Overview of the Use of Co-creation Tools for the Design of Sustainable Buildings

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Abstract. The transition toward sustainable building design increasingly emphasizes participatory approaches, where diverse stakeholders contribute to shaping solutions that balance environmental performance, social needs, and economic viability. This study provides an overview of the application of co-creation tools in the design process of sustainable buildings. Drawing on recent literature and practice-based examples, we examine how tools such as participatory design workshops, digital twins, virtual and augmented reality environments, and collaborative BIM platforms enable deeper engagement of users, designers, and decision-makers. The analysis identifies key benefits of co-creation, including improved user satisfaction, enhanced design adaptability, and stronger alignment with sustainability goals. It also explores challenges such as stakeholder coordination, data interoperability, and the need for capacity building in participatory methods. The study synthesizes findings across academic, professional, and policy domains to propose a typology of co-creation tools most relevant to sustainable architecture. The insights aim to inform both practitioners and researchers seeking to implement inclusive and effective design strategies in the built environment.

Keywords: Co-creation · sustainable building design · participatory design · Building Information Modelling (BIM) · Virtual Reality (VR) · user engagement

1 Introduction

The transition toward sustainable building practices is no longer driven solely by compliance with environmental standards or technological innovation. Increasingly, emphasis is being placed on participatory approaches that involve a wide range of stakeholders in the design and planning of buildings. Co-creation—defined as the collaborative process in which users, designers, engineers, and other actors jointly contribute to the development of solutions—has emerged as a key methodology for integrating social, environmental, and user-centric perspectives into sustainable architecture.

In the context of the built environment, co-creation tools include participatory workshops, stakeholder interviews, serious games, Building Information Modelling (BIM), digital twins, and immersive technologies such as virtual and augmented reality. These tools not only enhance user engagement and satisfaction but also improve the relevance

and effectiveness of sustainability strategies by embedding user needs and local knowledge directly into the design process. They enable early-stage dialogue, continuous feedback loops, and shared ownership of outcomes, making them particularly suitable for projects that aim to be inclusive, adaptable, and environmentally responsive.

Despite the increasing attention to co-creation in recent years, there remains a gap in synthesizing how these tools are being systematically applied, evaluated, and integrated into the workflows of sustainable building design. To address this, the present study offers a structured review of relevant literature, based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. An initial search yielded 72 scientific publications, from which 16 were selected through defined inclusion and exclusion criteria for full qualitative analysis. These studies form the core of the review and provide insight into the current state of co-creation practice within the sustainable construction domain.

The goal is to classify the co-creation tools used, identify their benefits and challenges, and provide a comprehensive overview to support future research and practice in collaborative and sustainable building design.

2 Methodology

This study applies the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to conduct a systematic literature review focused on the use of co-creation tools in the design of sustainable and smart buildings. The aim was to identify and analyze peer-reviewed research that investigates co-creation methodologies within architectural or building-related design processes that explicitly target sustainability or user integration. For the bibliographic analysis, the Biblioshiny interface of the Bibliometrix R package was used. The figures presented were generated through Biblioshiny to visualize thematic trends, keyword co-occurrence, and country-topic relationships within the selected literature.

The dataset was retrieved from the **Scopus database**, widely recognized for its broad multidisciplinary coverage and reliable metadata. The search was conducted in **March 2025**, targeting studies published between **January 2012 and March 2025**. The keywords used were **"smart buildings," "co-creation,"** and **"design,"** combined using Boolean operators (*AND/OR*) and applied to titles, abstracts, and author keywords.

In the **Identification phase**, a total of **72 records** were retrieved. No duplicates were found in the dataset. During the **Screening phase**, titles and abstracts were assessed for thematic relevance, resulting in the exclusion of 29 articles that were unrelated to the built environment, co-creation methods, or sustainability in building design. This yielded **43 studies** for full-text review.

The **Eligibility phase** involved applying inclusion criteria:

- The study must involve buildings or built environment projects;
- It must explicitly incorporate co-creation or participatory design tools;
- The research must describe or evaluate the use of these tools;
- It must be situated within a sustainability or smart building context.

After applying these criteria, **16 studies** were included in the **qualitative synthesis**. These studies form the analytical basis of the review, where co-creation tools are categorized, their use cases documented, and their role in promoting sustainable building outcomes evaluated. The 16 studies selected through the PRISMA process are listed in the references section of this paper. The PRISMA flow table summarizes the selection process (Table 1).

