Chapter 41

Next-generation Community Hubs for Socio-economic Empowerment: A Pilot Human-centred Framework and Participatory Digital Twin Approach

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Abstract

The University of Cincinnati's (UC) Future Mobility Design (FMD) Lab, in collaboration with the Ohio Department of Transportation (ODOT), developed a human-centred research (HCR), data-driven methodology to help communities and decision-makers co-create future-ready hubs that integrate transportation with access to healthcare, education, employment, and other essential services. The framework includes three components: a mixed-methods approach for data collection, a hubs typology matrix based on land-use and community needs, and a translation framework that enables stakeholders to design local hubs. Outputs include nine immersive digital twins (DTs) and the Future Hub Playbook, a participatory guide for inclusive stakeholder engagement. While full co-design workshops are planned for the next research phase, this pilot highlights the potential of combining mixed-methods and simulation technologies to empower communities and facilitate inclusive planning. The framework is currently being adapted with global partners, including the MIT City Science Network, for implementation across the U.S., the Global South, and Europe.

Keywords: *Community hubs, Digital twins, Human-centred, Design, Participation*

Introduction

Rapid urbanisation and accelerating technological change are reshaping how people live, move, and access services worldwide[1]. Traditional planning often overlooks local realities, perpetuating exclusion and access disparities[2]. These complexities require a new bottom-up approach that integrates community knowledge, data, and democratized planning[3]. Enhancing participatory processes with digital technologies can help bridge gaps in participation and access. Future hubs, multifunctional mobility and community centres, are used in this chapter as a case study due to their systemic potential and adaptability.

[1]Hannon et al., "An Integrated Perspective on the Future of Mobility," McKinsey & Company (2018) https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/an-integrated-perspective-on-the-future-of-mobility.

[2]Holmes et al., "Mismatch: How Inclusion Shapes Design", MIT Press (2018).

[3]Durand et al., "Access Denied? Digital Inequality in Transport Services," Transport Reviews 42 (2021): 32–57 https://doi.org/10.1080/01441647.2021.1923584.

This chapter presents a design-driven methodology developed by UC's FMD Lab, in partnership with ODOT, to co-create multifunctional, future-ready hubs that integrate transportation with essential services. Grounded in HCR and powered by DTs, the framework comprises three phases: 1. Mixed-methods methodology for participatory and context-aware data collection, 2. Translation framework to integrate data into design recommendations, and 3. Simulation tools for accessible stakeholder involvement. The research question is: How can HCR methods and emerging technologies enable participatory development of sustainable future hubs? This research contributes to participatory planning literature by embedding simulations and qualitative research into replicable, policy-aligned toolkits.

Background: Addressing Access Gaps Through Future Hubs

Global Access Inequities

Traditional car-centric planning, limited infrastructure, and exclusionary zoning have disproportionately impacted underserved communities. These environments restrict quality of life and reinforce barriers to essential services[4]. New global planning strategies emerge in response to the failures of the past and the demands of the future by addressing the diverse needs of urban, suburban, and rural populations[5]. Inclusive and participatory tools emerge as needed catalysts to bridge the access gap[6].

Future-ready Hubs

Future hubs serve as community anchors, integrating transport with essential services like education, healthcare, recreation, and commerce. Their impacts include economic resilience, equitable access, and spatial inclusion. While established frameworks for planning exist, stakeholder engagement remains underdeveloped[7], and few models enable communities to co-design these environments meaningfully.

Participatory and Tech-enabled Planning

Participatory co-design and stakeholder research are essential for tackling complex societal issues. These processes depend on collaborative, accessible tools that empower communities to shape planning outcomes[8]. DTs provide immersive, low-cost visualisations of spatial and social data, enabling deeper

[4]Hannon, et al., "An Integrated Perspective," (2018).
[5]"Global Street Design Guide". Global Designing Cities Initiative. Island Press, (2016).
[6]Bui et al., "Full Inclusive Participation (FIP) Approach: Design Process Case Study in Urban Mobility." Cumulus Association Conference Ethical Leadership, (2025).
[7]Pinheiro, "Multimodal Transport Hubs: Good Practice Guidelines. *Agence française de développement*," (2020) www.mobiliseyourcity.net/sites/default/files/2020-09/multimodal-transport-hubs-good-practice-guidelines.pdf.
[8]Sanders et al., "Co-Creation and the New Landscapes of Design." *CoDesign* 4, (2008). https://doi.org/10.1080/15710880701875068.

engagement, understanding, and consensus-building. When integrated into participatory processes, they help stakeholders visualize, explore, and shape potential futures[9].

