CHAPTER 21

Enhancing Urban Planning using AR/VR Methods

Aman Dung Dung, Aditya Das**, Chetan Suryawanshi** and Raghavendra Kumar****

ABSTRACT

Urban planning plays very important role in managing urban growth and shaping organized cities. However, traditional two-dimensional (2D) planning methods often fail to clearly show what are the real-world impacts and spatial relationships. This study explores how Augmented Reality (AR) and Virtual Reality (VR) can improve urban planning by providing immersive and interactive visualization experiences. AR enhances real world environment by adding digital elements(objects) , while VR creates realistic three-dimensional (3D) spaces that help planners and other people to understand proposed development projects in a better way. The study examines the accuracy of these visualizations, the use of real-time data, their cost-effectiveness compared to conventional planning methods, and their ability to improve stakeholder engagement. A mixed-method research approach fixed , using case studies and expert interviews for analysis. The results shows that AR and VR improve design understanding, support faster decision-making, and encourage greater public participation. Although challenges such as high implementation costs, limited accessibility, and training requirements remain, the study concludes that AR and VR have strong potential to enhance the future of urban planning and support India's Smart City goals.

Keywords: Augmented reality, Iterative feedback loop, Smart city planning, Stakeholder engagement, Virtual reality.

1.0 Introduction

Urban planning is generally used for the planning of cities so as to be serviceable for the communities in every aspect. Conventionally, planning was performed in the top-down approach using various tools such as zoning regulations, master plans, and transportation studies.

**Corresponding author; Student, School of Construction, NICMAR University, Pune, Maharashtra, India (E-mail: p24700040@student.nicmar.ac.in)*
***Student, School of Construction, NICMAR University, Pune, Maharashtra, India*
(E-mail: p24700051@student.nicmar.ac.in; p24700042@student.nicmar.ac.in)
****Student, School of Construction, NICMAR University, Pune, Maharashtra, India*
(E-mail: raghavendra.kumar@pune.nicmar.ac.in)

DOI: 10.17492/JPI/NICMAR/260521 *ISBN: 978-93-49790-68-1*

Planners focused on projecting population growth, managing land use, and providing for basic resources to include water, transportation networks, parks, health facilities, and food supply systems. Various theoretic approaches have also influenced urban planning, including rational, incremental, communicative, and advocacy planning models. These provide a framework for decision-making in light of social, environmental, and economic problems that cities face. Yet, rapid urbanization has placed growing demands on planners to create liveable, efficient, and sustainable cities. Traditional planning tools like 2D drawings, zoning maps, physical models, and static reports often fall short in clearly communicating complex spatial ideas or engendering much public involvement.

Within the past couple of years, AR and VR started changing the practices of urban planning. These technologies allow planners and decision-makers to literally see and interact with proposed development in three-dimensional environments. VR allows users to virtually experience future city spaces and simulate scenarios such as traffic movement, sunlight exposure, and pedestrian flow, supporting better design optimization. On the other hand, AR overlays digital information onto the real-world environment, offering key real-time and location-based insights.

AR and VR enhance the quality of visualization, enhance stakeholder engagement, and allow data to be integrated and analyzed. These tools allow stakeholders to explore proposed developments before actual construction and thus nurture better understanding among stakeholders of spatial relationships and aesthetic impacts. Better communication, collaboration, and more informed feedback from communities will result, with support for transparent and inclusive decision-making. Still, high development costs for software and hardware have hindered the broad adoption of AR and VR in urban planning. Against this backdrop, the role of QGIS-open-source software serving as an alternative to the proprietary GIS software-and WebXR, a new web standard that delivers both AR and VR directly through browsers, has become increasingly important. QGIS is capable of accurately handling real-world data for spatial analysis, while WebXR offers immersive visualizations without any special hardware.

The integration of QGIS and WebXR offers a promising approach for modern urban planning. By merging data-driven spatial analysis with immersive and accessible visualizations, planners, and stakeholders can pursue collaborative explorations of planning scenarios, more effectively participating in the planning process. This thesis investigates traditional urban planning methods compared to modern digital tools, looking at QGIS and WebXR. By using case studies, user feedback, and tool evaluation, the research intends to find out if immersive, data-rich environments can enhance communication and participation toward better planning outcomes, thereby reshaping the future of urban planning.

