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EDITORIAL

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How Can Games Transform Cities? Geogames as Tools for Research, Education, and Urban Praxis

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Abstract

Geogames have matured from an emergent field in the 2000s into a transformative intersection of game design, geographic information science, and games with a purpose. This thematic issue advances the geogames research, education, and praxis agenda through 10 articles organized into two sections. Section 1 establishes geogames as rigorous research and educational instruments, exploring their theoretical foundations, methodological applications, and pedagogical value for fostering spatial literacy and emotional engagement. Section 2 demonstrates geogames as operational tools for real-world urban planning, showcasing their implementation in participatory consultations, communicative planning, and sustainability initiatives. These contributions frame geogames as a socio-technical epistemology rather than mere representational or engagement tools, revealing their capacity to address complex contemporary urban challenges. By bridging virtual simulation with material intervention in games, this issue presents a unified framework for reimagining research, teaching, and the transformation of urban spaces through geogames—where the concept of Gaia (Earth as a living system) converges with gameplay—in an era marked by unprecedented spatial, environmental, and social challenges.

Keywords

game-based learning; game design; geogames; participatory planning; urban planning

1. Introduction: Can Games Transform Cities?

Cities are increasingly confronted with complex, interdependent challenges, including climate change, social inequality, spatial injustice, and the urgent need for sustainable and regenerative urban transformations. These challenges have catalyzed a fundamental epistemological shift in urban research, education, and planning practice, moving away from positivist, linear models that treat cities as systems amenable to top-down and expert-driven control. Traditional approaches have relied on static spatial representations—master plans, zoning maps, and deterministic forecasts—that privilege singular, authoritative visions of urban futures while marginalizing the knowledge, values, and agency of diverse urban actors. In response, scholars and practitioners have increasingly embraced relational, processual, and participatory frameworks that recognize cities as dynamic, contested, and co-produced spaces. This reorientation has demanded methods and tools capable of embracing uncertainty, facilitating multi-stakeholder deliberation, and supporting iterative exploration rather than fixed prediction. Geogames and other playful, interactive media have emerged as key instruments in this ongoing transformation, enabling participants to engage with urban complexity in ways that are simultaneously rigorous, accessible, and generative of new forms of spatial knowledge and collective agency. Geogames have become a powerful yet still contested medium for operationalizing these more fluid, diverse, and inclusive approaches to urban futures.

Geogames—games that explicitly engage with geographic space, spatial data, and place-based decision-making—have developed since the early 2000s at the intersection of game design, geographic information systems (GIS), and location-based games (Poplin, 2025; Poplin & Schwartz, 2020; Schlieder et al., 2005, 2006). The rise of this dynamic field has been driven by the urban planning domain's response, supported by digital technology advances and participatory demands, to pressing contemporary urban issues. Since the 1970s, serious games have been applied as multiple dialogue communication and training platforms, as well as consensus-reaching simulation tools on urban (re)development impacts (Abt, 1970; Duke, 1974; Sanoff, 1979; Summers, 1979). Initially explored as experimental and situated location-based tools for urban exploration, participatory planning practices, or educational purposes, geogames have been maturing into a consolidated knowledge field with distinct epistemological, methodological, and practical contributions (Ahlqvist & Schlieder, 2018). Rather than merely simulating cities or visualizing data, geogames invite players to inhabit urban systems, negotiate trade-offs, and experience spatial processes through play. This thematic issue asks a deceptively simple question: How can games transform cities? More precisely, it examines how geogames can contribute to urban research, education, and praxis in ways that extend beyond engagement towards knowledge production and action.

The growing relevance of geogames reflects broader shifts in urban scholarship and practice (Tomaszewski & Schwartz, 2017). Planning theory has long emphasized communicative, participatory, and collaborative approaches, yet implementation often struggles to meaningfully integrate diverse perspectives or address power asymmetries. Factors affecting urban and regional planning today may have multifaceted causes in historic, social, economic, political, and environmental realms (Levy, 2017), including overlooked decision-making aspects such as power and interest relations, conflicts, and coalitions related to stakeholders' attitudes and behaviors (Mayer et al., 2005). At the same time, digitalization has transformed how cities are modeled, governed, and experienced, while serious games and gamification have gained traction across policy, education, and governance domains (Tan, 2016). Geogames sit at the confluence of these developments. They are a fusion of geospatial technologies and visualizations, serious gaming

mechanics, and playful public participation, providing architects and urban planners with powerful tools to engage a range of stakeholders, simulate scenarios, and upscale decision-making environments (Ahlqvist & Schlieder, 2018; Andrade, 2020; Brković Dodig & Groat, 2019; Poplin et al., 2020). They may combine spatial data, visualizations, and modeling with rule-based systems, narratives, and embodied interaction, offering a medium through which urban futures can be explored, contested, and co-produced.

Importantly, geogames are not confined to digital environments. While early research focused heavily on computer-based simulations and virtual worlds, recent work has expanded the field to include analog and hybrid formats, such as board games and card-based systems. These formats foreground face-to-face interaction, negotiation, and reflection, challenging assumptions that technological sophistication alone determines the analytical or pedagogical value of games. Digital and analog geogames may form a continuum of practices that support learning, experimentation, and deliberation across varied contexts and audiences.

This thematic issue brings together 10 articles that aim to advance the consolidation of geogames as a knowledge field. The contributions move beyond viewing geogames as auxiliary tools for stakeholder engagement, positioning them instead as epistemological devices capable of generating insights into spatial processes, emotions, behaviors, and decision-making. The issue is organized into two complementary sections with five articles each. Section 1 focuses on geogames as research and educational instruments, examining their theoretical foundations, methodological rigor, and pedagogical potential. Section 2 shifts attention to demonstrating how geogames can be operationalized in real-world planning contexts. Ten published articles demonstrate an international reach providing examples and geographical contexts spanning Europe and North and South America, which underscores the global relevance of geogames in contemporary urban discourse. The collection is characterized by a rigorous balance between localized empirical case studies ranging from campus-scale interventions in Poland and energy-efficiency initiatives in the USA to high-level theoretical syntheses from institutions in Ireland, the UK, and Brazil. While the diversity of geographical contexts and methodologies suggests potential for cross-cultural replicability, these articles also reveal a critical tension between site-specific participatory needs and the universal nature of gamified frameworks. This variety ensures that the editorial scope is not merely descriptive but serves as a versatile toolkit for adapting participatory planning to distinct socio-spatial realities, provided that the inherent limitations of scaling local successes are critically addressed.

The 10 articles assemble cutting-edge insights in research, education, and practice of the ways geogames are being employed to tackle some of the most pressing issues in urban (re)development including, but not limited to, urban degradation and (re)urbanization; built heritage conservation and sustainability; affordable housing and diverse particular housing needs; public transportation, active mobility, and nature-based solutions for healthy and happy cities; circularity and energy efficiency; and the critical issues of adaptation planning towards climate change impacts. They illustrate how geogames can support dialogue, reveal stakeholder conflicts and synergies, and enable collective exploration of alternative urban futures. Rather than offering deterministic solutions, geogames function as spaces for negotiation, experimentation, and reflection within complex planning environments. Across both sections, a shared concern emerges: How to translate the playful, exploratory nature of geogames into tangible planning outcomes without sacrificing theoretical depth or methodological robustness?

2. Theoretical Developments and Practical Challenges

Over the past two decades, geogames have proven effective in engaging people with urban questions, yet defining what constitutes a "geogame" and what claims it can legitimately support remains challenging. This thematic issue positions geogames not as a single genre or platform, but as a knowledge practice that offers conceptual opportunities while exposing practical constraints. The contributions in this issue address these challenges through rigorous, scalable, and theoretically grounded applications in urban planning.

2.1. Conceptual Clarity Without Narrowing the Field

A primary theoretical challenge lies in defining geogames, which are often described through varying traits like GIS integration, location-awareness, or participatory intent that do not always co-occur. This thematic issue advocates for a productive middle ground, framing geogames as designed encounters with geographic knowledge where representation—models, maps, and rules—and experience—play, emotion, and debate—are inseparable. By treating geogames as socio-technical constructions rather than neutral mirrors of the city, the contributions move beyond a real versus virtual split to critically examine whose knowledge becomes dominant and how these structured ways of seeing prioritize specific urban values and power dynamics.

2.2. From "Gaia + Games" to Urban Praxis: Scale, Agency, and Responsibility

A second development concerns the relationality of urban problems, which increasingly unfold across systems like mobility, energy, and climate that interact with planetary processes. The "Gaia + Games" framework to design and assess games treats Earth ecosystems thinking not as an abstraction but as an experiential reality, though this creates a tension between making in-game scenarios become concrete and addressing the inherent complexity of situated urban systems. This is fundamentally a question of agency and accountability; by linking design choices to normative implications, the field can better scrutinize how gameplay loops naturalize assumptions about governance and trade-offs, ultimately determining which urban futures are made imaginable for both human and non-human actors.

2.3. The Practical Challenge of Measurement: Validity, Transfer, and Evaluation

Pragmatically, geogames must overcome challenges in measurement and evaluation to mature as dependable instruments of inquiry. This involves ensuring representational validity (correspondence to real-world phenomena), interpretive validity (distinguishing real-world preferences from game-winning strategies), and transferability (tracking how insights influence actual policy and learning). These concerns are particularly acute in participatory planning, where game-based formats can lower entry barriers but may also introduce new exclusions based on digital literacy or hardware access. Thus, the articles published in this issue emphasize that making geogames genuinely participatory requires transparent framing and explicit attention to equity to ensure they empower rather than merely perform consultation.

2.4. An Agenda of Responsible Innovation

These challenges suggest a current research agenda centered on responsible innovation, characterized by clearer typologies, mixed-method evaluation, and inclusion as a core design requirement. The contributions

assembled here do not resolve all of these tensions but instead demonstrate that geogames are becoming a serious arena for methodological invention and urban praxis. By introducing a public negotiation between evidence, experience, and action, this thematic issue maps a field that is consolidating its conceptual stakes while remaining theoretically unsettled, setting the stage for the operational case studies that follow.