Methods: Developing HCR and Data-driven Frameworks

Hubs Definition

To identify potential hub typologies across Ohio, an IRB-approved study was conducted using mixed methods: primary research (stakeholder interviews, surveys, site visits[10]) and secondary research (STEEP analysis[11] and trends forecasting[12]), uncovered current mobility experiences/challenges, and opportunities for future hubs (Figure **1**). Data included 81 survey responses from stakeholders across Ohio[13], 20 expert interviews from the U.S., and multiple site visits (Figure **2**).

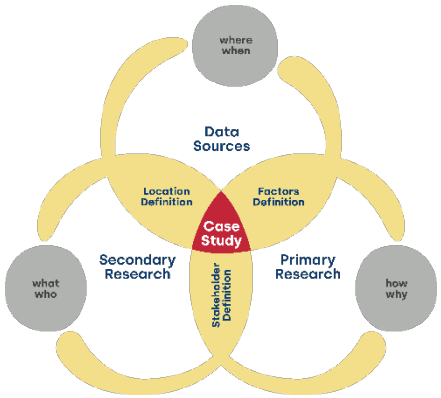

Figure 1: Case Study Definition.

Figure 2: Primary Data Collection.

These inputs revealed gaps, preferences, and infrastructure needs, leading to defining nine hub case studies and a Typology Matrix that accounted for urban, suburban, and rural land use, alongside levels of connection and size. The matrix was cross-validated with GIS data and planning tools from the UC Infrastructure Institute[14] (Figure **3**).

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[9]Lozano Robledo et al., "Digital Twins in Co-Design Workshops," *IDSA,* (2024).
[10]Kumar, "101 Design Methods: A Structured Approach for Driving Innovation in Your Organization," *John Wiley & Sons*, (2013) https://www.researchgate.net/publication/328861557_101_Design_Methods.
[11]Fisher et al., "STEEP," In Strategy in 3D," *Oxford University Press*, (2020) https://doi.org/10.1093/oso/9780190081478.003.0006.
[12]Hannon, et al., "An Integrated Perspective," (2018).
[13]Kumar, "101 Design Methods," *John Wiley & Sons*, (2013).
[14]Bonthu et al., "A Framework for Real-Time Road User Safety with Computer Vision and Vehicle-to-Everything (V2X) Alerts," University of Cincinnati, (2024) http://rave.ohiolink.edu/etdc/view?acc_num=ucin1721398325731484.

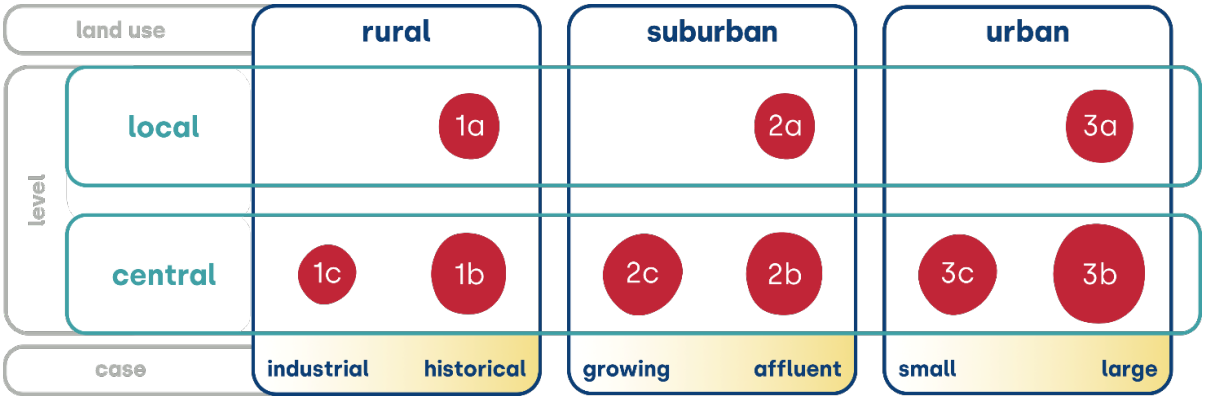

Figure 3: Typology Matrix.

Translating Data into Design Concepts

The translation framework converted insights into context-specific modules from the Typology Matrix, incorporating requirements from architecture, urban planning, design, user-experience, mobility, and other amenities (Figure **4**).