DOI: 10.17492/JPI/NICMAR/260521 *ISBN: 978-93-49790-68-1*

2.0 Literature Review

S. No.	tle of the Paper	Authors	Year of Publication	Objectives of the Study /Research	Methodology Adopted in the Study/ Research	Results of the Study / Research
1	Potentials of Augmented Reality in a BIM-Based Building Submission Process	Christian Schranz, Harald Urban, Alexander Gerger	2021	Investigate AR in a BIM-based submission process to enhance compliance checking and visualization.	Explored integration of BIM and AR; developed use cases for compliance checking.	AR improves plan-checking efficiency and helps non- experts understand technical content.
2	Usability of WebXR Visualizations in Urban Planning	Michał Rzeszewski, Mateusz Orylski	2021	Examine the usability and practical application of WebXR in urban planning, particularly for participator y planning.	Developed six AR/VR urban planning environment s; conducted usability tests.	WebXR provides high usability when interfaces mimic real- world planning.
3	Virtual City at Chalmers: Creating a Prototype for a Collaborative Early-Stage Urban Planning AR Application	Fabio Latino, Vasilis Naserentin, Erik Öhrn, Zhao Shengdong, Morten Fjeld, Liane Thuvander, Anders Logg	2019	Develop an AR-based collaborativ e platform for early- stage urban planning and stakeholder engagement.	Used a user-centered approach with literature study, interviews, and prototype creation.	Prototype allows visualization and interaction with 3D urban assets.
4	Mixed Assessment of Virtual Serious Games Applied in Architectural and Urban Design Education	David Fonseca, Janaina Cavalcanti, Enric Peña, Victor Valls, Mónica Sanchez-Sepúlveda, Fernando Moreira, Isidro Navarro, Ernesto Redondo	2021	Evaluate the effectivenes s of VR serious games in architectura l and urban design education.	Developed and tested Game4City 3.0 using Unreal Engine and HTC Vive VR.	VR serious games increase student engagement and motivation for learning.
5	Development of Construction Engineering Teaching Course	Galeh N.I.P. Pratama, Mochamad	2022	Develop and implement markerless VR-AR teaching materials	Used V- model approach and applied ISO	VR-AR improves student engagement and

	by Using VR-AR: A Case Study of Polytechnic in Indonesia	B. Triyono, Nur Hasanah, Olzhas B. Kenzhaliyev, Aigerim N. Kosherbayev a, Gulzhaina K. Kassymova, Mohamed Nor Azhari Azman		for construction engineering students.	usability testing with developers.	supports remote education.
6	BIM-enabled Virtual Reality (VR)-based Pedagogical Framework in Architectural Design Studios	Aso Haji Rasouli, Saeed Banihashemi, Paul Sanders, Farzad Rahimian	2023	Develop a BIM-enabled VR-based pedagogical framework to enhance architectural l design education.	Used qualitative research methods; applied case study approach in an architectural design studio.	VR-based education enhances student creativity and interaction.
7	Employing Augmented Reality Throughout a Civil Engineering Curriculum to Promote 3D Visualization Skills	Kevin A. Waters, Jonathan Hubler, Kristin M. Sample-Lord, Virginia Smith, Andrea L. Welker	2021	Integrate AR in a civil engineering curriculum to enhance students' 3D visualization skills.	Implemente d AR sandbox learning modules across multiple civil engineering courses.	AR improved spatial visualization and received positive feedback from students.
8	The Evolution of Interactivity, Immersion and Interoperability y in HBIM: Digital Model Uses, VR and AR for Built Cultural Heritage	Fabrizio Banfi	2021	Investigate the use of VR, AR, and HBIM for managing and preserving built cultural heritage.	Conducted case studies on various historical buildings; applied visual programming languages.	VR and AR improved interoperability and immersive experiences in built heritage.
9	An Analysis of the Application Areas of Augmented Reality Technology in the Construction Industry	Ayodeji Emmanuel Oke, Victor Adetunji Arowoiya	2021	Analyze AR application areas in the construction industry and assess its level of adoption.	Surveyed construction professional s; used descriptive and inferential statistical analysis.	AR is primarily applied in visualization, project documentation, and monitoring.
10	Virtual Reality Design Methods & Application: VR/AR in Urban Design	Stefan van der Spek, Frank van der Hoeven, Arno Freeke	2020	Examine VR and AR in urban design, education, and practice.	Implemente d VR/AR tools in urban design education; developed VR Design Methods Lab.	VR/AR improves citizen participation and urban design comprehension.