3. Structure of the Thematic Issue

The following sections detail how these works transition from research and educational frameworks to operational tools for real-world planning and policy.

3.1. Section 1: Research and Education

The first five articles establish geogames as rigorous instruments for spatial literacy and methodological innovation. Crilly et al. provide a foundational systematic review, synthesizing how game-based simulations intersect with systems theory and digital planning to facilitate citizen engagement. Building on this theoretical base, Andrade and Brković Dodig introduce a Gaia-inspired framework to bridge the gap between design theory and practical assessment, while Sousa et al. critically expand the field's boundaries by demonstrating that analogue board games function as effective, accessible geogames through their sophisticated spatial representation systems.

This section further explores the empirical application of these geogames in diverse urban contexts. Szot et al. utilize Minecraft to map collective emotions in urban spaces, proving that multiplayer environments can generate coherent affective data for planning. Complementing this, Albornoz del Valle and Núñez Cerda employ a dual-geogame framework using Cities: Skylines to simulate active mobility in Concepción, Chile. Together, these contributions transition geogames from mere entertainment to essential educational and research platforms that capture the complex interplay between technical simulation and human perception.

3.2. Section 2: Planning, Design, and Policy

Section 2 operationalizes geogames as practical instruments for real-world urban governance and stakeholder engagement. Cureton et al. bridge the gap between entertainment and professional practice by using a geodesign framework to translate Cities: Skylines gameplay into actionable land-use data in the UK. Szczepanska et al. introduce PaSyMo, a mobile simulation lab that combines agent-based modeling with tangible interfaces to facilitate consensus-building in Germany. These contributions demonstrate how game-based systems can transform complex socio-spatial data into accessible platforms for communicative planning and decision-making.

The remaining articles focus on the performative and behavioral impact of geogames within specific institutional and community contexts. Srivastava and Meza present a pervasive model that scales individual energy-saving actions into collective urban policy by leveraging the principle of nested urban scales, which aligns player identities across the home, block, and city. Förster et al. explore the co-creation of mobility hubs through the New European Bauhaus, emphasizing principles of situated play—such as bodily movement, material making, and open-ended storytelling—to foster corporeal and performative engagement. Finally, Wendland et al. apply these principles to institutional planning with *Campus Changer*, a

serious geogame that utilizes principles of social activation and volunteered geographic information within a 3D virtual environment to gather stakeholder input for the redesign of Warsaw University of Technology. Collectively, this research demonstrates that geogames are no longer merely speculative but are active tools for democratizing urban design and informing sustainable policy.

3.3. Cross-Cutting Insights

A defining insight across this collection of articles in the thematic issue is that geogames can function as socio-technical ecosystems, mediating the complex relationships between players, spatial data, and urban decision-making. The work of Szot et al. on multiplayer emotional dynamics, Szczepanska et al.'s integration of tangible interfaces with agent-based modeling, and Cureton et al.'s feedback loops between gameplay and professional planning illustrate how geogames can foster new forms of spatial agency. This shifts the research frontier toward understanding the novel capacities geogames can create within urban processes, moving beyond the technology itself to the relational shifts it enables.

While these contributions demonstrate significant success in stakeholder engagement, they also identify vital areas for future growth and longitudinal exploration. Förster et al. and Wendland et al. provide a foundation for understanding how playful interventions may influence planning, opening the door for systematic studies that track these impacts from design to policy implementation. The success in engaging youth and motivated citizens highlights an opportunity to further expand accessibility. Sousa et al.'s inclusion of analogue games provides a strategic pathway for bridging digital divide in order to foster the commitment to inclusive participation. Furthermore, Andrade and Brković Dodig's Gaia-inspired framework points toward a promising horizon where geogames can cultivate planetary consciousness, aligning urban planning with ecological limits and intergenerational justice. Ultimately, this thematic issue affirms that the transformative potential of geogames lies in their ability to bridge gaming abstractions with real-world change through collaborative and reflective practice.

4. Conclusion: Beyond Geogame Play

This thematic issue demonstrates that geogames have evolved into essential urban epistemic infrastructure—systems through which cities can be explored, sensed, narrated, and redesigned. Contributions assembled here demonstrate that geogames can reorganize urban knowledge production by generating evidence-based data, such as collective emotion maps, and may translate gameplay into actionable design propositions and model-mediated negotiations. By bridging the gap between simulation and material intervention, these articles showcase geogames as powerful tools that may authorize specific urban imaginaries and problem-solving frameworks.

The research agenda on geogames moving forward must address the critical questions of governance, ethics, and long-term impact. As geogames transition from research settings into formal planning, the field might explore who controls the underlying models and how to ensure that playful participation translates into accountable policy change. Future exploration could focus on developing robust frameworks for longitudinal evaluation—meaning ongoing, systematic assessment of geogame impacts over extended periods—centering equity to bridge the digital divide, and exploring Gaia-inspired designs that treat cities as living ecological systems characterized by feedback mechanisms, co-evolutionary dynamics, multispecies interactions, and

planetary thresholds. Ultimately, this thematic issue aims to shift the focus from the validity of geogames to their transformative praxis, challenging researchers and planners to bridge gaming abstractions with the urgent requirements of urban sovereignty and collective survival.

Conflict of Interests

The authors declare no conflict of interests.

LLMs Disclosure

ChatLLM Teams (Claude Sonnet 4.5) was used to assist with English language editing and reference list formatting in APA 7th edition style for papers cited in this editorial. All substantive content, analysis, and argumentation were developed by the authors.

References

Abt, C. C. (1970). *Serious games*. Viking Press.

Ahlqvist, O., & Schlieder, C. (Eds.). (2018). *Geogames and geoplay: Game-based approaches to the analysis of geo-information*. Springer. https://doi.org/10.1007/978-3-319-22774-0

Andrade, B. (2020). Climate geogames: A new paradigm to games as civic engagement tools for urban heritage sustainability. *International Journal of Environmental Resilience Research and Science*, *2*(1).

Brković Dodig, M., & Groat, L. N. (2019). Architecture and urban planning? Game on!: Games as tools for design, teaching/learning, and research in architecture and urban planning. In M. Brković Dodig & L. N. Groat (Eds.), *The Routledge companion to games in architecture and urban planning* (pp. 1–14). Routledge.

Duke, R. D. (1974). *Gaming: The future's language*. Sage Publications.

Levy, J. M. (2017). *Contemporary urban planning* (11th ed.). Routledge.

Mayer, I. S., van Bueren, E. M., Bots, P. W. G., van der Voort, H., & Seijdel, R. (2005). Collaborative decisionmaking for sustainable urban renewal projects: A simulation–gaming approach. *Environment and Planning B: Planning and Design*, *32*(3), 403–423. https://doi.org/10.1068/b31149

Poplin, A. (2025). Geogames: An expanded definition, application areas, geogame types, and a proposed research agenda. *Environment and Planning B: Urban Analytics and City Science*. Advance online publication.

Poplin, A., Andrade, B., & de Sena, Í. S. (2020). Geogames for change: Cocreating the future of cities with games. In D. Leorke & M. Owens (Eds.), *Games and play in the creative, smart and ecological city* (pp. 64–93). Routledge.

Poplin, A., & Schwartz, D. E. (Eds.). (2020). Gaming and geospatial information [Special issue]. *ISPRS International Journal of Geo-Information*, *9*(3).

Sanoff, H. (1979). *Design games: Playing for keeps with personal and environmental design decisions*. William Kaufmann.

Schlieder, C., Kiefer, P., & Matyas, S. (2005). Geogames: A conceptual framework and tool for the design of location-based games from classic board games. In *International Conference on Intelligent Technologies for Interactive Entertainment* (pp. 164–173). Springer.

Schlieder, C., Kiefer, P., & Matyas, S. (2006). Geogames: Designing location-based games from classic board games. *IEEE Intelligent Systems*, *21*(5), 40–46.

Summers, R. (1979). *Gaming: A technique for training and planning*. Gower Press.

Tan, E. (2016). The evolution of city gaming. In *Complexity, Cognition, Urban Planning and Design: Post-Proceedings of the 2nd Delft International Conference* (pp. 271–292). Springer.

Tomaszewski, B., & Schwartz, D. I. (2017). Critical spatial thinking and serious geogames: A position. In C. Schlieder & D. Pajarito (Eds.), *Proceedings of the AGILE 2017 Workshop on Geogames and Geoplay* (pp. 9–12). AGILE.

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Bruno Andrade is an architect and urbanist with a PhD in geodesign with expertise in the intersection of cultural heritage, community planning, and geogames. He leverages digital and analog technologies and games for participatory heritage management, drawing from extensive international experience across Brazil, Italy, Austria, Ireland, the Netherlands, and Portugal. He is currently assistant professor at the Architecture and Urbanism Bachelor program at Salvador University – UNIFACS, and visiting researcher at the School of Architecture, Federal University of Bahia (UFBA), Brazil, where he co-coordinates the Preserving Legacies: A Future to Our Past project, and leads the "PatrIA" project funded by CNPq, both in Salvador, focusing on the climate adaptation of Candomblé cultural heritage sites.

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David Schwartz, PhD, has worked in the academic field of game design and development since 2001, when he founded the Game Design Initiative at Cornell University. In 2007, Schwartz moved to the Rochester Institute of Technology as a game design and development faculty member who formed the School of Interactive Games and Media (IGM) in 2011. After receiving tenure in 2011, he became IGM's Director in 2015. His current research focuses on cybersecurity gamification, critical infrastructure, geogames, digital twins, and physically-based animation.

