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COMMUNICATIVE TOOLKIT OF VIRTUAL REALITY IN MODERN DESIGN PRACTICE AND ITS IMPACT ON PARTICIPATORY PRACTICES

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Abstract. This study examines the impact of virtual reality (VR) as a communicative tool in architectural design, specifically in the stages of analysis, modeling, and designing architectural environments. The global and Ukrainian experiences of using VR in the project process are compared, with a focus on participatory practices involving active engagement from the public and other stakeholders. The study explores how virtual technologies change the interaction between project participants and open up new opportunities for the future development of these practices.

The research analyzes successful case studies where VR has become an effective tool for improving communication and decision-making, comparing it to traditional methods of public engagement. Special attention is given to the influence of virtual technologies on the architecture profession, as well as the changes occurring in the processes of design and communication.

A key feature of the publication is the development of a model that systematizes the experience of using VR in architectural practice and identifies the potential of VR to optimize interaction between project participants at different stages of design. The study offers new approaches to forming participatory practices in the context of digital technologies and outlines the main advantages and challenges that may arise when integrating them into architectural practice.

Virtual technologies have immense potential to enhance communication and improve interaction with the community. They not only allow visualizing the final result but also modeling potential development scenarios of the urban environment, assessing risks, and evaluating possible consequences for the environment, society, and the economy. According to recent research, VR contributes to accelerating decision-making processes in public discussions by enabling the demonstration of different project options and obtaining real-time feedback, which improves the accuracy and speed of decision-making.

Thus, virtual technologies hold significant potential for improving participatory practices, providing more interactive, realistic, and effective interaction between all participants in the design process. However, for their widespread implementation, it is necessary to overcome technical and organizational barriers that limit their use. Further research will help not only refine tools for participatory design but also expand educational programs by integrating VR as a core tool for modeling, analysis, and designing architectural environments.

Keywords: virtual reality, architectural design, participatory practices, communication, interactive technologies.

Relevance of the research.

In the modern world, virtual reality (VR) is becoming an important tool in many fields, including architectural design. The significance of this topic is particularly evident in the management of architectural activities, where communication gaps frequently arise between architects, clients, municipal authorities, and the community.

Thanks to VR's ability to replicate reality with exceptional accuracy and detail, this technology creates new opportunities to enhance collaboration and interaction among all participants in the project process. It can significantly ease decision-making, identify potential problems, model alternative options, and minimize errors and misunderstandings that often arise with traditional

working methods. As a result, the use of VR has the potential to reduce design costs and timelines, while also fostering more efficient and effective communication. The research is especially relevant for modern architectural practice, where we observe the need for adaptation to new technological realities and changes in the ways communication occurs among project participants.

Statement of the problem. Despite the enormous potential of virtual reality in supporting participatory practices in architecture, the implementation of this technology in design processes and public engagement faces several challenges. One of the main issues is the adaptation of traditional communication methods and public involvement to the digital domain. This requires significant efforts from architects and designers, as well as from the community and clients, who are often unprepared to integrate new technologies into their workflows. Therefore, it is crucial to determine which types of virtual reality – ranging from VR to augmented reality (AR) or mixed reality (MR) – are most effective for ensuring active citizen participation at various stages of the design process, from analysis and modeling to decision-making.

Another challenge is the need to establish effective interaction between architects, clients, the community, and other stakeholders, which is a vital aspect of participatory practices. The use of VR can significantly improve this process by creating an interactive environment for exchanging ideas, identifying needs, and visualizing future changes. However, for VR to be effectively implemented, it is crucial to clearly identify the stages of the design and interaction process where the technology will be most beneficial, while also evaluating its limitations and potential. This will enable the development of recommendations for its optimal integration into architectural practice and public communication processes.

Analysis of recent research and publications. Søren S. Sørensen was engaged in research on augmented reality in architecture and argued that AR serves as an intermediary for idea development between the designer and the client [1]. Jürgen Döllner suggests creating 3D models of virtual cities as integrated, complex systems that utilize diverse information about urban spaces. The application of this standardized model can be done through various layers, which will visually represent the urban environment. These layers should include terrain, buildings and vegetation, roads, and transportation systems. The 3D model of the virtual city is aimed at combining three categories of data: cadastral data with buildings and ownership rights, a digital terrain model, 3D building models obtained through laser scanning and photogrammetry methods, and architectural models with historical references [2, 3].