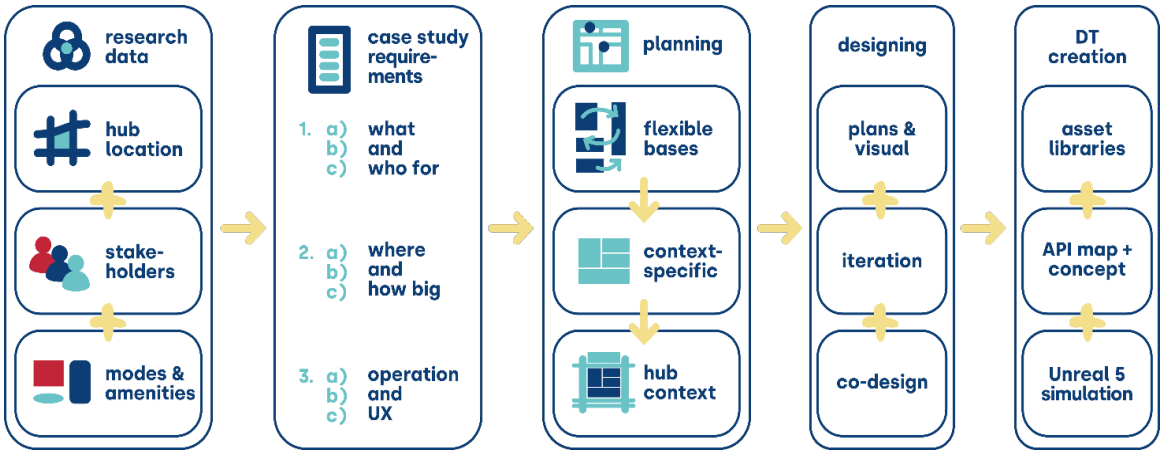

Figure 4: Translation Framework.

The design process included bubble diagrams[15] (Figure **5**), which translated floor plans into designs, and concept-sketching and 3D-modeling, which applied aesthetics to create hub concepts. To refine scale, collaborative AR/VR bubble exercises were conducted in Gravity Sketch. Concepts were contextualized with local datasets and validated through research feedback, ensuring designs reflected stakeholder needs and future scenarios.

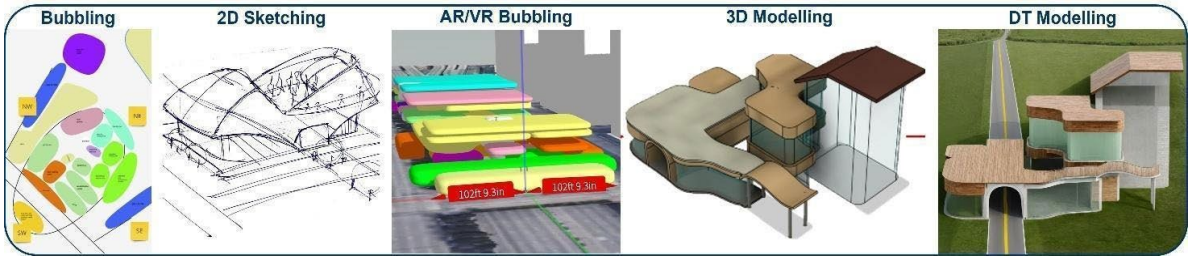

Figure 5: Design Process.

[15]Emmons Paul, "The Cosmogony of Bubble Diagrams," *86th Annual Association of Collegiate Schools of Architecture,* (1998): 420–25.

DT Simulation Framework

Using TwinMotion software, and following the typology matrix, DT hubs were created, each combining site topography, design concepts, animations, and environments to produce realistic, walkable, interactive, and VR-compatible simulations (Figure **6**). Stakeholders could visualize pedestrian activity, multimodal traffic, architectural features, and amenities in real time. DTs enable a low-barrier entry point for discussion, aligning data, planning, and community vision into a shared language. This framework will enable further workshops where participants co-create future hubs (Figure **7**).

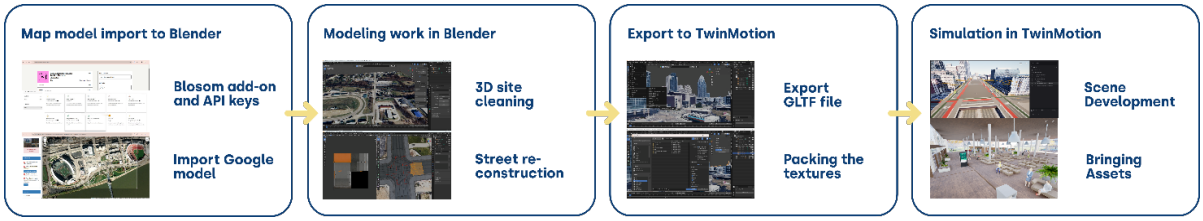

Figure 6: DT Process.