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ARTICLE

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Experimenting With Gamification and Geogames in Urban Planning: A Systematic Literature Review

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Abstract

This systematic literature review examines the complex intersection of gamification and urban planning with particular attention to the interrelated fields of experimental urbanism, systems theory, digitalization of the urban planning system, game theory, and agent-based modelling. As such, this article addresses the critical gap of an existing systematic and detailed literature review in this emerging area of using geogames in urban planning research and practice. The review synthesises both the available scholarship and related grey literature to understand how simulations and game-based approaches are utilized in citizen engagement and urban planning policy. This article identifies the current priority themes in the application of gamification to urban planning through a temporal and thematic exploration of a mix of theoretical frameworks, empirical studies, practice-based experiments, and software applications. This has been undertaken through a multi-dimensional analysis of mixed academic and media databases. Moreover, it evaluates the effectiveness of urban simulations and game-based planning interventions, highlighting the most promising areas for future applied research. The findings suggest that gamification and urban planning simulations represent a change in focus in planning theory and practice, offering new tools for participatory scenario-based planning, urban analytics, and understanding or managing complex urban systems. The article concludes by highlighting current research gaps and proposing a dynamic future research agenda to advance the understanding and effective implementation of simulated approaches and geogames in urban design and planning.

Keywords

experimental urbanism; gamification; geogames; systems theory; urban planning; urban simulation

1. Introduction

There has been a considerable rise in scholarship in the past 10 years documenting a variety of applications of gamification in urban design and planning, with the first annual Geogames Symposium being held in 2024 in Portugal at Portucalense University. This has increased the need to take stock of this novel and expanding exciting field of research and attempt to collate and synthesise it, identifying the main caveats as well as the most promising avenues for future development and practical application. Professionals working within the built environment professions are experiencing a growing interest in the loosely defined field of "geogames" which, through a variety of different analogue and digital applications, aim to go beyond the value of "pure entertainment," being described often as "serious games" (Connolly et al., 2012), to deal with practical real-world applications (de Sena et al., 2021) or to focus on specific educational and environmental learning outcomes (Pilote & Chiniara, 2019).

In practice, urban planning-themed games can be both analogue and digital, often transversing the boundaries between the different formats or media to the point of influencing or informing the content of each other. They demonstrate the complex and dynamic interactions among objects, agents, and events in whatever format the games are presented. Serious urban planning geogames can be understood as material representations of real-world systems, based on thematic abstraction, but also being capable of providing meaningful insights into the specific system's behavior in the particular gameplay setting. Several writers have already undertaken research compiling large game datasets and analysing the key mechanics, components, and patterns found within these games, including the key spatial dimensions (Davidsson et al., 2004; Sintoris, 2015) of locality, proximity, navigation, race, and collection (Ahlqvist & Schlieder, 2018, p. 10). The locality and proximity patterns evident in geogames are fundamental in the sense that any location-based game engine (or board) must support at least one such pattern. These game patterns and structures refer to a range of complex core concepts such as networks, granularity, events, or values, and it is possible to identify associated clusters of patterns comprising these concepts or characteristics describing different spatial activities.

This article explores these game-based concepts by first presenting a comprehensive, systematic literature review of gamification with related fields of knowledge, highlighting the connections among them and urban planning applications. The guiding research question is understanding the current state of research on gamification and geogames in relation to urban design and planning, including the origins within the application of systems theory and game theory within urban simulations. This has been broken down into three sub-questions: Firstly, what are the key research fields that address geogames and gamification in relation to urban planning and their convergence, divergence, and possible overlaps? Secondly, what are the key applications of gamification in urban planning practice and the main limitations? Thirdly, what are the most promising avenues for future research in this novel field of enquiry?

As such, the article begins by setting out a suitable conceptual framework for exploring these linked research questions and provides a detailed methodology for the systematic review of the linked thematic literatures. It then addresses the main current applications of gamification in urban planning, identifying the limitations in practice and areas of future research.

2. Conceptual Foundations and Methodological Approach

As is often the case with city planning games, the deliberate starting point here is SimCity, with one of the original software developers, Gingold (2024), writing about the background to the game's development in the chapter "Simulation as Analogy" that analogue and digital have the same roots. They share the same underlying structures and rules. They are not opposites (a mistaken assumption within systems thinking) but are part of the same developmental timeline. In such an urban planning game or simulation, there was an emergent characteristic in the need for self-organisation and the ability to set your own goals for city building. In effect, within the game or simulation, the user has agency in decision-making within the virtual simulations, and this has strong parallels with many forms of practical urban planning (Devisch, 2008), seen as significant for pedological reasons (Kim & Shin, 2015) within real-world scenarios (Plass et al., 2015).

This article presents a response to this specific history in the form of a timeline of overlapping concepts and literatures relating to (a) gamification/game theory, (b) urban simulations/systems theory, (c) cellular automata/agent-based modelling, (d) experimental urbanism, and (e) digital planning, with the last two areas of literature aiming to bring some current real world applications and impact to the work undertaken in the first three areas identified. These literatures were explicitly selected in reference to Gingold's (2024) analysis of the origins of SimCity, with the identified sources of academic and popular literature crossing the analogue and digital boundary. We accept that this is a selective overview of sources and inspirations and understand that there are contrasting and evolving ideas and definitions of what virtual, augmented, and mediated reality relate to (Mann et al., 2023). However, they all have common roots in theories about urban systems and "the common denominator is that the art of the…game is not simply synonymous with entertainment, but with life" (Garriott, as cited in Donovan, 2010, p. X). The detailed search strategy, including the semantic keywords and scope of databases (Table 1), is described below as the basis of a transparent and reproducible method.

The initial searches yielded over 180,000 potentially relevant articles, papers, or software applications. These results were screened and analysed chronologically, in each case, identifying the (a) earliest reference source as a proxy for the first "recorded" occurrence of the term's historical context and foundational theories; (b) the point of going "viral" or becoming mainstream, indicative of emergence of the term as a popular trend; and (c) the key reference to highlight this "peak" point of usage based on the most cited sources prior to charting any observable decline with the number of sources (up to end of 2024, albeit several pre-publication sources for 2025 were identified within the review). We have highlighted the overall number of sources by year to understand any trend(s) in the concepts where they exist. The choice of maintaining this clear focus on the important stages within the developmental timeline of the concepts was a pragmatic decision given the large number of papers in certain areas of research.

Given the scope of the meta-study and the overall numbers and scope of references, many of which were software or media-based as well as published sources, the research team adopted a pragmatic staged process of screening for the sources used in the synthesis and mapping (Figure 1). The summary outcomes from this meta-study are presented below and provide the basis for an overall pattern of progression in the use of different theories and systems.

Table 1. Summary of "semantic" or "keywords" used for the literature review and overview of databases reviewed as part of the formal literature review.

Key literature	Semantic keywords
Game theory/gamification	Game theory; gamification; geogames; serious games
Systems theory	Complex systems; complex urban systems; dynamic models; systems theory; wicked problems
Cellular automata	Agent-based modelling; biomimicry; dynamic geographic information systems (GIS); fluid dynamics; multi-agent planning; PacMan; Sims; Space Syntax
Experimental urbanism	Ad hoc urbanism; experimental urbanism; informal urbanism; temporary urbanism
Digital planning	City information modelling; computer-aided process planning; digital planning; digital twin; planning support systems; PSS; platform urbanism; smart city
Source(s)	**Description**
Scopus/Web of Science/ Google Scholar	Academic literature database sources subject to peer-review
ResearchGate/Academia	Collection of the most well-used (van Noorden, 2014) social networking platforms for academics and researchers, albeit with a limited repository of open-source papers/documents and restricted scope for data analysis and exporting
Wolfram	Simulation database sources. Wolfram (n.d.) curated a collection of open-source programmes/demonstrators and computer models
IMDB/IGDB/Learning on Screen/Internet Archive	Linked media database sources. UK public broadcast database that includes searchable programme transcripts. A mix of video, games, and a linked publication database available as software and mixed media file formats

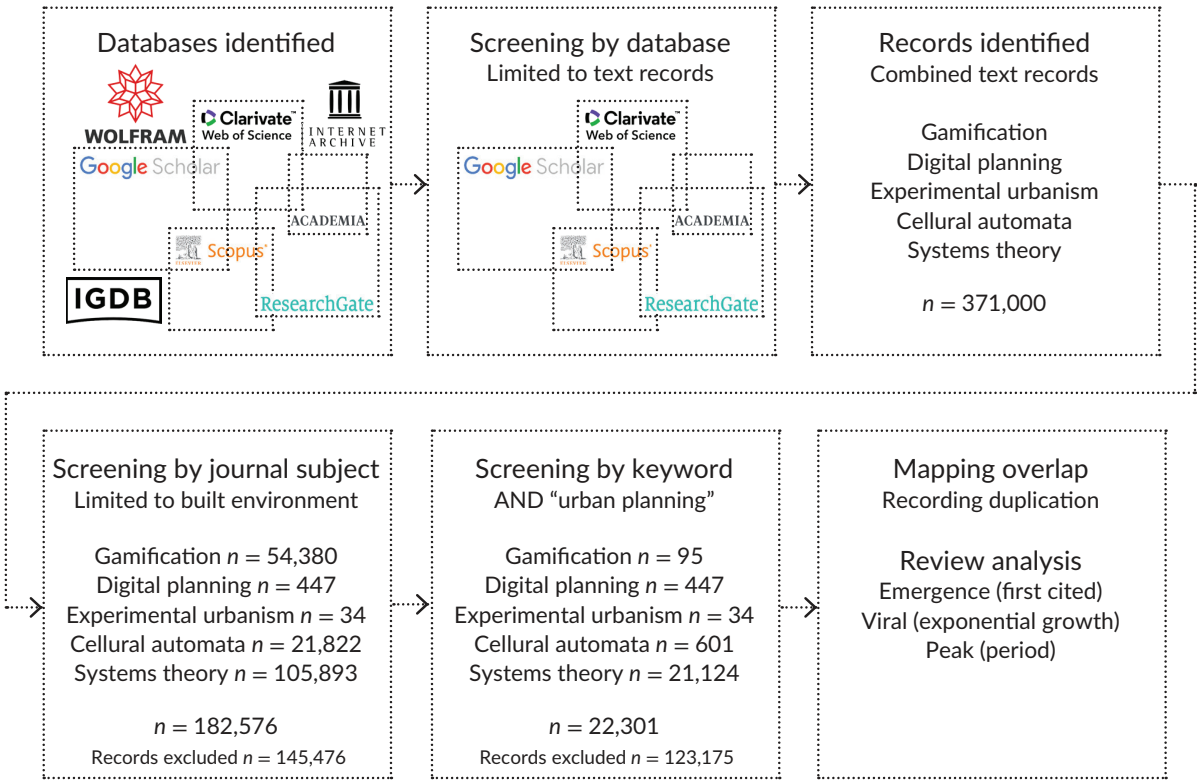

Figure 1. Process chart adapted from PRISMA showing stages undertaken as part of the systematic review.