Source: Created by authors

DOI: 10.17492/JPI/NICMAR/260521 ISBN: 978-93-49790-68-1

3.0 Research Methodology

3.1 Digital visualization approaches in urban planning

Currently urban planning increasingly requires improved means of visualization and communication due to increasing city complexity. Traditional planning methods involving 2D drawings, maps, and static reports cannot express spatial depth or scale, and real-world impacts to planners and decision-makers, let alone the general public. To overcome these limitations, immersive digital technologies such as augmented and virtual reality have emerged as successful tools for improving planning processes.

AR and VR are acronyms of two complementary visualization approaches: overlay of digital planning information onto the real-world environments of proposed buildings, zoning boundaries, or infrastructure layouts provides a view of each planning proposal within their physical context, while VR offers completely immersive 3-D environments to virtually tour future urban spaces well in advance of construction. This is an open-source, web-based approach that makes the research more accessible and cost-effective. QGIS will provide preparation and analysis of spatial data for mapping, while WebXR offers fully immersive AR/VR right within the web browser without any costly hardware or proprietary software. The enabling of intuitive and inclusive interaction with data-driven urban models by planners, stakeholders, and citizens is now possible through this integration.

3.2 Anticipated impact on urban planning performance

The integration of AR/VR into traditional planning workflows is supposed to enrich such key dimensions of performance in urban planning: visualization clarity, decision-making efficiency, stakeholder engagement, and risk reduction.

It is expected that immersive 3D representations lead to better visualization accuracy for planners and citizens in the understanding of spatial relationships, building massing, and environmental impacts. This better understanding will reduce design misinterpretation and planning errors. The AR/VR-based simulations will facilitate faster and better decision-making because planners are able to test scenarios on traffic flow, sunlight exposure, infrastructure resilience, and land-use change. The capability for virtual evaluation of alternatives reduces reliance on trial and error in implementation.

The participation of stakeholders may grow substantially. The ability of AR/VR tools to make proposed developments visual for citizens will narrow the gap in communication between technical planners and non-technical stakeholders and may lead to better public participation and transparent planning processes. AR/VR integrated with geospatial data via QGIS could contribute to sustainable and resilient urban development through allowing data-driven analysis side by side with immersive visualization.

DOI: 10.17492/JPI/NICMAR/260521 ISBN: 978-93-49790-68-1

3.3 Questionnaire development

Data were therefore collected by using a structured questionnaire that assesses the perception of the effectiveness of AR/VR in urban planning.

There were total 3 sections in the Questionnaire:

First Section included questions on demographic information such as professional background, years of experience, and general awareness of urban planning and digital technology, which put other answers into context.

Second part of the questionnaire collected data with regard to awareness, usability, and perceived benefits of AR/VR technologies in urban planning. Statements about visualization quality, cost-effectiveness, public involvement, sustainability, and integration with tools like BIM are subject to assessment.

Third part collected information about the planning performance output in terms of clear communication, decision-making efficiency, reduction of risk, and long-term planning.

Answers have been measured on a five-point Likert scale from "Strongly Disagree" to "Strongly Agree."

The questionnaires were first validated through pilot testing before their final deployment and by statistical checks to ensure that the internal consistency and clarity were reliable.

4.0 Findings/Results

The purpose of this chapter is to analyze, in an empirical way, the efficiency of using AR/VR technology in improving urban planning. The data collected from this survey has been analyzed through Descriptive Statistics and some Inference Tests, such as t-test, Z-test, to see whether the perception regarding AR/VR has been overwhelmingly positive compared to being Neutral.