Table 1. Summary of PRISMA Selection Process.

Stage	Number of Records
Records identified through database searching (Scopus)	72
Records after duplicates removed	72
Records screened (title and abstract)	43
Full-text articles assessed for eligibility	25
Studies included in qualitative synthesis	16

3   Results and Discussion

Fig. 1. Sankey diagram linking countries, keywords, and application domains in co-creation research.

Figure 1 presents a Sankey diagram mapping country contributions to keywords and their downstream application domains. It highlights the dominant role of countries like the **USA, UK, Japan, and Italy**, which lead the scholarly production around concepts such as *smart city*, *internet of things*, and *co-creation*. The visualization makes clear that **co-creation serves as a bridging term**, connecting diverse research fields such as urban

planning, smart homes, and sustainable development. This suggests that co-creation is not limited to stakeholder workshops or early design phases, but is increasingly adopted as a system-level methodology across the entire building lifecycle—from concept to implementation and even into use-phase governance.

What is particularly notable in Fig. 1 is the strong flow from *co-creation* to *co-design* and *smart homes*, reinforcing the hypothesis that participatory practices are increasingly embedded in residential and user-interactive domains. The presence of terms like *value co-creation*, *urban planning*, and *air pollution* as downstream applications indicates that co-creation is also being leveraged to integrate environmental and policy objectives into the built environment, aligning with goals of sustainable development.

Figure 2, the word cloud, highlights **dominant and frequently co-occurring terms** in the reviewed literature. *Sustainable development*, *smart city*, *internet of things*, *intelligent buildings*, and *co-creation* emerge as the most prominent. This confirms the increasing convergence of digital and participatory paradigms in building design. Terms like *human computer interaction*, *environmental monitoring*, and *citizen participation* signal that researchers are moving beyond technical performance metrics to incorporate user-centered and societal perspectives. Importantly, **co-creation is surrounded by a set of complementary terms such as** *automation*, *budget control*, *urban planning*, **and** *energy efficiency*, suggesting that the practice is maturing into a structured and outcome-oriented design philosophy.

The presence of *computer-aided instruction* and *virtual reality*—though smaller in scale—points to an **emerging interest in immersive tools**, which support learning and visualization within participatory design processes. These tools, while not yet as central as the dominant terms, are gaining traction as facilitators of real-time user interaction, experiential feedback, and iterative refinement in co-design settings.
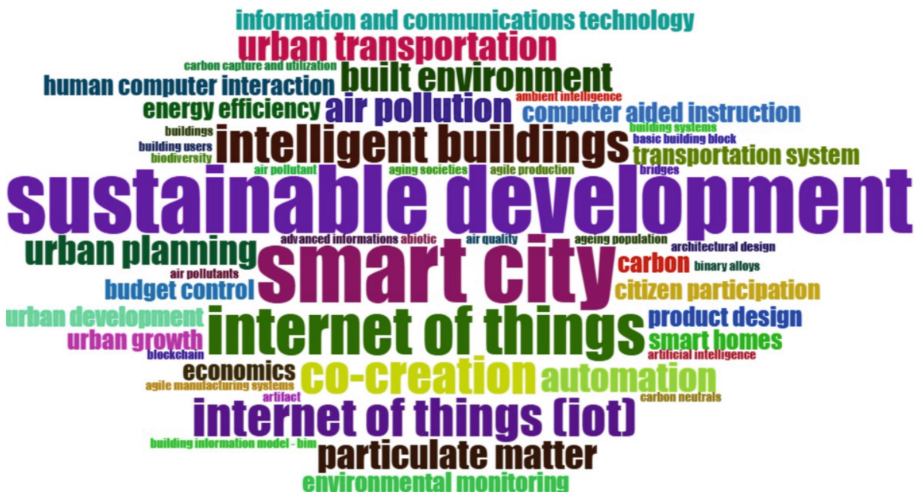

Fig. 2. Word cloud showing dominant terms in co-creation and sustainable building literature.

Figure 3, the thematic map, provides a two-dimensional representation of how central (relevant) and developed (dense) different research themes are within the field. The cluster in the upper-right quadrant, comprising **"co-creation," "built environment," and "carbon,"** is especially relevant. These are **well-developed and increasingly integrated themes**, representing domains that are not only rich in academic content but also vital to interdisciplinary research and practical application. Their location in the quadrant suggests that co-creation is transitioning from an emerging method to a well-established pillar within sustainable building practices.