2.1. Gamification and Game Theory in Urban Planning

The concepts of "gamification" and "game theory" arguably have common origins in the work of von Neumann and Morgenstern (1944) and were initially developed to assess utility and risk in the prediction of human behaviour. Since then, game theory and applied forms of gamification have evolved into multiple different areas of human behaviour, including the fields of urban planning and city design. In this context, Juul (2005) argues that games are simultaneously "real" in their structure of rules and "fictional" in their narrative and representational elements. This duality is relevant to urban planning, as planners and participants attempt to navigate real-world hindrances (such as budgetary or environmental limitations) within a board and/or video game's more malleable and extravagant confines. The rise in interest and application of gamification is in part due to the perceived benefits from dealing with complex, controversial, impractical, or problematic concerns within real-world scenarios. Increasingly, urban planning gaming applications are seen to have didactic (Seelow, 2022) or pedagogical value (Balbin, 2024; Bereitschaft, 2021; Hartt et al., 2020; Lobo, 2007; Pearson, 2020) and characterised by an underlying "deep learning," both emotional and experiential, gained through (mostly digital) applications. Nevertheless, critics argue that these gamified approaches present a fixed technocratic and data-driven planning system (mostly based on North American land-use zoning) rather than a pragmatic, negotiated, compromising, or collaborative system. Jenney et al. (2018) examine how visualisation techniques, such as 3D modelling, layered mapping, and interactive dashboards, greatly inform communication strategies within the field of urban planning. These innovations in gaming interfaces can be understood as a simplification or the condensing of complex data into a visually accessible format to support better understanding, engagement (Akbar et al., 2024; Devisch et al., 2016; Vanolo, 2018), and potentially empowerment (Fuchs et al., 2014) for a range of urban stakeholders normally excluded from more traditional planning engagement processes, albeit with the area of application beginning to overlap with virtual reality (Özden et al., 2023) applications.

The critical text and stages in the development of game theory since the work of von Neumann and Morgenstern (1944) highlight the beginning of a "boom" arising from a highlighted gap in the scope of applications around the potential of widening participation in urban planning (Ampatzidou et al., 2018; Baušys et al., 2021; Christodoulou et al., 2018; Thiel et al., 2017), a theme that has consistently repeated itself in a series of similar case studies (Fox et al., 2022), reviews (Latifi et al., 2022; Resek et al., 2022), and exploratory experiments regarding the specification (Szot, 2024), the use of different digital interfaces or development scenario options (Muehlhaus et al., 2022), or utilisation of commercially available digital modelling or city planning games (for example, in the use of Minecraft as the world's most popular game; Delaney, 2022), albeit variations of serious analogue games also remain effective in practice (Hügel & Davies, 2022; Sousa, 2020; Tan & Portugali, 2012). This peak level of interest is driven (Figure 2) in part by a thematic issue of the *Urban Planning* journal and by unrealised potential that so far has not been tapped.

It is important to note that while these concepts share a common origin in theory and inspiration, there is a growing differentiation between the two terms in practice and wider academic usage that is also appearing within the key literature. In respect to "game theory," the characteristics are based on rationality and mathematical modelling, evident in the non-game with no clear objectives, akin to technological or futuristic forecasting. There is an emphasis on the mathematical properties of the model, structures, and rules. In contrast, "gamification" is understood as a growing area of games study that includes serious games, interaction, and the culture of play. There is an emphasis on applied characteristics of gameplay and design

"Foundational"/emergence of concept or application	"Going viral"/most cited	"Peak" period characteristics references
von Neumann and Morgenstern (1944), who directly inspired the theoretical background of SimCity	Ampatzidou et al. (2018), recognition of the potencial and "gap" for games within public participation in urban planning (Christodoulou et al., 2018; Mueller et al., 2018)	Seelow (2022), Muehlhaus et al. (2022), Fox et al. (2022), and Latifi et al. (2022) special journal issue highlighting potential applications for digital/analogue "serious games"

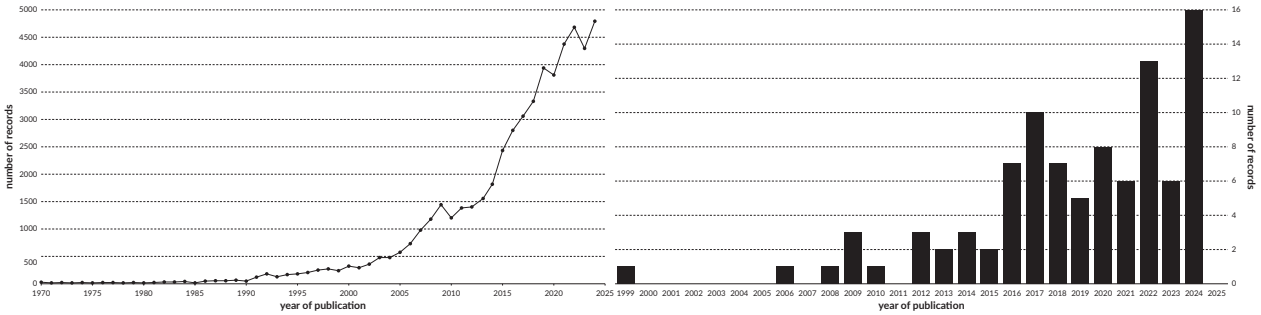

Figure 2. Key stages in the development of "game theory" and "gamification" and the number of game theory/gamification records (graph of sources selectively limited to Web of Science) by year of publication and number of similar records with the addition of "urban planning" used as a search term.

to social contexts, where there are objectives, incentives, and rewards for participants set within an overall game narrative (Aarseth, 1997; Juul, 2005).

2.2. Systems Dynamics in Urban Planning

Urban planning games are almost exclusively grounded in the systems theory, which is the transdisciplinary study of the abstract organisation of interconnected phenomena and complex entities (von Bertalanffy, 1968), using (usually mathematical) models to describe them (Heylighen & Joslyn, 1992). Systems theory emerged from the physical sciences, specifically engineering, computing, and ecology, to be applied in the social systems and urban planning sectors from the 1970s onwards to describe the operation of complex social phenomena. "The [systems theory] discipline sports a distinguished pedigree" in its potential to shape urban planning decision making (Berlinski, 1976, p. 5) using urban simulation models for analytical planning (Hull, 1969). The use of the systems theory has proved useful in identifying and calculating transitions in all aspects of planning, including urban sustainability (Grin et al., 2010) and resilience (Shi et al., 2021; Sun et al., 2024). Modelling these systems has taken many forms, with GIS as the most notable and a spatial evolution of earlier approaches to linked database management, decision/planning support, and expert systems (Kontokosta, 2021). In planning practice, complex urban system simulations were first used (Kelly, 1974) to produce a large-scale, data-dependent, interactive set of computer models for the Vancouver urban area. This novel application evolved through practice in "anticipating the future and evaluating policies" (Engelen, 1988, p. 44) for a variety of urban contexts.

Since the 2010s, complex urban systems have become more substantially common (Figure 3) for exploring dynamic simulations in the urban planning discipline, including disaster planning and mitigation (Galderisi, 2014; Grinberger & Felsenstein, 2014), policy options for public health (Tonne et al., 2021), and the relationship with

urban planning. There is an overlap with the "cellular automata" for modelling geographical phenomena (Yeh & Li, 2006) and the spatial and temporal dimensions of planning processes and systems (Sante et al., 2010) in transport planning simulations (Waddell et al., 2007) changes on land use, and the consequent feedback effects allowing for cost effective testing and evaluation of possible policy interventions.

"Foundational"/emergence of concept or application	"Going viral"/most cited	"Peak" period characteristics references
von Bertalanffy (1968), Hull (1969) urban simulation models; Berlinski (1976) system analysis	Liu (2022) urban planning applications	Grinberger and Felsenstein (2014), Galderisi (2014) dealing with linked "wicked" problems spanning the physical and social sciences

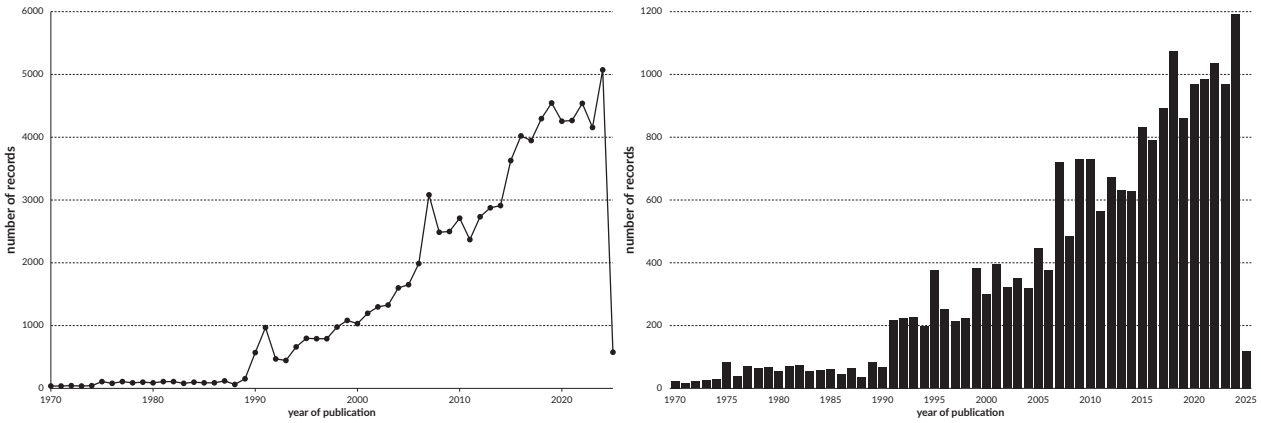

Figure 3. Key stages in the development of "systems modelling" and the number of "systems theory" or "complex systems" records (graph of sources selectively limited to Web of Science) by year of publication and number of similar records with the addition of "urban planning" used as a search term.