Figure 7: Final DTs

Future Hub Playbook: A Participatory Framework for Hub Planning

The Future Hub Playbook is a participatory and data-informed tool designed to translate complex research into accessible planning resources[16]. This tool combines the framework from Section 3 and leverages DTs for low-cost simulations, also empowering participatory processes with diverse stakeholders by enhancing the context and leveraging data-driven mixed-use methods.

It translates the research framework into clear prompts, amenity checklists, stakeholder guides, and design concepts, enabling community leaders, planners, policymakers, companies, and nonprofits to collaboratively design future-ready hubs.

Structured for scalability and accessibility, the playbook introduces the theory of future hubs, articulating their role in addressing equity challenges, and outlining a 4-pillar step-by-step planning process for all stakeholders (Figure **8**):

[16]"Future Mobility Design Lab," *University of Cincinnati, Office of Research, (2025).* https://ucdigitalfutures.com/future-mobility-design-lab/.

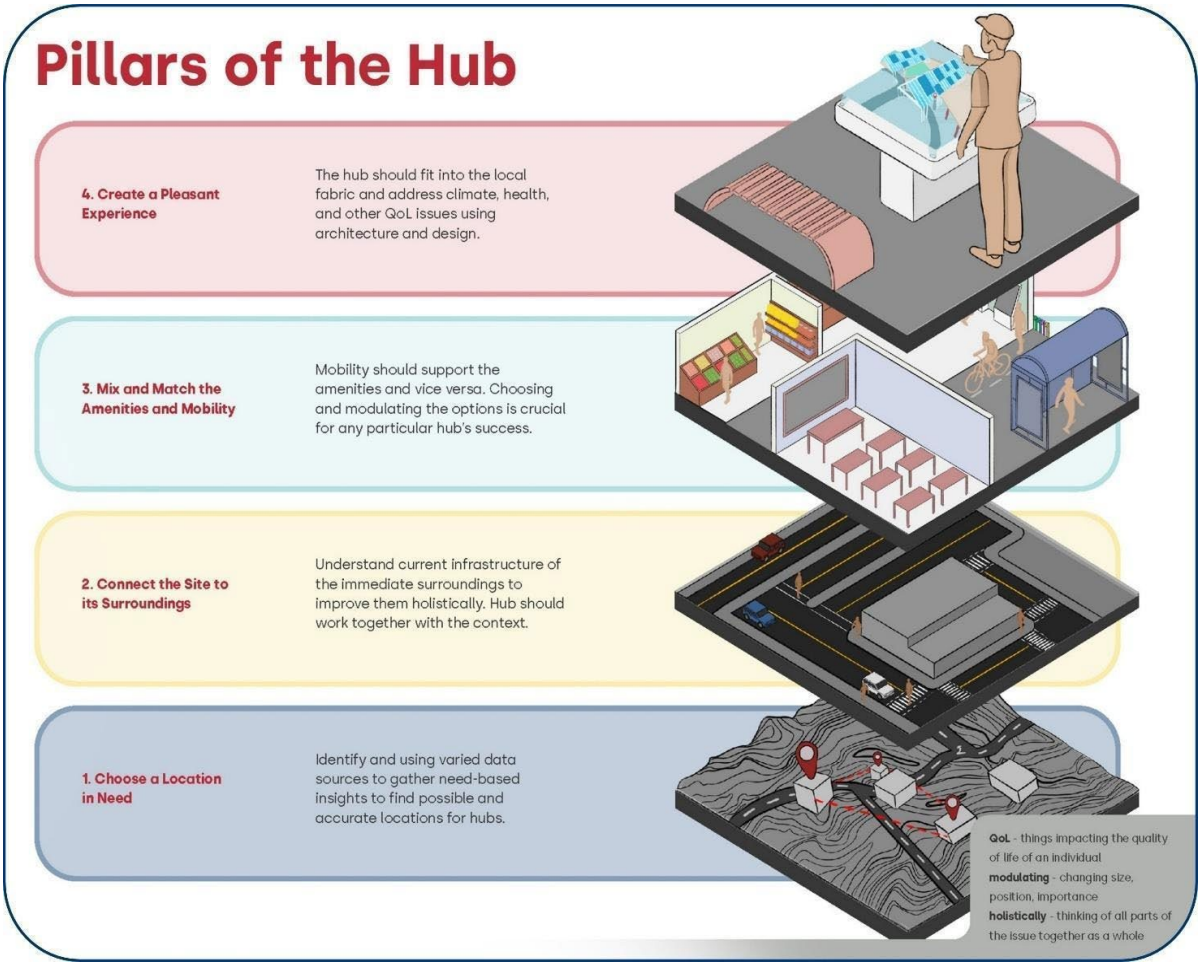