Hartmut Seichter researched aspects of the collaborative design process alongside the use of 3D models and AR tools. Experiments were conducted to capture users' reactions to tools in the fields of design communication, physical interaction, and the concept of presence. Observations showed that the introduction of new methods and tools for a better understanding of space is effective for design processes [4].

Xiangyu Wang demonstrates the connection between MR, VR, and AR, highlighting their potential applications in architecture and design. The researcher explores various software and its use at different stages of the design process [5]. Julie Milovanovic emphasizes two key aspects of AR and VR: interaction and immersion. She investigates the application of AR and VR at different stages of the design process [6].

The analysis of the cultural city and the research of the communication it generates were carried out by scientists Rudi Papa and Llazar Kumaraku from the Sapienza University in Rome, Italy. They focused on the multifunctionality of architectural communication in the material dimension and its intangible component, as well as the integration of virtual reality technologies into cultural heritage [7].

The uses and challenges of applying VR in architecture were investigated by researchers from Effat University in Jeddah, Saudi Arabia, dividing them into several categories, namely: landscape, building, interior and exterior [8]. The aim of the study by Majed Alzara from Jouf University in Al Jawf Region of Saudi Arabia, was to use modern technologies for virtual rebuilding and data documentation of the old market in the city of Domat al-Jandal [9].

Jing Wen and Masoud Gheisari from University of Florida, Gainesville, Florida, USA, studied the use of virtual reality to facilitate communication in the fields of architecture, engineering, and construction, which exist in a dynamic environment and require regular communication between multiple stakeholders. The researchers note that current communication practices do not meet the demands of increasingly complex projects and highlight the trend towards creating a digital communication environment for stakeholders [10].

Currently, the procedures for using VR for various project tasks, such as analysis, modeling, and designing architectural environments, are insufficiently researched. Existing studies only superficially highlight the impact of VR on participatory practices and how virtual technologies change communication with urban communities. Therefore, there is a need for a more in-depth analysis and systematization of current practices for community engagement. This will enable a more precise identification of tools that can enhance the quality of interaction and communication among project participants.

Purpose. The purpose of the paper is to identify the features of using virtual reality as a communicative tool in participatory architectural design practices, as well as to develop a model that allows systematizing the experience of using VR during the analysis, modeling, and design of the architectural environment.

Presentation of the main material. In analyzing the theoretical experience related to the topic of our study, we found that research on the communicative tools of VR and their potential for engaging communities in shaping urban environments is a particularly promising direction. Thus, we will contrast traditional participatory practices with those incorporating virtual technologies.

In foreign design practices, significant attention is given to the public assessment of project decisions by residents. Participatory practices in architectural design foster greater engagement of communities and stakeholders in the decision-making process, leading to more inclusive and accountable projects that take into account the interests of various population groups. Feedback from the community aids in more accurately formulating the project brief, justifying the selection of methods for solving it, and evaluating the completed project solution, etc. [11, 12, 13, 14, 15, 16]. Let us now examine some examples of traditional participatory practices.

Figure 1 shows a multifunctional residential complex located at a prominent site in the heart of Copenhagen’s harbor. This site had been a gap in the continuous rows of old warehouses positioned perpendicular to the harbor and had served as both an architectural and political arena in Copenhagen for over a decade.

Fig. 1 Housing complex Krøyers Plads, Copenhagen, architects Vilhelm Lauritzen Architects and COBE

When the final project for this beautiful historical location was developed by the architects Vilhelm Lauritzen Architects and COBE, many architectural proposals had already been rejected by

local organizations and politicians for various reasons. In 2003, an architectural competition for the site was announced. The community disliked the initial proposal, and the city council rejected the district's planning. As a result, a new master plan for the area was commissioned from BIG company. However, in 2006, the project was once again rejected by the city council and halted due to the financial crisis. It was only in 2011, when a new proposal by Vilhelm Lauritzen Architects and COBE was presented, that it received positive feedback from the community and was approved by the city council. Construction began in 2012 and was completed in 2016 [17].

If participatory practices are not properly implemented, it can lead to project delays. One of the main reasons for this is insufficient community involvement at early stages, such as analysis, modeling, and concept development. Instead of active participation during the project creation phase, the community is often only engaged at the stage of evaluating the final project solution. This limits the opportunity to consider the needs and feedback of all stakeholders at early stages, which can later lead to additional revisions and delays.