2.3. Agent-Based Modelling and Cellular Automata

The origins of the links between urban systems and cellular automata also lie in von Neumann's aspiration to create a model of a "self-reproducing machine," presented at the Hixon Symposium in 1948 (Damerow, 2010). Practically, this can be defined as a "discrete" computational model that consists of a regular finite grid of standard dimensioned cells arranged uniformly in a grid (Bhardwaj & Upadhyay, 2017) and then subject to change throughout various stages, depending on transition rules (O'Sullivan & Perry, 2013) applied to the system. Such a cellular automata approach was made famous by John Conway's Game of Life in the 1970's, which arguably remains the most famous application of agent-based modelling that has been revisited in many digital forms since its initial publication. This Game of Life had a different aim than that of von Neumann, it being to create a "playerless" game (Numberphile, 2015). The game is considered by academics to be Conway's most famous creation and "the most interesting and fundamental cellular automata construction," because of how the rules of the game manifest complexity (Pena & Sayama, 2021). The Game of Life is also widely recognised as the first game to contain cellular automata, and the method has been continuously used within video games ever since. Some of the earliest games utilising cellular automata were a genre known as falling-sand games (for example, Falling Sand and Powder) that involved players selecting and inserting a range of materials into the world, and, like Conway's game, do not have any winning criterion. Minecraft also contains cellular automata for certain essential gaming functions and

demonstrates "transition rules" very similar to the Game of Life (Pagáč, 2022). However, SimCity is likely to be the most widespread example of cellular automata being used to simulate the outcomes of a city. Utilisation of cellular automata as a basis for city experimentation in a professional capacity has been explored with increasing interest since the 1990's, exploring forms, dynamics, and alternative future land use scenarios (Engelen, 1988; X. Li, 2008).

Similarly, agent-based modelling traces its origins to the advent of cellular automata (Chen, 2012) and has been used for advancing the sophistication and complexity within geographical models and simulations (Crooks & Heppenstall, 2012) as part of the growth in agent-based applications (Figure 4). Macal (2016) adds to the specific definition of the different characteristics of agent-based models (individual, autonomous, interactive, and adaptive typologies), each with its own specific behavioral characteristics, with the key perspective for urban planning being the overall complexity and corresponding unpredictability of outcomes arising from the interaction of multiple agents within the simulation. Yet there are clear limitations and weaknesses in cellular automata applied to real-life situations. It is challenging to model the influence of "human" political or behavioural factors, such as political factors (X. Li & Liu, 2007).

"Foundational"/emergence of concept or application	"Going viral"/most cited	"Peak" period characteristics references
von Neumann and Morgenstern (1944)	Conway, Gardner (1970), "SimCity," "Sleuth," "Metronamica"	Chen (2012) and Macal (2016)

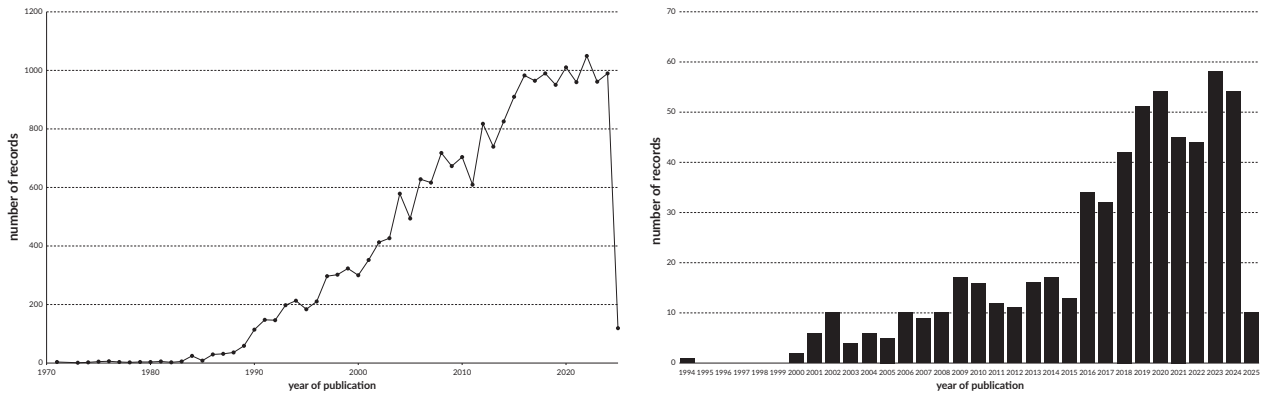

Figure 4. Key stages in the development of "agent-based modelling" and number of "cellular automata" records (graph of sources selectively limited to Web of Science) by year of publication and number of similar records with the addition of "urban planning" used as a search term.

2.4. Digital Planning

The history of digital technology within the development and operation of the UK planning system began with leveraging "mainframe computing and cybernetics" (Goodspeed, 2015), progressed through the use of desktop tools for data analysis, forecasting, and plan production (Klosterman & Landis, 1988) especially GIS, public participatory GIS (Feneri, 2016) and recently the application of virtual/augmented reality and the rise of social media: "platforms [that] have provided planners with new tools and opportunities to collect and analyse information, and create dialogue between stakeholders" (Wilson et al., 2019, p. 289). There has been a focus on the use of "capturing and digitalizing data and mapping to visualise existing and proposed

land-use" (Hussnain et al., 2020, p. 2) in the use of GIS spatial analysis, making this resource accessible to non-technocratic professions (Sheppard et al., 1999). To a lesser extent, there has been an overlap with urban simulations seeking practical applications, albeit these have been largely restricted by the cost of realistic data, licensing, and computing power required by individual planning authorities. As such, cost restrictions have reduced, and applications have become more accessible and affordable. Through the corresponding number of internet of things (IoT) devices (Syed et al., 2021), digital planning has gone viral (Figure 5) and become the basis for the emergence (Mahizhnan, 1999) and growth of "smart cities" and "digital twins" (Piras et al., 2024) or virtual replicas of cities that can be used to simulate theories and experiment relatively risk free by utilising live data gathered from installed IoT sensors (Carrasco et al., 2022), albeit with the growth of big and real time data there are also challenges with the quality of data (accuracy and bias) that is derived from smart city platforms (Green, 2019; Matheus et al., 2020).

"Foundational"/emergence of concept or application	"Going viral"/most cited	"Peak" period characteristics references
Mahizhnan (1999)	Smart cities and the broad use of "platform urbanism"	Not yet reached

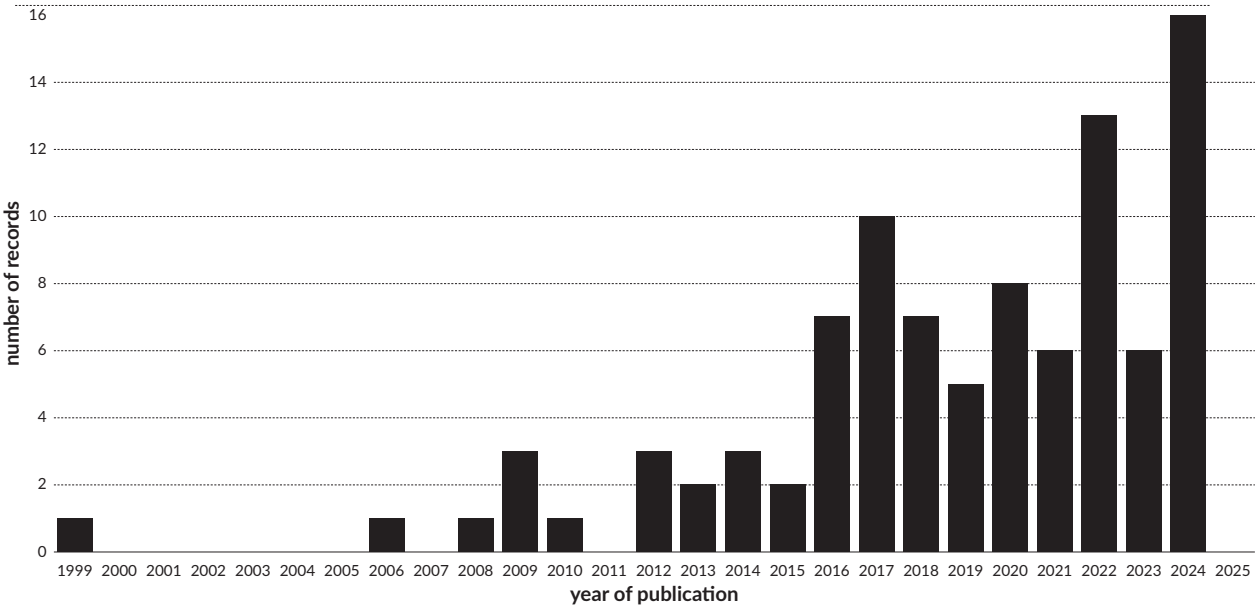

Figure 5. Key stages in the development of "digital planning" and number of "digital planning" records (graph of sources selectively limited to Web of Science) by year of publication.

The focus of digital planning to date has been promoting better understanding and engagement within non-professionals (Göçmen & Ventura, 2010), maintaining an "emphasis on the relevance and user-friendliness of software, cost of technology, skills of planners, and data availability" (Potts & Milz, 2024, p. 329). Effectively, the literature shows there is currently very little dynamic modelling and/or simulation aspects and that the weight of this literature remains with the effective, mostly graphic, presentation of data rather than any exploration of the underlying structures and rules regarding how different spatial data sets interact.