Figure 8: Hub Pillars Overview (1-Choosing location, 2-Connecting sites to surroundings, 3-Combining amenities and mobility, 4-Creating pleasant experience).

Each pillar is supported by research insights, visual DT examples, and checklists that guide stakeholders through design decisions. Rather than dictating solutions, the playbook encourages collaborative adaptation to local contexts. As both a technical and facilitation tool, it lowers barriers to civic engagement by combining HCR, data insights, and immersive technologies (Figure **9**, Figure **10**, Figure **11**).

Although this phase is a methodological pilot, the playbook has undergone multiple revisions. ODOT experts have shown strong interest and are partnering with the FMD Lab to implement it in Ohio communities. The framework has been showcased at four regional events, including at OTEC 2024, ODOT Future Mobility and All Aboard Ohio webinars, and City of Cincinnati Port Authority demonstration. These sessions engaged planners, policymakers, transportation experts, and community members. Feedback has been overwhelmingly positive, and findings are being compiled by the FMD Lab (Figure **12**).

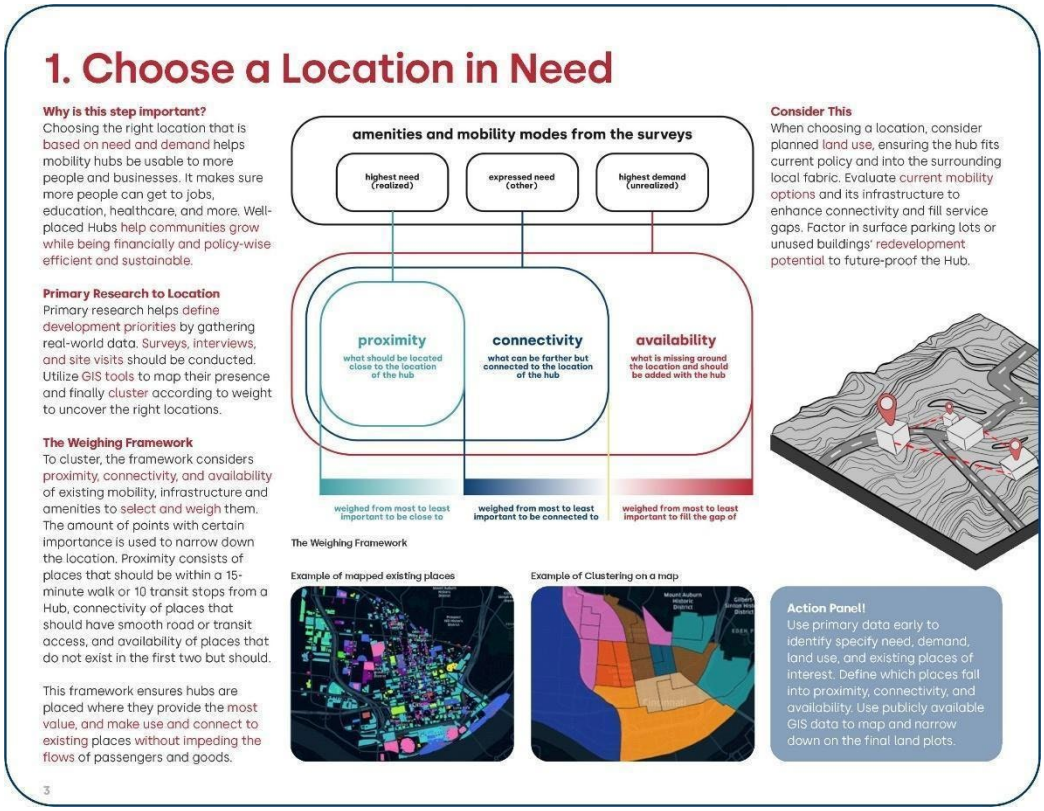

Figure 9: Pillars 1 and 2.

Figure 10: Pillars 3 and 4.

