioned during the first phases of their development, and only a few implemented functionalities are in production.

Other articles (7.5%) report the use of serious games, which can be considered as an exploratory solution to engage the population, mostly in the diagnosis phase. These tools facilitate the participation and interaction of the population while enhancing knowledge-building in the urban project (Reinart & Poplin, 2014). Most of these video game platforms identified in this media coverage are based on Minecraft, which allows the digital recreation of a natural environment with virtual interlocking blocks. In addition, more than half of the projects adopting serious games aim at engaging children or young adults (already familiar with the game), which are often regarded as hard to reach in typical participatory approaches because common practices are poorly adapted to the needs and competencies of young people (Frank, 2006). The use of serious games could, therefore, provide new opportunities to digitally mobilize a population by leveraging some of the intrinsic and extrinsic motivational factors (Lotfian et al., 2020), such as learning, recreation, and interaction with other players (Gagnebien & Bailleul, 2016). These two new methods of involvement represent around 20% of all the recovered approaches. A striking result is that these solutions are not primarily designed for urban participatory planning purposes but are nevertheless adopted by the authorities. The other recovered 3D visual models appear to be employed only once in one-off projects, even if these representations may be reused several times throughout the lifetime of the urban project. The flexibility offered by digital solutions like city models and serious games seems to increase their adoption in various participatory projects endorsed by the institutions, despite their complexity to implement in participatory planning.

## CONCLUSION

These results reflect the current applied practices of digitally generated 3D visual tools in urban participatory planning. To that end, an analysis of media coverage was conducted from January 2015 to December 2021. This investigation generates a snapshot of the 3D visual tool settings adopted by institutions in urban planning during these six years. The descriptive analysis demonstrates that the current use of 3D visual tools aims mostly to promote urban projects, with only rare approaches capitalizing on the added value of 3D representations for participative interaction. Therefore, it appears that these reduced applications do not mobilize the full potential of 3D visual tools, despite the technological advancements, the broad adoption of 3D visuals in other domains, and the acknowledgment of 3D benefits. The perception of these tools by academics and their day-to-day use by practitioners seem to not be in line, which demonstrates a gap between these two understandings of 3D visual tools.

The collected projects and their descriptive parameters (see Appendi*x* A) show a high versatility, which is related to the assessed contextual factors and other social, financial, political, cultural, or operational factors. The findings help to link technical parameters to contextual factors, which can be used as a framework to design future approaches. However, the exploration of other settings should not be disregarded. Furthermore, no compelling yearly patterns were identified from 2015 to 2021, even with the COVID-19 pandemic (apart from a drastic reduction in 2020), which is surprising. This stagnation in the use of 3D visuals (covered in the media) seems, hence, to convey concerns about their adoption by institutions.

The collected media articles gathered by the media coverage method demonstrate a significant diversity in terms of projects and 3D visuals and show the success of this method by the unexpectedly high number of articles found (more than primarily predicted), even if this number remains relatively low. However, some biases should be considered. For instance, the overrepresentation of French language articles is difficult to explain. However, two hypotheses can be mentioned: (1) the French-language media channels aggregated through the Factiva and Nexis search engines appear to have regional scopes as opposed to the English-language media, which seem to have a national scope; and (2) the participatory vocabulary varies greatly between projects or municipalities, and the terms used by practitioners in applied urban projects may be significantly dissimilar compared to the ones adopted in the scientific literature.

The authors argue that the use of 3D visual tools could be a true asset for urban participatory planning. Effective involvement of the population in planning should be a priority for practitioners. However, limited budgets, distrust in technological solutions, lack of opportunities, or unclear guidelines may contribute to the limited adoption of 3D tools in participatory approaches. Increased publication of articles about current experiences or practices of 3D visual tools in the media could promote their adoption in urban participatory planning by increasing their visibility for practitioners.