2.5. Experimental Urbanism

Linking all the mentioned literature is the novel concept of "experimental urbanism." "Urban experimentation" as a term was first used, albeit in a significantly different meaning from current usage, in the 1960s (Lubove, 1967) and was increasingly used in the following decades to refer to space travel and settlement (Paine, 1969). It is a self-explanatory concept, as it deals with very complex urban issues through testing, piloting, trial, and error. It is the act of "viewing the city as a laboratory for field-testing new practices, or as a setting for experimental sites" (Evans, 2016, p. 429). This literature (Figure 6) shows quite a variety of terms and concepts used in relation to urban experimentation, such as "guerrilla urbanism" (E. Wilson, 2022), the "experimental city" (Evans et al., 2016), "unplanned urbanism" (Lehmann, 2023), "do-it-yourself urbanism" (Talen, 2014), and "tactical urbanism" (Webb, 2018). Recently, urban experimentation has received attention as a method of non-traditional planning with potential to address urban sustainability and climate change through innovation and "progressive potentials" (Bulkeley, 2022; Karvonen & van Heur, 2014; Y. Li & Li, 2022).

"Foundational"/emergence of concept or application	"Going viral"/most cited	"Peak" period characteristics references
Relatively new concept with the current definition being applied to urban planning	Karvonen and van Heur (2014)	Practical applications arising from post-pandemic opportunities (Oswell & Varna, 2024)

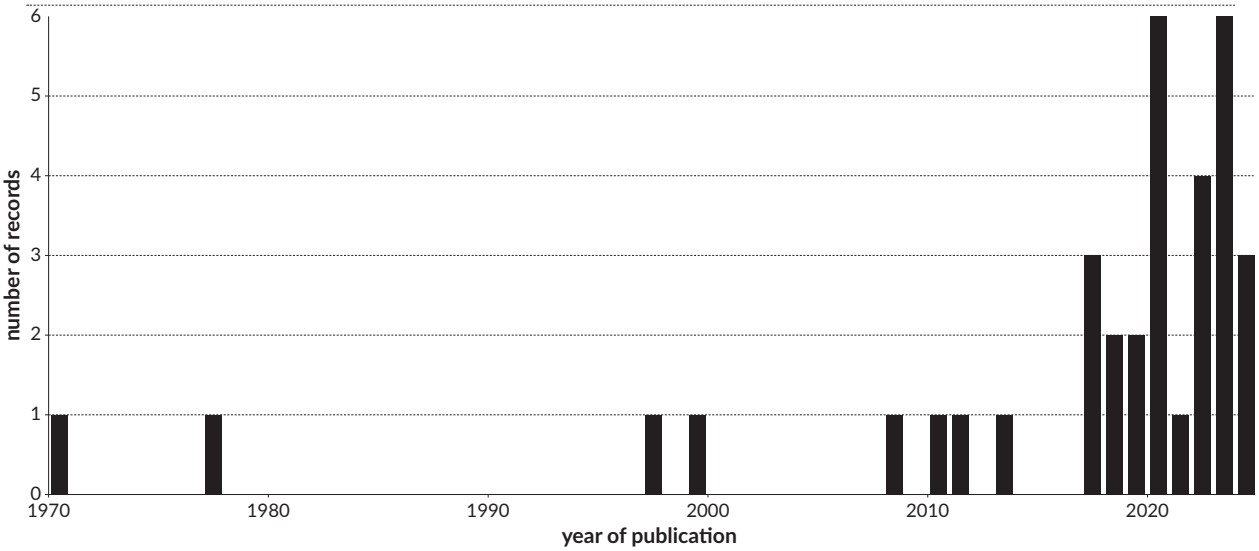

Figure 6. Key stages in the development of "experimental urbanism" and number of "experimental urbanism" records (graph of sources selectively limited to Web of Science) by year of publication.

However, it should be noted that multiple authors suggest that any relationship between planning and experimentation hinges on the planning culture in any context, with local governance and planning arrangements influencing any experimentation outcomes, be they practical testing, simulations, or simply thought experiments around policy options and scenario outcomes. Furthermore, Mukhija and Loukaitou-Sideris (2015, p. 1) argue that urban experimentation isn't limited to testing pre-planned hypotheses through a structured and organised research process, but that "there is ample evidence that

informality is an integral and growing part of cities in the developed world." There are suggestions that policymakers can see informal activities as peripheral and unimportant, and as such, one challenge of experimentation is the learning (often from failure) and applications of lessons from one context to another, as well as the expansion of experimentation across wider urban landscapes.

3. Cross-Analysing the Five Fields of Research: An Archipelago of "Islands of Research"/"Knowledge Islands"

This review incorporated seminal works on game theory, systems theory, and experimental urbanism to provide the necessary theoretical context. We used multi-criteria and cross-analysis (Ladany et al., 2012) as an approach to identify and visualize common patterns and overlaps between the five fields of knowledge investigated. The focus of the structured and systematic analysis highlights some important relationships within the literature that reflect the shared influences and often cited common inspirations between urban planning and systems theory, research, and practical gaming applications. We have chosen to summarise and represent these connections in the form of a chronological mapping of key influences (Figure 7) that highlight the historical progression, cross-pollination of ideas, and expansion in applications, primarily of systems theory into agent-based modelling applications. We acknowledge that this is an edited and selective timeline that is limited (mostly due to space) to the most popular data points (outputs, applications, or events), albeit these are based around the overarching significance of SimCity as a central point within the timeline. However, it does meet our intended purpose of demonstrating the academic influences that informed it; as explicitly referenced in the software biography (Gingold, 2024) and in interviews and transcripts with the key software developers (Long Now Foundation, 2006); and the progression of the most significance aspects of the SimCity simulation in the form of the Unreal games engine, as the basis for the design and creation of digital environments without any need for additional gaming objectives; and the development of agent-based simulations as a form of artificial life. An extended version of this timeline also makes the progression from SimCity and the emerging game engine into more professional applications in the field of architecture and the built environment, including building information modelling and the growth in digital twins.

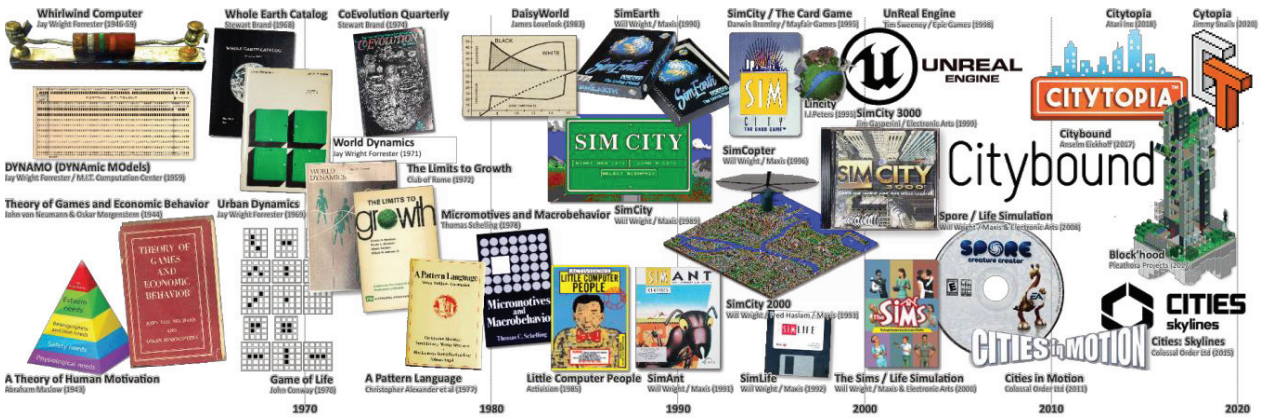

Figure 7. Indicative timeline of key stages and significant/influential "data points" identified between the academic literature and agent-based or urban planning simulations.

These areas of overlapping literature have also been represented as conceptual "islands" of research, inspired by Will Wright's (the creator of SimCity) "possibility spaces" and the concept of thinking of a "game as a map." In several social media interviews and panel discussions, Wright provides examples of different dimensions of material and social success within The Sims, which were subsequently mapped in relation to the achievements of multiple players (Long Now Foundation, 2006). In this form of "mapping," generative algorithms (Figure 8) were used to amplify dimensions, from the individual agents using simple sets of rules, including cellular automata, to spatial rules based on proximity and other more complex agents. With a large dataset derived from the behaviour of online gamers, Wright and his software collaborators have been able to describe the most successful criteria and paths of gameplay within The Sims.

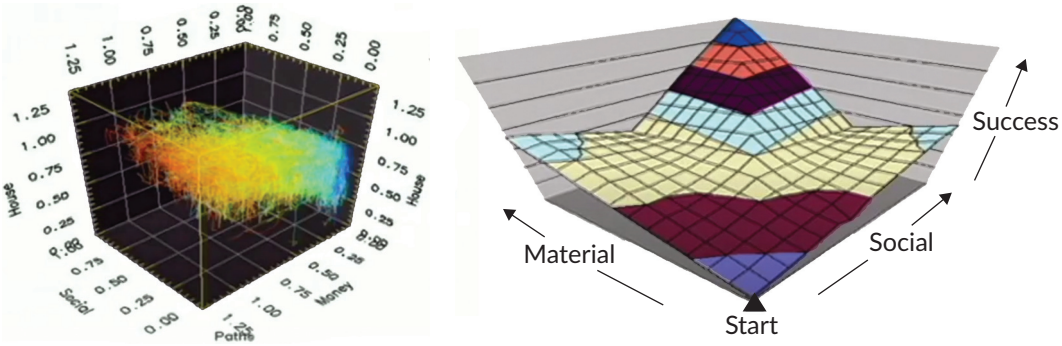

Figure 8. Mapped dimensions of assumed success in The Sims as mixed social, financial/material extracted from video. Source: Long Now Foundation (2006).