Figure 2 depicts a workshop involving both residents and architects, centered around a residential project in Munich. Completed in 2016, this project was part of an innovative architectural design approach that prioritized active resident participation. This approach integrated participatory practices, where residents played a direct role in creating and shaping the living space, rather than merely assessing it at the final stages [18].

Fig. 2 Workshop of residents and architects of a housing project in Munich (image: Udo Schindler)

In contrast to traditional participatory practices, let's consider the experience of conducting participatory practices with the use of VR. In the Millennium Park project in Chicago (Fig. 3), virtual reality played a key role in engaging the community in the park's development process. The creation of interactive virtual models allowed residents to explore different parts of the park, interact with the design, and provide real-time feedback. This enabled the community to actively participate in the conceptualization and design process, fostering a greater sense of involvement in the project. Architects from Skidmore, Owings & Merrill utilized VR for virtual tours, which facilitated effective communication among project participants and garnered support from the city's residents [19].

Fig. 3 Project “Millennium Park”, Chicago

In the project for the new railway station and railway line in Oslo (Fig. 4), virtual reality was actively used at all stages, from analysis to design. The VR program was developed by a joint venture between Scandinavian engineering giants Sweco and Rambøll Group, based in Stockholm and Copenhagen, respectively. To kick off the project, a VR theater was set up in the city of Moss, where residents could virtually “ride” through the future station and railway, providing feedback at the early stages. VR helped identify transportation infrastructure issues before construction began. Autodesk InfraWorks was used to model the road infrastructure, allowing the evaluation of different traffic scenarios. The station was modeled with high detail using Navisworks Simulate, ensuring all architectural and engineering solutions were considered. The BIM Track program facilitated interactive communication with the public, allowing their input to be incorporated during the design phase [20].

Fig. 4 Project for a new intermediate station and 10-kilometer railway line, Oslo, architects Rambøll/Sweco

Another interesting example is the project within the "Rebuild by Design" initiative in New York (Fig. 5), aimed at restoring infrastructure after Hurricane Sandy and developing measures to protect against flooding and storm surges. Virtual reality was used to analyze and model the potential outcomes of various infrastructure changes, such as strengthening the coastline, integrating green infrastructure solutions, and improving drainage systems. The community actively participated, providing feedback on preferences and priorities, which helped create more resilient and effective solutions for protecting the city from natural disasters. The use of VR allowed for testing possible changes in the landscape and construction, contributing to the improvement of the city's defenses against future threats [21].

Fig. 5 Project within the "Rebuild by Design" initiative, New York

"The Tide" project in London became an example of effective interaction between architects and the local community through AR technologies and traditional participatory practices. The initial stages involved public consultations and open forums where residents could share their thoughts, ideas, and discuss potential changes in the urban environment. Residents were able to interact with real-time 3D models of the embankment using mobile applications, evaluating architectural solutions and providing feedback. This interactive process allowed their suggestions to be incorporated, improving the landscape design and the integration of the water space with the urban environment [22].

In "The High Line" project in New York, architects held public events to engage with the community, presenting project concepts and ideas while gathering feedback and suggestions from local residents and stakeholders [23].

Architects conducted consultations with community representatives, local authorities, organizations, and public interest groups to discuss key aspects of the project. To engage a larger audience and provide opportunities for interaction with the project, virtual reality was used to recreate the new reconstruction plan of a well-known park area. Residents were able to participate in virtual tours and share their thoughts on the new design.

In "The Shipyard Project" in San Francisco, USA (Fig. 6) [24], architects used virtual reality to create virtual models of future residential complexes and infrastructure, allowing local residents to explore and share their thoughts on the development of the area. Augmented reality was also employed in this project to create interactive visualizations in the real world.

Fig. 6 Project of the San Francisco Shipyard

Within the project “MINDSPACES” artists and architects initially created a design for the city square, which was then transformed into a digital simulation. Local residents could “see” the modeled project by wearing a pair of VR glasses. Users also utilized lightweight devices that measured brain activity, skin response, and pulse while exploring the virtual space. These diverse scenario testing models are created to help architects receive real-time feedback on the impact of projects on mental health. Neurologists, using specialized devices, can determine the most inspiring or emotionally appealing aspects of the proposed design [25].

To systematize the contemporary experience of using VR tools, we have developed a model that reflects the interaction of project participants with the environment through various types of virtual reality (Fig. 7). This model is applied in practical activities during the analysis, modeling, and design of architectural environments.