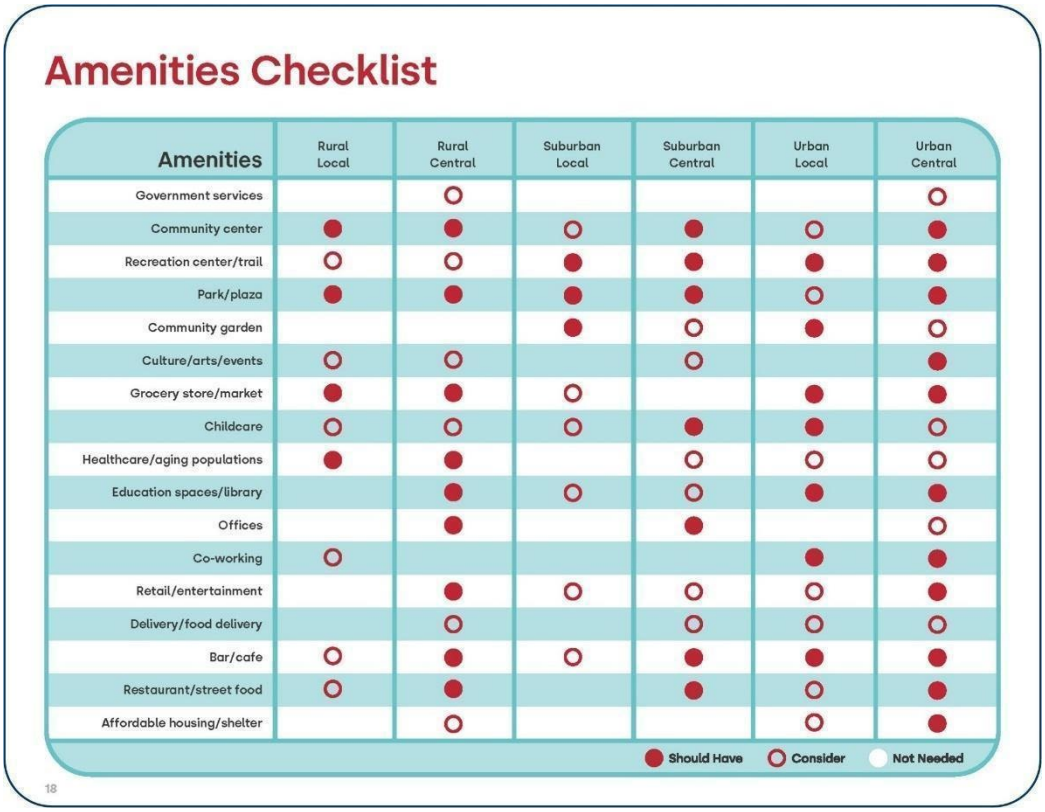

Figure 11: Stakeholders Checklist.

Figure 12: Validation.

Conclusions: Laying the Foundation for Global Adaptation

This framework offers a replicable model that bridges local knowledge, immersive simulation, and participatory design, creating new pathways for equitable infrastructure development. Three key contributions and future work opportunities emerge:

DTs as Democratising Tools

DTs proved essential for facilitating understanding and stakeholder alignment. Their immersive realism supports data-visualisation, scenario exploration, and community engagement, making complex planning processes more inclusive. Built using game engine platforms, the nine high-fidelity DTs enabled early validations for diverse stakeholders to visualize how land-use, transportation networks, and community amenities converge. Future work includes integrating these tools into XR platforms and developing open-source frameworks for broader adoption, particularly by underserved municipalities.

Future Hub Playbook: An Empowerment Tool

The Playbook transforms research into actionable steps for a wide range of stakeholders, reframing planning as an iterative and inclusive process, empowering communities to identify priorities and engage meaningfully in co-creating context-specific hub solutions. Unlike traditional technical reports, it invites collaboration and adaptability, providing visual tools, checklists, and stakeholder prompts to support informed decision-making. Early feedback from Ohio stakeholders confirmed its scalability and potential for wider use. Future iterations will include modules for public use, training resources, and expanded digital integration.

From Ohio Pilot to Global Application

While rooted in Ohio, the framework is already being adapted globally. Current partnerships with the MIT City Science Network and regional entities in the Global South and Europe aim to adapt the methodology to new socio-political and urban contexts. Future publications will document these adaptations, with co-creation sessions, participatory evaluation, and comparative analysis. The work presented serves as the foundation for an evolving global network of case studies using the proposed core methodologies.

Acknowledgments

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