In writing about the theoretical grounding and background influences on the development of SimCity, Gingold (2024, p. 107) suggests that this "history reveals many islands of practice separated by time, terminology, agenda, and forum....As a result, every history of cellular automata is partial...[and] this archipelago thwarts neat historical narratives." This inspiration is also an established analogical approach (Figure 9) to mapping literature that has been utilised in similar academic contexts (Burnett et al., 2013; Di Renzo et al., 2021) to highlight the connections between what appear as disparate areas of research.

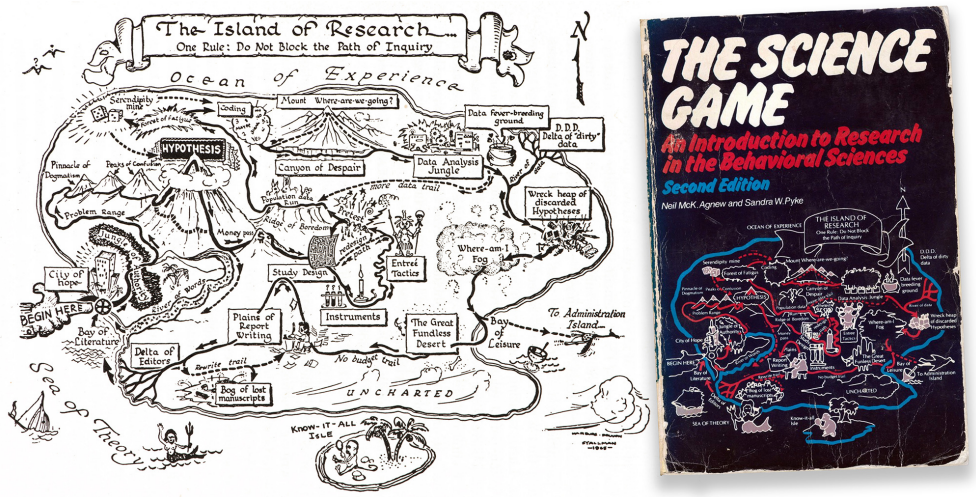

Figure 9. Earnest Harbury's Island of Research as reproduced in *American Scientist*, 1966. Source: Harbury (1966), recreated on the front cover of Agnew and Pyke (1969).

In this tradition of mapping data, we have represented the systematic literature review in the form of a "map" drawn using the SimCity terraforming function. In this map, we have included the emergence or date of first occurrence of the concept (represented by the height), the scope/quantify of sources (diameter), and the archipelago interconnections (isthmus connections) between them (Figure 10). This is intended to visually summarise the complex relationship between disparate data sources.

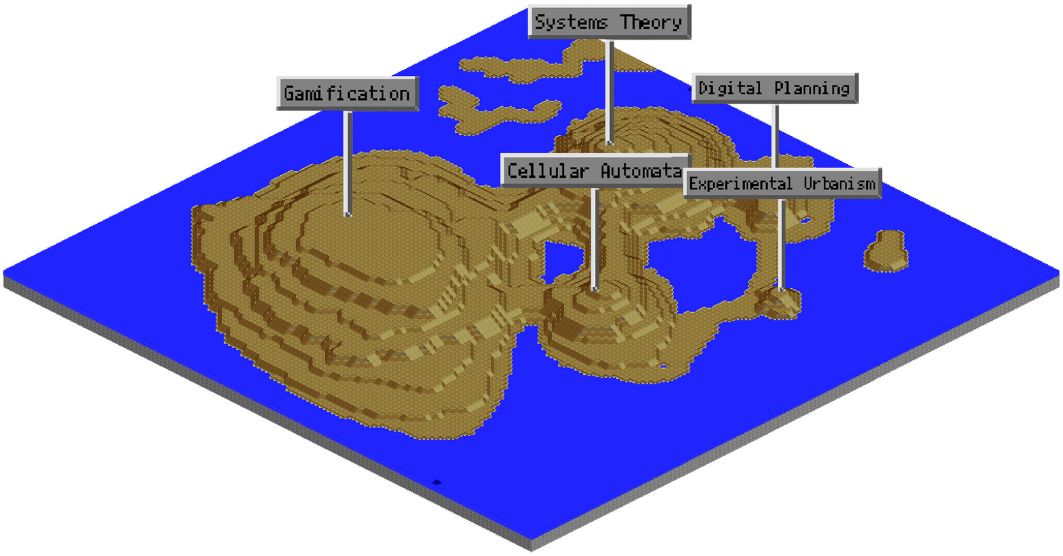

Figure 10. Representation of "islands of research" and their connections in relation to gamification in urban planning.

The scale of these "islands of research" is based on a quantitative analysis set out in tabulated form (Figure 11) relating to the number and origin dates of references for the specific keywords used to construct the research island. The origin date is largely based on the first keyword occurrence but checked against any individual paper and/or reference to identify any specific error or potential outlier in the dataset. In a few

	"Systems theory" OR "Complex systems" (n = 85,739)	"Game theory" OR "Gamification" (n = 55,404)	"Cellular automata" (n = 21,348)	"Digital planning" (n = 470)
"Systems theory" OR "Complex systems" (*n* = 85,739) (1970)				
"Game theory" OR "Gamification" (*n* = 55,404) (1970)	393			
"Cellular automata" (*n* = 21,348) (1971)	887	95		
"Digital planning" (*n* = 470) (1983)	1	0	0	
"Experimental urbanism" (*n* = 8) (1997)	0	0	0	0

	"Systems theory" OR "Complex systems" AND "Urban planning" (n = 21,367)	"Game theory" OR "Gamification" AND "Urban planning" (n = 42,782)	"Cellular automata" (n = 21,348)	"Digital planning" (n = 470)
"Systems theory" OR "Complex systems" AND "Urban planning" (*n* = 21,367) (1970)				
"Game theory" OR "Gamification" AND "Urban planning" (*n* = 42,782) (1999)	393			
"Cellular automata" AND "Urban planning" (*n* = 608) (1994)	887	95		
"Digital planning" (*n* = 470) (1983)	1	0	0	
"Experimental urbanism" (*n* = 8) (1997)	0	0	0	0

Figure 11. Cross-tabulated number of records found based on structured systematic search by year of publication for each of the linked literatures.

occurrences, we have thus made the decision to ignore specific individual outlier data points where these are clearly non-continuous areas of research or have used the keyword for a different semantic meaning. The expectation is that over time, the islands of research become less isolated as subject areas.

4. Key Current Applications of Gamification in Urban Planning and Main Limitations

There are several significant trends within this interrelated literature that are becoming apparent as the waters around the islands of research recede to expose new areas for experimental academic exploration and enquiry. The following section summarises these principal findings from the analysis of the literature and dominant applications of gamification and urban simulations.

4.1. Participatory Planning and Civic Engagement

Within the collective literature, participatory planning, as one of the current dominant paradigms within planning theory and practice (Healey, 2006; Jenney et al., 2018), is also one of the most prominent areas of applications of gamification in urban planning. This is mostly with an explicit aim to enhance public participation and civic engagement. More traditional public participation processes suffer from apathy, low attendance, limited diversity of participants, and superficial engagement with complex planning issues (Arnstein, 1969; Bishop, 2015; Montgomery, 2015). Gamification, and to a lesser extent, urban simulations, offer potential innovative solutions by making participation more accessible, engaging, and meaningful. Several studies have documented successful applications of game-based participation tools. Gordon and Baldwin-Philippi (2014) analysed community planning games that apply role-playing and scenario-building to engage residents in neighborhood planning processes. Their research found that game-based approaches increased participation rates and improved participants' understanding of planning trade-offs and constraints. The Block by Block initiative, developed by UN-Habitat in partnership with Mojang (creators of Minecraft), represents a notable example of gamification in participatory planning. This uses Minecraft as a platform for community members to visualize and design public spaces, with success in engaging young people who are often excluded from traditional planning processes (Olsson et al., 2020). Evaluation of the Block-by-Block projects has shown increased civic engagement, improved design outcomes, and enhanced community ownership of planning decisions.

Gamification has also shown some promise as a means for testing urban policies that require behavioral change. Certain applications draw on behavioral economics (or game theory) insights about how game mechanics can influence human behavior through psychological mechanisms like loss aversion, social comparison, and immediate gratification or feedback (Thaler & Sunstein, 2008). Some of the most effective of these are focused on areas of climate change and energy conservation programmes (for example the OhmConnect in California gamifies energy reduction by awarding points to residents who reduce electricity consumption during peak demand periods), transport or travel behaviour (for example, Streetbank and Cycle Atlanta) through rewarding sustainable transport choices (Kazhamiakin et al., 2015), and waste management (for example, Recyclebank) that reward recycling (Nomura et al., 2011). Reviews of these programs have also shown significant levels of public engagement (Kahma & Matschoss, 2017) in comparison to traditional engagement methods. This area continues to grow through an increasing number of mobile applications; for example, some recent apps like FixMyStreet and SeeClickFix gamify the process of reporting and management of the city by incorporating points, badges, and leaderboards. Research on these platforms suggests there is a potential to increase civic

participation, improve municipal responsiveness, and even influence behavioural change, though questions remain about their effectiveness in addressing complex planning challenges versus basic service requests (Johnson & Robinson, 2014). More significantly, these applications tend to be both specific to single-issue concerns within urban management rather than dealing with complex systems and largely static rather than dynamic forms of gamification.

4.2. Urban Simulation and Scenario Planning

Gamification has proven particularly valuable for urban simulation and scenario planning, allowing stakeholders to explore the consequences of different planning decisions in risk-free virtual environments and in a manner that can sometimes include dynamic scenarios. It is at this point that "serious games" (Dörner et al., 2016; Vaz de Carvalho et al., 2016), games designed for purposes beyond entertainment, have emerged as powerful tools for urban planning education and decision support. Although not explicitly falling within the definition of a serious game, the SimCity franchise has had a particularly significant impact on planning practice and education "parall[eling] and even influenc[ing] the now omnipresent, if not always well-conceived, use of computer simulation in contemporary urban planning….Versions of the game add power-trip possibilities that would give a city planner a God complex" (Lobo, 2004, para. 18). SimCity has been widely used in planning classrooms and professional training programs to illustrate urban systems dynamics and planning principles (Balbin, 2024; Devisch et al., 2016; Robinson et al., 2021). However, critics (such as Bereitschaft, 2021) have noted that SimCity embeds assumptions about urban development that may not align with contemporary planning values, particularly regarding environmental sustainability and social equity. City Skyline is the current leading simulated digital environment for any urban planning enthusiast and experimenter as the inheritor of the urban complexity simulations first explored in SimCity (Jolly & Budke, 2023).