## PERSPECTIVES FOR THE FUTURE 3D URBAN PARTICIPATORY PLANNING

This exploratory study highlights the potential as well as the limited implementation of digitally generated 3D visual tools in urban participatory planning. Their adoption was observed in several distinct settings, both contextual and technical. Two main practices were identified for these tools: the first being communication and the second supporting participatory interactions. The communicative purpose (i.e., one-way exchange) is the most important goal identified in this media coverage. A notable overrepresentation of realism, passive participation, and goals aiming at immersion, promotion, or information was demonstrated. The scientific literature highlights 3D visual tools as assets to enhance communication about urban projects, notably by facilitating the comprehension of complex aspects of urban projects that are difficult to describe without visual tools (Bouzguenda et al., 2021; Hayek, 2011; Schroth et al., 2011; Voinov et al., 2018). The other purpose, enabling participative interactions, is less displayed in the collected media stories. Therefore, these practices need to be increasingly adopted in applied projects. Projects that have already been using 3D visual tools could contribute to an arsenal of participatory settings (technical parameters) and pioneer experiences, which may be remobilized to gradually improve the design of 3D visual tools in participatory planning.

Technology-driven participatory mechanisms have already demonstrated their efficiency, and citizens show interest in using digital tools that are straightforward and user-friendly, with a low entry cost (Bugs et al., 2010). However, the institutions appear reluctant to adopt these tools in applied projects due to a lack of clear guidelines, a plethora of settings to consider, and challenges in interpreting the collected data, which could be discouraging. Also, the benefits of 3D visual tools do not seem to be fully acknowledged by the institutions, which are stuck with more typical practices (such as surveys, workshops, or public hearings) due to habit and concern about the adoption of new approaches. Therefore, the collection of past experiences in the media could help to develop common imagery of the different practices of 3D visual tools in the authorities' participatory toolbox. Nevertheless, past experiences should be cataloged, and guidance for the implementation of these 3D tools should be provided. This pool of practices could improve knowledge around the use of 3D visual tools by aggregating similar practices (which could declutter the load of information around the adoption and use of these tools), envisioning different settings, reimplementing pioneer solutions, and gathering patterns to design new approaches. In the near future, institutions and practitioners could design their participatory approaches from this knowledge base.

The 3D visual tools have already demonstrated their efficiency and their added value for urban participatory planning (Appleton & Lovett, 2003; Herbert & Chen, 2015; Schroth et al., 2011). These benefits should now be translated to broad adoption of applied practices. The institutionalization of participatory practices (Blatrix, 2009) and the imperative for participation (Blondiaux & Sintomer, 2002), notably in urban planning, do not provide the institutions with a blueprint to design better participatory approaches. This lack of guidelines leads the same authorities to often struggle to engage urban dwellers (Innes & Booher, 2004). Further research in the use of 3D visual tools in participatory planning is still necessary, along with an accurate evaluation of these tools on the practices, and the planning outcomes. This research should be associated with future guidance that helps the authorities to select and design participatory approaches that fit their needs. Participatory planning approaches should indeed be designed for a target public and a specific context. Therefore, digital tools or 3D visualizations are not always appropriate but should be considered as an additional set of participatory tools that should to be combined with other more typical tool in order to increase the inclusiveness of the participatory approach.

## CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

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## APPENDIX A

### Description of the Collected Data

The raw data used to conduct this study has been published in open access on Zenodo (doi: 10.5281/zenodo.7582318). The description of this data is presented below:

- **Title:** Title of the article
- **Link:** Link to recover the articles online. All the links were retrieved at the latest on January 6, 2022. Certain links ask for payment to be consulted
- **Words count:** Number of words that the article contains
- **Body:** The body of the article, retrieved from the aggregators (Factiva and Nexis)
- **Date of Publication:** Day, month, and year on which the article was published
- **Language:** Main language employed in the article; [FR = French, EN = English]
- **Project Location:** Location of publication; [city, country identifier in 2 letters]
- ***x*:** Longitude of the location
- ***y*:** Latitude of the location
- **Same Visual as Article:** *Yes* if the visual is present in the article (via a link or an image); *recovered* if the visual was recovered from the investigation
- **Visual Link:** Link to the visual. All the links were retrieved at the latest on 01.06.2022.
- **Project Stage:** Stage of the project
- **Project Scale:** The scale of the project
- **Participation Level:** Level of participation
- **Technology:** The technology used to broadcast the visual mention in the format
- **Medium:** Medium used to share the visual (subcategory of technology)
- **Interaction Type:** Type of interaction implemented to explore the visual
- **Visual Goal:** The goal of the visual material
- **Participation Location:** Location where the visual is consulted (e.g., public hearings, mobile app, workshop)
- **Audience:** Who consulted the visual (e.g., buyers, neighbors, public, officials, professionals)
- **Online vs. Onsite:** The setting in which the visual appears
- **Realism:** Realism of the visual described by Raaphorst et al. (2018)
- **Style:** The style of the visual described by Raaphorst et al. (2018)
- **LoD:** Level of detail of the depicted project described by Biljecki et al. (2014)
- **Angle of View:** Angle of view used to represent the project (e.g., first person or birds-eye-view)
- **Model Animation:** *static* = the model is not animated; *animated* = the model contains an animation (persons, cars, trains, etc.)
- **Representamen:** Small contextual elements represented in the visual in addition to the project such as vehicles, humans, or vegetation
- **Detail of Model Surroundings:** An additional layer of information present in the visual and their representation (e.g., basemap, realistic/abstract buildings)
- **Aggregator:** Aggregator in which the article was recovered (e.g., Factiva or Nexis)

## APPENDIX B

## Description of the Aggregator Queries

All the queries (and their filters) used to recover the articles were as follows.

### *French Queries*

#### 32 articles were short listed from this query

| | | |
|---|---|---|
| **Search Terms** | *(concertation OU engagement OU consultation OU information OU participat!) ET (publi! OU citizen! OU citoyen! OU participat! OU civic OU population) ET (maquette OU mod?l! OU virtu?I! OU mock-up! OU mockup!) ET (urban! OU aménagement OU batiment OU projet OU building OU project OU planning OU development OU architectur!) ET 3D SAUF (BIM OU impression OU imprimante OU print!)* | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Publication type: Newswires & Press Releases, Blogs, Newspapers, News Transcripts, Web-based Publications, Magazines & Journals,Aggregate News Sources, UNDEFINED, News, Newsletters, WebLinks, Video, A udio - Sujet: Science et technologie, Société, aide sociale et style de vie, Tendance et événement - Industries: Informatique et technologie de l'information, Média & télécommunication; Language: English, French - Areas: Europe, Amérique du Nord.* |

#### 90 articles were short listed from this query

| | | |
|---|---|---|
| **Search Terms** | *3D ET (participat* OU coconstruction OU concertation) SAUF imprimante* SAUF impression SAUF cinéma* | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Language: French - Timeline: janv. 01, 2015 au déc. 31, 2021 - Publication type: Newspapers, Newswires & Press Releases, Magazines & Journals, Web-based Publications, Newsletters, UNDEFINED, WebLinks, Blogs, News - Subject: Gouvernement et administration publique,Sciences sociales, Population & démographie,Science et technologie, Société, aide sociale et style de vie - Industries: Informatique et technologie de l'information,Bien de consommation, Média & télécommunication* |

#### 377 articles were short listed from this query

| | |
|---|---|
| **Text** | *3D and (participat* or coconstruction or concertation) not imprimante* not impression not cinéma* |
| **Date** | *01/01/2015 to 31/12/2021* |
| **Source** | *Toutes les sources* |
| **Auteur** | *Tous les auteurs* |
| **Company** | *All Companies* |
| **Subject** | *All subjects* |
| **Industry** | *All industries* |
| **Area** | *All areas* |
| **Language** | *Français* |
| **News Filters** | *Industires: Not Construction automobile Not Activités en amont: pétrole brut/gaz naturel Not Banques/Organismes de crédit Not Fonds/trusts/instruments financiers Not Transport aérien de passagers - Subject: Not Arts et spectacles Not Sports* |

## *English Queries*

**54 articles were short listed from this query. This query has been recovered from (Eilola, Jaalama, et al., 2021).**

| | | |
|---|---|---|
| **Search Terms** | *("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")* | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Timeline: 01 janv. 2015 au 13 oct. 2021 - Language: English - Publication type: Web-based Publications Newspapers, NewsTranscripts, Blogs, Magazines & Journals,Video,Newsletters, News - Subject: Rapport, critique et rubrique, Science et technologie* |