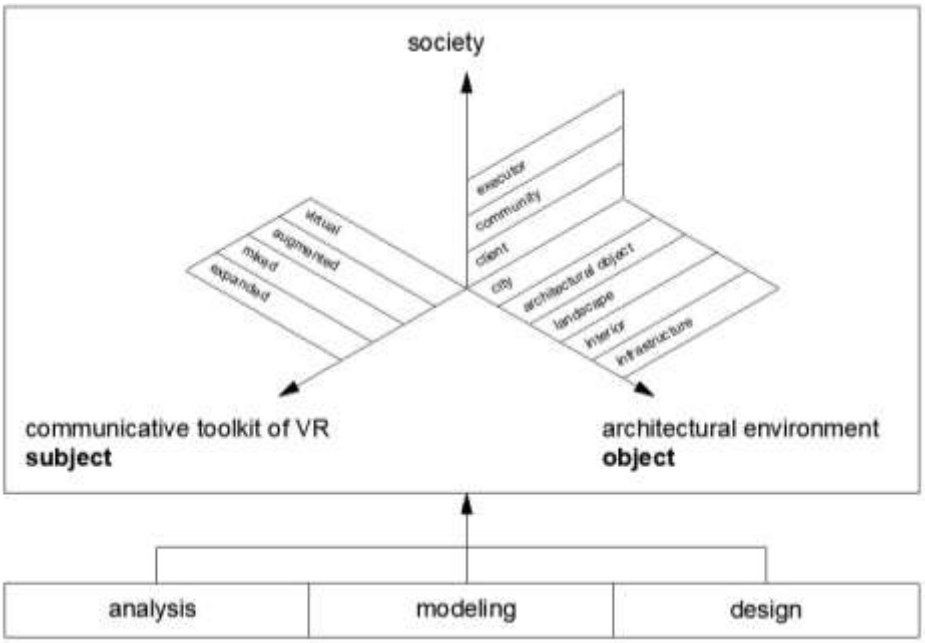

Fig. 7 Model of interaction between project process participants and the environment

The Ukrainian experience of using virtual reality in significant urban and community projects is more often related to the analysis and modeling of architectural environments. VR can play a particularly important role in the preservation and popularization of cultural heritage.

The Ukrainian team Skeiron is engaged in digitizing architectural landmarks and creating their 3D models. They closely collaborate with regional and local authorities, foundations, and architectural studios, focusing on the digital preservation of Ukraine's most valuable monuments [26].

The Shukhevych Museum in Lviv was destroyed by a Russian attack (Fig. 8). It is planned to rebuild it after the victory, and for this purpose, the digital model created by Skeiron in 2021 could be very useful (Fig. 9) [27]. Additionally, those who did not have the chance to visit the museum in person can explore it through the digital model.

The company has also created an app that allows users to "unveil" the historical architecture of Khmelnytskyi and see what it looked like in the past, before the ads, signs, and other changes.

In 2021, Skeiron worked on a heritage promotion project in the city of Khmelnytskyi. They researched old photographs and drawings, conducted laser scanning of buildings and streets. Based on this data, they created 3D models of 37 historical buildings. As a result of their work, Proskurivska Street was recreated in its authentic form, free of ads and other visual noise. The outcome can be viewed using a special app: you point your phone's camera at a building, and it uses augmented reality technology to reveal the building's original facade, removing any unnecessary elements.

The goal of this project is to draw the community's attention to the issue of preserving and restoring architectural heritage, as it impacts the city's tourism and investment appeal.

Fig. 8. Fire at the Shukhevych Museum after shelling

Fig. 9. 3D model of the Shukhevych Museum

An interesting practice took place in Kharkiv and Kyiv, where an art festival focused on VR and AR was held. The idea behind the festival was to offer cities certain modern solutions and "integrate" art into urban spaces. For this, the possibilities of augmented reality were used: QR codes were placed on the streets, and with their help, people could see sculptures created by artists for the project on their phone screens. This way, thanks to the latest technologies, it was possible to show what these art pieces would look like in the city if there were no budget or form restrictions [28].

In general, the practice of using VR and traditional participatory methods in Ukraine, unfortunately, has not yet become widespread. Due to the legacy of the Soviet system, residents often believe that a building ends at the door of their apartment, and that the creation of the architectural environment is the responsibility of certain services, architects, and authorities. However, we are currently seeing the emergence of active communities that want and are able to participate in shaping the urban environment.