By contrast, the lower-left quadrant includes *air pollution* and *urban development*, themes which may be either emerging or declining. This shift suggests that **the field is evolving away from siloed environmental metrics toward more systemic, participatory frameworks**—with co-creation and smart technologies at their core.

Meanwhile, the cluster labeled as "motor themes" in the top-right corner—*smart city*, *internet of things*, and *sustainable development*—reinforces that these are the anchors of current scholarly attention. The relative position of *co-creation* just outside this dominant cluster further emphasizes its growing recognition and strategic alignment with broader goals in digital urban transformation and sustainability transitions.
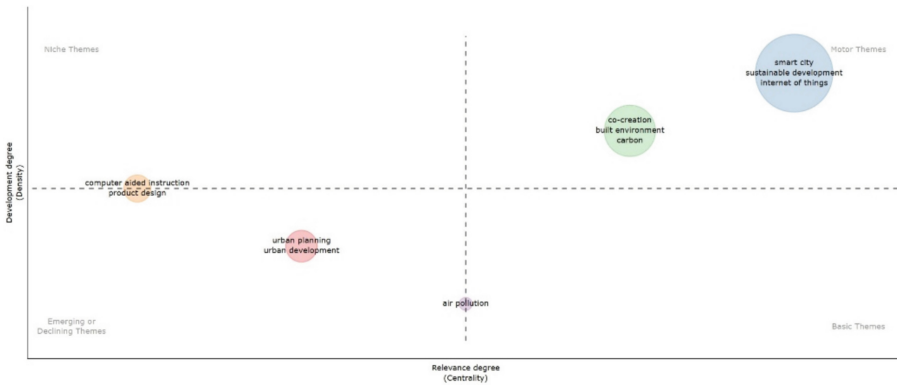

Fig. 3. Thematic map of research clusters by centrality and development within the field.

Figure 4, a co-word network focusing on immersive design and participatory technologies, adds nuance to this evolution. The centrality of *virtual reality* and *co-creation*, surrounded by terms such as *participatory design*, *user-centered design*, *design process*, *immersive environment*, and *e-learning*, provides compelling evidence that **Virtual Reality (VR) is rapidly becoming a methodological enabler of co-creation**. VR is situated at the core of networks that emphasize experiential design, collaborative interaction, and architectural simulation, supporting use cases ranging from civic engagement to energy-aware user behavior modeling.

Moreover, the visual clustering of VR with *training simulation*, *students*, *qualitative research*, and *real-world* applications underscores its dual role as both a research and educational tool. This positions VR as an accessible medium not only for professional design teams but also for diverse user groups, including future occupants, stakeholders,

and even policymakers. By enabling stakeholders to visualize, explore, and modify spatial concepts in real time, **VR strengthens the feedback loop between users and designers**, turning abstract sustainability objectives into tangible design actions.

Taken together, the four figures support a clear narrative: **co-creation is a mature and central theme in sustainable building research**, with growing influence in the digital and smart design domains. While many traditional tools and participatory practices remain relevant, the bibliometric evidence strongly indicates that **Virtual Reality is emerging as a powerful and increasingly integrated method** within this ecosystem. Its capacity to simulate, engage, and co-create design solutions places it at the frontier of participatory architecture, especially in smart and sustainable buildings where complexity and stakeholder diversity demand new forms of communication and collaboration.
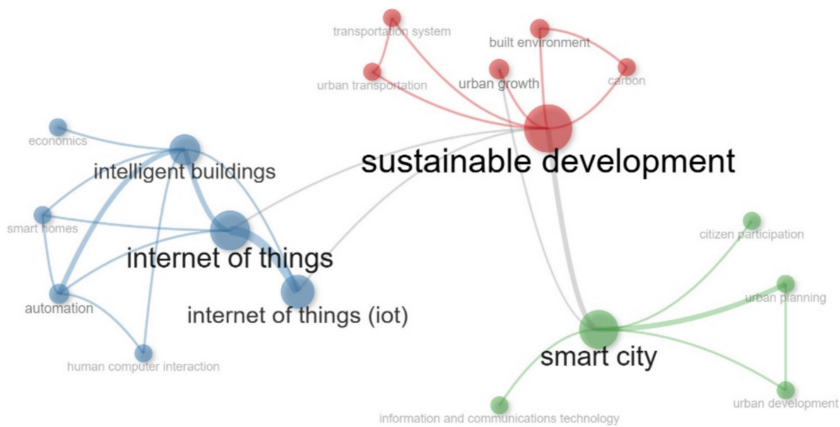
Fig. 4. Co-word network highlighting the role of virtual reality in participatory design.