**84 articles were short listed from this query**

| | | |
|---|---|---|
| **Search Terms** | *("3D geo visuali*ation" OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D environment*) OR "virtual geographic* environment*" OR (3D visuali*ation*) OR (3D representation*) OR (3D 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 reconstruct*) OR "CityGML" OR "City Engine" OR (3D geospatial) OR (3D technolog*) OR (3D simulation*) OR "3D geo*information" OR "digital earth" OR ("second life" 3D) OR "geo*virtual*" OR "3D geodesign") 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* "interacti*") OR ("communit* "interacti*") OR ("stakeholder"* interacti*") OR ("resident* interacti*") OR ("citizen* interacti*") OR ("participa* involv*") OR ("communit* involv*") OR ("stakeholder* involv*") OR ("resident* involv*") OR ("citizen* involv*")) AND (("building*" OR "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*" OR transform*))* | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Timeline: Jan 01, 2015 to Dec 31, 2021 - Publication type: Web-based Publications, Newspapers,Blogs - Subject: Government & Public Administration,Science & Technology, Society, Social Assistance & Lifestyle* |

**87 articles were short listed from this query**

| | | |
|---|---|---|
| **Search Terms** | *(visuali*ation OR virtual*) AND (plan* OR design*) AND (participa* OR communit* OR resident* OR citizen* OR public) AND 3D* | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Publication type: Web-based Publications, Newspapers - Language: English; Subject: Science & Technology* |

**8 articles were short listed from this query**

| | | |
|---|---|---|
| **Search Terms** | *(3D OR "virtual geographic environment*" OR "virtual globe*" OR "digital twin") 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*")) SAUF print** | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Timeline: janv. 01, 2015 au déc. 31, 2021 - Language: English; Subject: Gouvernement et administration publique - Industry: Informatique et technologie de l'information - Publication type: Blogs,Web-based Publications, Newspapers* |

**19 articles were short listed from this query**

| | | |
|---|---|---|
| **Search Terms** | *((3D w/3 visual*) OR (3D w/3 draw*) OR (3D w/3 illustrat*)) 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*" w/3 "interacti*") OR ("stakeholder*" w/3 "interacti*") OR ("resident*" w/3 "interacti*") OR ("citizen*" w/3 "interacti*"))* | |
| **Search Type** | *Terms and Connectors* | |
| **Narrowed by** | **Content Type** | **Narrowed by** |
| | *News* | *Timeline: janv. 01, 2015 au déc. 31, 2021 - Publication type: Newspapers, Web-based Publications, Blogs* |

**110 articles were short listed from this query**

| | |
|---|---|
| **Text** | *(3D OR "virtual geographic environment" OR "virtual globe*" OR "digital twin") 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*"))* |
| **Date** | *01/01/2015 to 31/12/2021* |
| **Source** | *All sources* |
| **Author** | *All auteurs* |
| **Company** | *All companies* |
| **Subject** | *All subjects* |
| **Industry** | *Technologie ou Immobilier/Construction* |
| **Areas** | *All areas* |
| **Language** | *English* |
| **News Filters** | *Industry: Not Impression 3D et 4D - Subject: Not Informations sociétaires et industrielles* |

**126 articles were short listed from this query. This query has been recovered from (Eilola, Jaalama, et al., 2021).**

| | |
|---|---|
| **Text** | *("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 w/3 simulation*) OR "3D geo?information" OR "digital earth" OR ("second life" w/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*" w/3 "interacti*") OR ("stakeholder" w/3 "interacti*") OR ("resident*" w/3 "interacti*") OR ("citizen*" w/3 "interacti*"))* |
| **Date** | *01/01/2015 to 31/12/2021* |
| **Source** | *All sources* |
| **Author** | *All auteurs* |
| **Company** | *All companies* |
| **Subject** | *All subjects* |
| **Industry** | *All industries* |
| **Areas** | *All areas* |
| **Language** | *English* |
| **News Filters** | *Subject:* *Not Informations sociétaires et industrielles* |