In our opinion, the use of VR at the city level will help engage citizens and provide effective communication tools to interact, influence the condition of their yard or neighborhood, and contribute to the overall shaping of the city's architectural environment. Virtual models will allow people to view the city not as a set of separate systems (transport, economic, social, etc.), but to see the overall urban fabric. This approach will help to better understand scale, experiment more, and make necessary changes to the model faster.

Additionally, integrating all components of the city into one model will improve communication between various services and give residents a real opportunity to influence the urban fabric. Such a model will also promote the development of related fields, such as tourism, navigation systems, climate research, noise studies, and more.

In summary, looking at global and Ukrainian practices, we can determine that virtual reality can promote the development of participatory practices in the following ways:

1. *Virtual public presentations and virtual tours of future objects.* Architects can create virtual models of upcoming projects or urban infrastructure that can be used during public meetings and consultations with residents. Virtual tours of future objects will make it easier to understand their scale and overall concept. The creation of three-dimensional virtual models of cities or their parts for analyzing urban infrastructure development, road networks, building placement, etc., allows planning urban development and expansion in a more effective way. Architects can also use VR to create interactive presentations that may be more persuasive and effective in highlighting key aspects of projects.

For example, the company Iris VR developed a platform that allows users to view 3D models of buildings in virtual reality, improving communication between architects, clients, and other participants in the project process [29].

2. *Interaction in virtual environments.* VR can create opportunities for architects, communities, and authorities to collaboratively work on projects, make changes, discuss details, and make decisions in real time within virtual environments. This enhances communication and mutual understanding between architects, the community, and the authorities, fostering greater public involvement in the discussion and alignment of urban development projects.

3. *Virtual tourist attractions*. Creating virtual tourist routes to attract tourists and promote the city's tourism appeal is a new way to communicate about the city and reveal its tourism potential.

4. *Simulation of planning crisis situations*. Using VR to train evacuation plans, analyze human behavior in emergency situations, and assess potential risks in urban environments.

The development of such participatory practices involving VR must be implemented with the support of IT specialists.

Conclusions. Analyzing modern global practices, it becomes obvious that virtual technologies are shaping a new experience of participatory practices:

1. Augmented reality (AR) is more accessible for implementation in participatory design processes, as its technologies require less specialized infrastructure. At the same time, virtual reality (VR) provides a much deeper and more realistic effect, allowing users to fully immerse themselves in a simulated environment and interact with it at all stages of design. However, mixed reality (MR) and expanded reality (XR) are rarely used due to their technical complexity and high cost of integration into existing workflows.

2. Traditional participatory practices are usually limited to gathering public opinions and feedback at the stages of project presentation and evaluation, often carried out through meetings, discussions, surveys, workshops, and physical models. Modern participatory practices using virtual technologies significantly expand interaction possibilities by providing more interactive simulations, real-time testing, and modeling. They offer a deeper and visually comprehensible representation of projects, allowing the community and stakeholders to actively engage with the future environment.

3. In global practice, virtual technologies are actively used at all stages of design – from analysis and modeling to actual design, where they facilitate decision-making, allow for the quick

identification of potential problems, and optimize projects. This accelerates the decision-making process and enables the impact of a project on the urban environment to be assessed at early stages.

In Ukraine, virtual technologies are primarily used at the stage of modeling and analyzing existing architectural solutions, particularly for demonstrating projects, preserving cultural heritage, or creating interactive exhibitions. Unfortunately, they are still less commonly applied in the design of new objects, but they already serve as a powerful communication tool for conveying the value of cultural heritage.

4. To systematize the modern experience of using VR tools, we have developed a model that reflects the interaction of project participants with the environment through various types of virtual reality. This model not only allows to systematize the use of VR at different stages of design but also identifies the most effective tools for specific tasks. It can also be used to formulate recommendations for architects and urban planners on integrating VR into their workflows, optimizing the use of this technology according to the needs at each project stage.

5. It is worth noting that, in global practice, we have not yet found examples of virtual participatory practices that specifically engage special social groups such as children, elderly people, or individuals with disabilities. However, in our opinion, the use of VR in participatory practices opens up opportunities for research within social groups that do not perceive drawings. For example, VR could be used to analyze the behavior of children in virtual spaces of a future school or kindergarten. Thus, we are observing an expansion of possibilities for obtaining feedback from social groups of various age categories.