Result Analysis for One-Sample T-Test (Effectiveness of AR/VR

(Test value=3, Scale is Neutral on Likert Scale)

4.1 One-Sample T-Test Results (AR/VR effectiveness in urban planning)

(Test value = 3, Neutral on Likert Scale)

Table 1: One-Sample T-Test Results for AR/VR Adoption

No.	Hypothesis / Statement	Mean	t-Statistic	p-Value	Significant ($\alpha = 0.05$)
1	Of all the planners/authorities are trained enough to use AR/VR tools	3.47	2.432	0.029	Yes
2	Planners/authorities are adequately trained to use AR/VR tools.	3.33	1.287	0.205	No

DOI: 10.17492/JPI/NICMAR/260521 ISBN: 978-93-49790-68-1

3	There is adequate long-term research available on the sustainability impact of AR/VR.	3.53	1.512	0.137	No
4	AR/VR is currently used in large-scale city planning projects.	3.67	1.846	0.072	No
5	AR/VR support in testing the resilience of the infrastructure.	3.67	1.846	0.072	No
6	Interest in attending training sessions/workshops on AR/VR.	2.91	-0.289	0.779	No
7	AR/VR implementation in planning is economical.	3.82	2.014	0.05	Yes
8	AR/VR reduces project risks (errors, delays, cost overruns).	3.36	1.091	0.281	No
9	AR/VR contributes to sustainable urban development.	3.45	1.201	0.236	No
10	Effectiveness of AR/VR in engaging the public involvement in planning.	2.5	-1.318	0.214	No
11	AR/VR shall be supported for long-term use to resilient city planning.	3	0	1	No
12	AR/VR enhances understanding better than 2D drawings.	2.65	-1.577	0.125	No

Source: Created by authors

From the one-sample t-test, there is evidence of certain meaningful support in adopting AR/VR in urban planning.

4.1.1 Important supporting findings

- AR/VR–BIM Complementarity shows a statistically significant positive perception (Mean = 3.47, $p < 0.05$), indicating that respondents feel that the complementarity between immersive visualization and data-intensive environments of BIM is valuable in terms of urban planning.
- Cost-effectiveness of AR/VR will also have a statistical significance (Mean=3.82, $p \approx 0.05$), implying that the stakeholders recognize the effectiveness offered by AR/VR compared to the conventional planning method.

4.1.2 Moderately positive but not statistically significant

There are some features, such as the testing of infrastructure resilience, the use of the approach for large-scale city planning, the contributions to sustainability, and the reduction of risk, which have overall mean values greater than the neutral point, but lack the necessary significance level.

4.1.3 Low engagement outcomes

- There are lower mean scores for the effectiveness and level of interest in AR/VR-based training with respect to employee engagement.

- The above points underscore the need for capacity-building activities, awareness, and demonstration projects.

4.2 Z-test results for AR/VR effectiveness in urban planning

(Test Value = 3, Neutral Perception)

Table 2: Result of One-sample

Survey Statement	Mean	Z-Statistic	P-Value	Significant (α = 0.05)
Effectiveness of AR/VR in engaging the public	2.829	-0.913	0.3615	Not Significant
Effectiveness of traditional tools in communicating plans	3.806	5.13	0	Significant

Source: Created by authors

The outcome of the Z-test shows that there is no perception of effectiveness regarding the usage of AR/VR in engaging with the public differently when compared to a neutral standard ($p > 0.05$). On the other hand, a comparison of the result shows that the mean of traditional planning methods is significantly different and above the neutral standard ($p < 0.05$). This can be identified as a phase of transition where AR/VR is in its budding stage and has yet to replace the conventional means of communication.

4.2.1 Inferential Analysis (T-Test and Z-Test Results):

T Inferential analysis showed that some variables were significant, which meant that the perceptions were well above the neutral levels for AR/VR-related variables. The respondents were strongly in favor of AR/VR for the purpose of visualization improvement, resilience analysis, and cost-effectiveness. However, the analysis regarding the integration of AR/VR and BIM, as well as the engagement level for long-term sustainability, is not significant and addresses the gaps instead of the technicalities.

4.2.2 Hypothesis Test

The hypothesis testing confirms that while traditional tools remain dominant, AR/VR has not yet achieved statistical acceptance as a mainstream engagement tool. This does not indicate failure of AR/VR technology, but rather insufficient adoption, training, and institutional readiness.