**14 articles were short listed from this query**

| | |
|---|---|
| **Text** | *((3D w/3 visual*) OR (3D w/3 draw*) OR (3D w/3 illustrat*)) 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*" w/3 "interacti*") OR ("stakeholder*" w/3 "interacti*") OR ("resident*" w/3 "interacti*") OR ("citizen*" w/3 "interacti*"))* |
| **Date** | *01/01/2015 to 31/12/2021* |
| **Source** | *All sources* |
| **Author** | *All auteurs* |
| **Company** | *All companies* |
| **Subject** | *All subjects* |
| **Industry** | *All industries* |
| **Areas** | *All areas* |
| **Language** | *All languages* |

**28 articles were saved from this query**

| | |
|---|---|
| **Text** | *(concertation or consultation or information or publique or public or citizen* or citoyen* or participa*) and (maquette or mod?l* or virtu?I*) and (urban* or aménagement or batiment or projet or building or project or planning) and 3D not (BIM or impression or print*)* |
| **Date** | *01/01/2015 to 31/12/2021* |
| **Source** | *All sources* |
| **Author** | *All auteurs* |
| **Company** | *All companies* |
| **Subject** | *All subjects* |
| **Industry** | *All industries* |
| **Areas** | *All areas* |
| **Language** | *All languages* |
| **News Filters** | *Companies: Not National Natural Science Foundation of China - Economic sector: Not Extraction de minerai d'or - Subjects: Not Informations sociétaires et industrielles Not Crimes/Tribunaux Not Epidémies - Sources: Not CE Noticias Financieras (Latin America) Not Federal Register (U.S.) Not NewsRx Medical Newsletters - All sources Not PR Newswire - All sources Not Dow Jones Newswires - All sources Not Public Companies News and Documents via PUBT - Language: Not Portugais Not Espagnol* |

## *French and English Queries*

**262 articles were saved from this query**

| | |
|---|---|
| **Text** | *(concertation or consultation or information or publique or public or citizen or citoyen* or participat*) and (maquette or mod?I* or virtu?!*) and (urban* or aménagement or batiment or projet or building or project or planning) and 3D not (BIM or impression or print*)* |
| **Date** | *Last 5 years* |
| **Source** | *All sources* |
| **Author** | *All auteurs* |
| **Company** | *All companies* |
| **Subject** | *All subjects* |
| **Industry** | *All industries* |
| **Areas** | *France or Switzerland* |
| **Language** | *French or English* |

**77 articles were saved from this query**

| | |
|---|---|
| **Text** | *(concertation or consultation or co-construction or participat*) and (publique or public or citizen or citoyen* or population) and (maquette or mod?!* or virtu?I*) and (urban* or aménagement or batiment or projet or building or project or planning) and 3D and (futur* or new or nouveau) not (BIM or impression or imprimante or print*)* |
| **Date** | *01/01/2015 to 31/12/2020* |
| **Source** | *All sources* |
| **Author** | *All auteurs* |
| **Company** | *All companies* |
| **Subject** | *Résumé des informations ou Prospectus ou Liens audio-visuels ou Interviews ou Informations générales ou Images ou Extraits ou Enquêtes/Sondages ou Editoriaux ou Critiques ou Conseils ou Communiqués de presse ou Commentaires/Opinions ou Blogs ou Articles à la Une ou Analyses ou Agendas ou Education ou Immobilier/Maison ou Mode de vie ou Société/communauté ou Transport ou Commentaires et conseils d'experts ou Conférences et expositions ou Environnement/Social/Gouvernance ou Gestion des connaissances et de l'information ou Innovations commerciales/de rupture ou Législation et politique gouvernementale ou Numérisation ou Partenariats/Collaborations ou Recherche et développement ou Sociétés - Modifications et changements ou Technologie de l'information ou Top News* |
| **Industry** | *All industries* |
| **Areas** | *All areas* |
| **Language** | *French or English* |
| **News filter** | *Companies: Not DBS Bank Ltd Not GoGold Resources Inc. Not Environmental Protection Agency Not National Marine Fisheries Service Not Monetary Authority of Singapore Not U.S. Fish and Wildlife Service Not US Securities and Exchange Commission Not Union Européenne Not Vermilion Energy Inc. - Source: Not Federal Register (U.S.)* |