Virtual technologies have enormous potential for improving communication and enhancing interaction with the community. They allow not only to visualize the final result but also to model potential development scenarios for the urban environment, assess risks, and evaluate the possible consequences for the environment, society, and the economy. According to current research, VR helps accelerate decision-making processes in public discussions by allowing different project options to be demonstrated and feedback to be gathered in real time, which improves the accuracy and speed of decision-making.

Thus, virtual technologies have significant potential to enhance participatory practices, ensuring more interactive, realistic, and effective interaction among all participants in the design process. However, for their widespread implementation, it is necessary to overcome the technical and organizational barriers that currently limit their application.

Future research prospects. Further research of VR application in participatory practices can significantly expand opportunities for engaging the community in the formation of urban environments. Studying the mechanisms of interaction between architects, clients, and the public through VR will help create new models of collaboration, where the technology will become an important tool for communication and idea exchange. Promising areas for research include studying social interaction in virtual environments, analyzing the impact of VR on the perception of architectural concepts, and exploring ethical considerations in VR usage, particularly regarding privacy and user security.

It is also important to assess the effectiveness of VR in visualizing and interacting with architectural projects, as this could improve decision-making at various stages of design. Further research will not only refine tools for participatory design but also expand educational programs, integrating VR as a key tool for modeling, analysis, and design of the architectural environment. Ultimately, this will allow for the development of criteria to assess the effectiveness of VR in design and the integration of new technologies into traditional architectural practices.

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КОМУНІКАТИВНИЙ ІНСТРУМЕНТАРІЙ ВІРТУАЛЬНОЇ РЕАЛЬНОСТІ У СУЧАСНІЙ ПРОЄКТНІЙ ПРАКТИЦІ ТА ЙОГО ВПЛИВ НА ПАРТИСИПАТИВНІ ПРАКТИКИ

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Анотація. У даному дослідженні розглядається вплив комунікативного інструментарію віртуальної реальності (VR) на архітектурне проєктування, зокрема на стадіях аналізу, моделювання та проєктування архітектурного середовища. Порівнюється світовий та

український досвід використання VR у проєктному процесі, з акцентом на партисипативні практики, що включають активну участь громадськості та інших зацікавлених сторін. Зокрема, розглядається, як віртуальні технології змінюють взаємодію між учасниками проєкту та відкривають нові можливості для розвитку цих практик у майбутньому.

Аналізується досвід успішних кейсів, де VR став ефективним інструментом для полегшення комунікації та прийняття рішень, порівнюючи його з традиційними методами залучення громадськості. Окрему увагу приділено впливу віртуальних технологій на професію архітектора, а також на зміни, що відбуваються в процесах проєктування та комунікації.

Особливістю публікації є розробка моделі, що систематизує досвід використання VR в архітектурній практиці, а також визначення потенціалу VR для оптимізації взаємодії між учасниками проєкту на різних етапах проєктування. Дослідження пропонує нові підходи до формування партисипативних практик у контексті цифрових технологій, а також визначає основні переваги та виклики, які можуть виникнути в процесі їх інтеграції в архітектурну практику.

Віртуальні технології мають величезний потенціал для поліпшення комунікації та покращення взаємодії з громадою. Вони дозволяють не лише візуалізувати кінцевий результат, а й моделювати потенційні сценарії розвитку міського середовища, оцінювати ризики та можливі наслідки для навколишнього середовища, соціуму та економіки. З огляду на сучасні дослідження, VR сприяє пришвидшенню процесу прийняття рішень у громадських обговореннях, дозволяючи демонструвати різні варіанти проєктів і отримувати зворотний зв’язок у реальному часі, що покращує точність і швидкість прийняття рішень.

Таким чином, віртуальні технології мають значний потенціал для вдосконалення партисипативних практик, забезпечуючи більш інтерактивну, реалістичну та ефективну взаємодію між всіма учасниками проєктування. Однак для їх широкого впровадження необхідно подолати технічні та організаційні бар’єри, що обмежують їх застосування. Подальші дослідження допоможуть не лише вдосконалити інструменти для партисипативного дизайну, але й розширити навчальні програми шляхом інтеграції VR як основного інструменту для моделювання, аналізу та проєктування архітектурного середовища.

Ключові слова: віртуальна реальність, архітектурне проєктування, партисипативні практики, комунікація, інтерактивні технології.