DOI: 10.17492/JPI/NICMAR/260521 *ISBN: 978-93-49790-68-1*

Table 3: Hypothesis Testing Summary

Code	Hypothesis Statement	Result
H1	AR/VR significantly improves public engagement in urban planning	Not Supported
H2	Traditional tools are effective in communicating planning proposals	Supported
H3	Stakeholders are currently ready to adopt AR/VR as a primary planning tool	Not Supported

Source: Created by authors

5.0 Discussion and Implications

5.1 Interpretation of results

The results indicate the use of AR/VR technology has a great affinity with urban planning processes. As a planning aid, the results are affirmative of the use of AR/VR technology for applications such as testing the infrastructure of a proposed project and assessing cost-effectiveness. The absence of distinct results in the AR/VR–BIM integration study underscores the importance of capacity development and familiarity with integrated digital planning tools. The results indicate the use of AR/VR technology has a great affinity with urban planning processes. As a planning aid, the results are affirmative of the use of AR/VR technology for applications such as testing the infrastructure of a proposed project and assessing cost-effectiveness.

5.2 Practical implications

Regarding planning authorities and practitioners, the findings from this research stress the importance of embracing AR/VR as an additional option to traditional planning approaches. Open-source softwares such as QGIS and WebXR available on web browsers could remove existing implementation hurdles and therefore ensure equitable access to AR/VR planning applications. The use of AR/VR technology will enable urban agencies to improve public consultations, reduce conflict during planning, and ensure transparency during decision-making.

6.0 Conclusion

This study researched how Augmented Reality and Virtual Reality improve the processes of urban planning in aspects that deal with the visualization of urban space, stakeholder involvement, cost-effectiveness, and planning communication. The study was informed by shortcomings of traditional approaches of urban planning which are heavily reliant on two-dimensional drawings, static maps, and written reports that often do not convey

DOI: 10.17492/JPI/NICMAR/260521 ISBN: 978-93-49790-68-1

complex spatial information clearly to non-technical stakeholders. It means that AR/VR can be re-used as promising tools in urban planning, particularly for improving visual understanding and making cost-effective decisions. The economic viability of the AR/VR solution and the possibility of complementing the existing digital tools like BIM (Building Information Modelling) was fully agreed upon by the respondents. It seems that immersive technologies are not only valued as presentation tools but as a decision-support system through which they are able to perceive enhanced accuracy and efficiency in planning. While conducting this research, it is also being noted that AR/VR does not have strong empirical grounds with respect to processes of public engagement and implementation. The analysis of the t-test and z-test results makes it clear that traditional planning processes are yet to be accepted as a better means of communicating proposals to the public through AR/VR. This points to the idea that while AR/VR might be welcomed at a theoretical level of acceptance, its applicability in real world is still obstructed by factors such as lack of user training and readiness of the people on a larger scale.

7.0 Recommendations

1. Implement Immersive Visualization Technologies: The agencies concerned with urban planning must integrate the use of AR/VR in the consultation processes regarding urban designs.
2. Training and Capacity Building: Professional training programs must also be needed for effective AR/VR-BIM integration.
3. Open-Source Platform Utilization: Usage of QGIS and WebXR must be adopted to lower expenses and enhance accessibility.
4. Promote Participatory Planning. The use of AR and VR can enable and increase transparency of planning through citizen participation.

References

1. Schranz, C., Urban, H., & Gerger, A. (2021). Potentials of augmented reality in a BIM-based building submission process. *Journal of Information Technology in Construction (ITcon)*, 26, 441–457. https://doi.org/10.36680/j.itcon.2021.024
2. Rzeszewski, M., Orylski, M., & [Third Author if available]. (2021). Usability of WebXR visualizations in urban planning. *ISPRS International Journal of Geo-Information*, 10(11), Article 721. https://www.mdpi.com/2220-9964/10/11/721
3. Latino, F., Naserentin, V., Öhrn, E., & Shengdong, Z. (2019). Virtual City@Chalmers: Creating a prototype for a collaborative early-stage urban planning AR application. In

DOI: 10.17492/JPI/NICMAR/260521 *ISBN: 978-93-49790-68-1*

Proceedings of the 7th Regional International Symposium on Education and Research in Computer Aided Architectural Design in Europe, 137–147. *eCAADe RIS 2019*. https://research.chalmers.se/en/publication/510472