4   Conclusions

This study provides a structured overview of co-creation tools used in the design of sustainable buildings, with insights drawn from a targeted bibliographic analysis of 16 studies selected through the PRISMA methodology. The findings confirm that co-creation is now widely recognized as an essential component of sustainable and smart building design, enabling the integration of stakeholder knowledge, behavioral insights, and context-specific needs into early planning and decision-making processes. Tools such as participatory workshops, stakeholder consultations, serious games, and collaborative digital platforms like BIM and digital twins are increasingly embedded in architectural workflows, enhancing transparency, adaptability, and design acceptance. The thematic clusters and keyword analyses indicate a well-developed and maturing research field that aligns co-creation with strategic goals in energy efficiency, climate resilience, and social inclusivity. As sustainability targets become more ambitious and the built environment more complex, co-creation methodologies will play an increasingly strategic role in ensuring user engagement and long-term performance outcomes. Among the variety of tools examined, Virtual Reality (VR) was identified as an emerging method with unique

potential to enhance user experience and spatial understanding in co-design processes. Continued integration of co-creation into mainstream practice will be vital in shaping resilient, inclusive, and future-ready buildings.

References

1. Nidam et al. (2025). Practicing data inclusion: Co-creation of an urban data dashboard. *Environment and Planning B: Urban Analytics and City Science*, 52(1)
2. Zhang et al. (2024). Exploring the nexus of smart technologies and sustainable ecotourism: A systematic review. *Heliyon*, 10(11)
3. Sameer et al. (2024). Toward smart sustainable cities: assessment of stakeholders' readiness for digital participatory planning. *Archnet-IJAR: International Journal of Architectural Research*, 18(4)
4. Theodoropoulou et al. (2024). Glare-based control strategy for Venetian blinds in a mixed-use conference space with fully glazed facades. *Journal of Building Engineering*, 82
5. Berigüete et al. (2024). Digital Revolution: Emerging Technologies for Enhancing Citizen Engagement in Urban and Environmental Management. *Land*, 13(11)
6. Royo-Vela et al. (2024). The role of value co-creation in building trust and reputation in the digital banking era. *Cogent Business and Management*, 11(1)
7. Zwick et al. (2024). Examining the Smart City Generational Model: Conceptualizations, Implementations, and Infrastructure Canada's Smart City Challenge. *Urban Affairs Review*, 60(4)
8. Florentin et al. (2024). Facilitating citizen participation in greenfield smart city development: The case of a human-centered approach in Kashiwanoha international campus town. *Telematics and Informatics Reports*, 15
9. Violano et al. (2024). From Self-Reliant to Sufficiency Design: Predictive and Forecasting Features of Technology Approach. *Lecture Notes in Networks and Systems*, 1189 LNNS
10. Harra et al. (2024). Developing sustainable and ethically valid gerontechnology: A comprehensive approach to aging, diversity, and participation. *Gerontechnology*, 23
11. Huang et al. (2024). Application Models and Innovative Approaches of Smart Libraries from the Perspective of MR Technology. *Journal of Library and Information Science in Agriculture*, 36(9)
12. Ma et al. (2024). Developing a Manufacturing Industrial Brain in a Smart City: Analysis of fsQCA Based on Yiwu Knitting Industry Platform. *Buildings*, 14(5)
13. Zhang et al. (2023). Shaping a Smart Transportation System for Sustainable Value Co-Creation. *Information Systems Frontiers*, 25(1)
14. Badawi et al. (2023). Towards a Value Co-Creation Process in Collaborative Environments for TVET Education. *Sustainability (Switzerland)*, 15(3)
15. Slingerland et al. (2023). Beyond human sensors: More-than-human Citizen Sensing in biodiversity Urban Living Labs. *ACM International Conference Proceeding Series*
16. Kormann-Hainzl et al. (2023). Smart Regions in the Age of the Citizen Developer: A Service-Oriented Engineering Approach. *ACM International Conference Proceeding Series*