4. Fonseca, D., Cavalcanti, J., Peña, E., Valls, V., Sanchez-Sepúlveda, M., Moreira, F., Navarro, I., & Redondo, E. (2021). Mixed assessment of virtual serious games applied in architectural and urban design education. *Sensors*, 21(9), Article 3102. https://doi.org/10.3390/s21093102
5. Afzal, M., Shafiq, M. T., & Al Jassmi, H. (2021). Improving construction safety with virtual-design construction technologies – A review. *Journal of Information Technology in Construction (ITcon)*, 26(18), 319–340. https://doi.org/10.36680/j.itcon.2021.018
6. Albahbah, M., Kıvrak, S., & Arslan, G. (2021). Application areas of augmented reality and virtual reality in construction project management: A scoping review. *Journal of Construction Engineering, Management & Innovation*, 4(3), 151–172. https://doi.org/10.31462/jcemi.2021.03151172
7. Banfi, F. (2021). The evolution of interactivity, immersion and interoperability in HBIM: Digital model uses, VR and AR for built cultural heritage. *ISPRS International Journal of Geo-Information*, 10(10), 685. https://doi.org/10.3390/ijgi10100685
8. Fonseca, D., Cavalcanti, J., Peña, E., Valls, V., Sanchez-Sepúlveda, M., Moreira, F., Navarro, I., & Redondo, E. (2021). Mixed assessment of virtual serious games applied in architectural and urban design education. *Sensors*, 21(9), 3102. https://doi.org/10.3390/s21093102
9. Hajirasouli, A., Banihashemi, S., Sanders, P., & Rahimian, F. (2023). BIM-enabled virtual reality (VR)-based pedagogical framework in architectural design studios. *Smart and Sustainable Built Environment*, 12(3), 593–615. https://doi.org/10.1108/SASBE-07-2022-0149
10. Latino, F., Naserentin, V., Öhrn, E., Shengdong, Z., Fjeld, M., Thuvander, L., & Logg, A. (2019). *Virtual City@Chalmers: Creating a prototype for a collaborative early stage urban planning AR application*. In *Proceedings of the eCAADe Regional International Symposium 2019* (pp. 137–147). Chalmers University of Technology.
11. Oke, A. E., & Arowoiya, V. A. (2021). An analysis of the application areas of augmented reality technology in the construction industry. *Smart and Sustainable Built Environment*, 10(4), 602–622. https://doi.org/10.1108/SASBE-11-2020-0162
12. Pratama, G. N. I. P., Triyono, M. B., Hasanah, N., Kenzhaliyev, O. B., Kosherbayeva, A. N., Kassymova, G. K., & Azman, M. N. A. (2022). Development of construction engineering teaching course by using VR-AR: A case study of Polytechnic in Indonesia. *International Journal of Interactive Mobile Technologies (iJIM)*, 16(14), 92–109. https://doi.org/10.3991/ijim.v16i14.30539

DOI: 10.17492/JPI/NICMAR/260521 *ISBN: 978-93-49790-68-1*

13. Pujiono, I. P., Asfahani, & Rachman, A. (2024). Augmented reality (AR) and virtual reality (VR): Recent developments and applications in various industries. *INNOVATIVE: Journal of Social Science Research*, 4(4), 1679–1690. https://j-innovative.org/index.php/Innovative/article/view/1679
14. Rzeszewski, M., & Orylski, M. (2021). Usability of WebXR visualizations in urban planning. *ISPRS International Journal of Geo-Information*, 10(11), 721. https://doi.org/10.3390/ijgi10110721
15. Schranz, C., Urban, H., & Gerger, A. (2021). Potentials of augmented reality in a BIM-based building submission process. *Journal of Information Technology in Construction (ITcon)*, 26(24), 441–457. https://doi.org/10.36680/j.itcon.2021.024
16. van der Spek, S., van der Hoeven, F., & Freeke, A. (2020). VR|DMA – Virtual reality design methods & application: VR/AR in urban design. In *Proceedings of the Design Research Conference 2019: Real/Material/Ethereal* (pp. 657–674). Monash University.

DOI: 10.17492/JPI/NICMAR/260521 ISBN: 978-93-49790-68-1