Yet, like the participatory planning applications above (Section 4.1), there are a growing number of thematically focused urban simulation games that have been developed specifically for limited planning applications. For example, the InfraSIM game, developed for infrastructure modelling, allows participants to explore the interdependencies between different infrastructure systems and long-term consequences of investment decisions (Meijer & Perpinya, 2012), finding that participants demonstrated improved understanding of infrastructure complexity. Virtual and augmented reality technologies are also extending the possibilities for urban simulations. Projects like CityScope, developed at MIT Media Lab, are combining physical models with digital parametric overlays to create interactive tools that allow users to manipulate urban designs and immediately see the effects (Larson & Gruen, 2013). Recent work on immersive environments and "digital twins" has increased in sophistication, and these immersive technologies have the potential to provide more realistic and engaging simulation environments. For example, recently, Epic Games has created interactive real-time architectural models to test the new version of their 3D game engine (Dreith, 2023), further blurring the distinctions between architectural visualization and gaming environments. Albeit most simulations still maintain a single thematic focus, be it visual impact or the efficiency of specific urban systems or networks, it is questionable if this leads to more informed planning decisions compared to traditional planning exercises. It is this potential to address complexity in the urban system that will make a more practical connection with the growth in digital planning.

4.3. Data Collection, Citizen Science, and Urban Analytics

Gamification applications increasingly offer innovative approaches to collecting urban data. Traditional data collection methods, such as surveys, focus groups, and observational studies, can be expensive, time-consuming, and limited in scope. Experimental game-based approaches (for example, apps like Foursquare and Swarm) can potentially overcome some of these limitations by gamifying location-sharing features. While not explicitly designed for planning purposes, location data generated by many applications has been used by researchers and planners to understand urban mobility patterns, commercial activity, and neighborhood dynamics (Cranshaw et al., 2012). More explicit planning-oriented data collection games have been developed for specific research purposes. For example, the Place Pulse project at MIT used online games to collect perceptions of neighborhood safety, attractiveness, and other qualitative parameters by asking participants to compare pairs of street view images (Salesses et al., 2013), an approach that would be impractical through traditional survey methods. Similar citizen science applications (for example, projects like iNaturalist and eBird, which gamify biodiversity monitoring) incorporate gamification elements to encourage volunteers in different forms of urban data collection. Urban planners have begun using data from these platforms to inform green infrastructure planning and biodiversity conservation strategies (Bonney et al., 2009).

5. Conclusions, Limitations, and Future Research Directions for Gamification Applications in Urban Planning

Gamification offers a powerful, yet complex and challenging set of tools for urban planning. The literature demonstrates the potential to enhance public participation, improve realistic visualisation of urban environments, and even promote more sustainable behaviours. However, the field is ripe for more rigorous and theoretically grounded research. This section sets out the main directions for future applied research within the current limitations of practice.

5.1. Limitations of Current Practice

The current limitations in the context of simulations and gamification applications in urban planning are that they are largely sector or topic-specific, provide time-limited or static viewpoints, or linear in the consideration of end-state planning. All these concerns highlight the differences between gamification or urban simulations and the complexity of real-world urban planning.

In this set of limitations, the first key critique of current practice is the necessary reductionist approach to the gamification and simulation of complex real-world urban systems. This level of simplification is often due to the sector or professional-specific perspective and interest in urban planning and/or management. In this instance, there is a risk that game-based approaches may obscure important aspects of urban challenges or promote overly simplistic solutions (Bogost, 2007). Urban planning involves navigating complex trade-offs between competing values and interests that may not translate well into simple game formats. Related to such overt reductionist approaches are the associated issues of social justice, environmental sustainability, and economic equity, which require nuanced consideration that may be difficult to capture in gamified formats designed for broad accessibility and engagement. Indeed, one additional significant concern about gamified planning approaches is the bias created by the “digital divide” (Crilly et al., 2023) between different social groups and

the exacerbation of existing inequalities in civic participation. Research on digital divide issues in planning has well documented persistent disparities in technology access and use across demographic groups (Stern et al., 2009; Trevisan, 2022). Gamification typically relies on technologies that may not be accessible to all agents, particularly older adults, low-income residents, and those with limited digital literacy (Hargittai, 2002). If gamified planning tools primarily engage already privileged community members, they may inadvertently marginalise the voices of those most affected by planning decisions and place undue emphasis on the urban issues of the more digitally active agents.

A consequence of any reductionist application, even where this is justified as a specific policy approach, is the dominance of static outputs synonymous with end-state planning. In practice, this simply means that applications have been designed for a particular policy purpose with associated budgets and timescales. Applications are designed to assist time-critical or targeted decision-making and thus remain short-term. A significant gap remains in understanding the long-term effects of gamification on sustained civic engagement and behavioral change.

Finally, there is the limitation regarding scenarios and options around the consideration of possible futures based on decisions made within any urban game or simulation. There are concerns that preset narratives within many geogames will ultimately have limited outcomes, potentially to the point where certain futures are inevitable, or from a "closed" set of options. In this context, critics have raised concerns about the dangers of gamification to manipulate rather than empower participants in planning processes and signpost them towards a preferred policy outcome. The psychological mechanisms that make games engaging—variable reward schedules, social pressure, and achievement systems—could potentially be used to steer participants toward predetermined outcomes rather than facilitating genuine democratic deliberation (Morozov, 2013). The concept of "dark patterns" in game design—techniques that manipulate users in ways that may not serve their best interests—has relevance for gamified planning applications. If planning professionals use gamification primarily to generate support for predetermined plans rather than to facilitate genuine community input, the democratic legitimacy of planning processes could be undermined (Gray et al., 2018).

5.2. Future Research Directions

In response to the core limitations of the practical applications of geogames and urban simulations, we argue that the response must address real-world complexity as far as practical, increase the dynamic capabilities, and provide the ability to consider multiple options and alternatives for future development.

The concern around addressing complexity in urban simulations is that even a complex game, model, or simulation will ultimately remain reductionist, although we suggest that more complexity is always going to be more informative and more practical. This challenge is set within the developing complex systems literature and the benefits of "breadth over depth" in the scope of applications or simulations with the use of urban data and information modelling. Implicit within this expectation of complexity are concerns about displacement or unexpected consequences or outcomes arising from any decision or intervention. Linked to the challenges of understanding urban complexity is the sub-challenge to rationality and agent decision-making in addressing real-world wicked problems. Once you include the unpredictability and irrational behaviour of human agents into any planning context, you depart from the underlying structures

and rules implicit in the design of any urban game or simulation. This complexity challenge also relates to the development of robust evaluation frameworks that go beyond easily quantifiable metrics like participation rates and user satisfaction. Broader, more sophisticated, or comprehensive frameworks are needed to assess impacts on planning outcomes, democratic legitimacy, and urban conditions. If effective, it becomes harder to dismiss any data or evidence gathered through gamified or simulated methods as limited in scope.

The challenge of dynamic simulation is in part about thinking long-term and adding the time-dimension to gamified applications. While questions remain about the long-term effectiveness of gamification approaches in maintaining civic engagement and behavior change. The novelty effect that often drives initial participation in gamified systems may fade over time, leading to declining engagement and effectiveness (Hamari et al., 2014). Yet, positive research on gamification in other contexts has documented the challenge of maintaining user engagement beyond initial adoption periods. This raises important questions about the sustainability of gamified planning initiatives and the need for ongoing innovation and adaptation to maintain effectiveness. We collectively need to assess time effects, comparing gamification versus traditional planning methods, and ensure longitudinal research and approaches that consider dynamic parameters such as initial starting positions and externalities to the urban systems being considered.

The challenge of "open" outcomes of multiple options is a consideration related to impact in the real-world. To be fully effective as a practical tool for urban planning, future research should explore how gamified and simulated approaches to urban planning can be effectively integrated with statutory planning systems as part of the growth in digital planning. Application of these novel approaches may require integration with the current and largely normative methods used in planning or provide a more effective replacement for certain tasks. We anticipate a growth in testing, investigating optimal combinations of gamified and conventional participation tools, and understanding how to sequence different engagement approaches for maximum effectiveness. Studies should also explore how to successfully embed gamification into urban digital twins for participatory modeling and scenario testing.

Finally, we suggest the need for a stronger theoretical framework underpinning urban planning applications that begins to integrate the underlying theory alongside the methods of gamification and urban simulation. While some studies do touch on the relationship between underlying theory, particularly with concepts like systems or game theory, there remains a lack of holistic integration. Unified frameworks that connect systems theory, game theory, and gamified methodologies in urban planning are sparse, and there is significant scope for more action-research that embraces experimental processes in this area. Thus, future research should move beyond the simple application of game elements and explore how the theoretical underpinnings of game design can be more fully leveraged to address complex urban challenges.

As cities and urban contexts across the globe become more interconnected and complex, gamification presents an appealing tool, but only if implemented thoughtfully. Systems thinking ensures design depth, game theory offers structure and fairness, and experimental urbanism injects critical creativity. Integrating these dimensions within digital urban planning systems could enable scalable, inclusive, and transparent public engagement; support strategic collaboration across stakeholders; and foster adaptation and experimentation in our rapidly changing urban environments.

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Conflict of Interests

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References

Aarseth, E. J. (1997). *Cybertext: Perspectives on ergodic literature*. JHU Press.

Agnew, N., & Pyke, S. W. (1969). *The science game: An introduction to research in the behavioral sciences* (2nd ed.). Prentice-Hall.

Ahlqvist, O., & Schlieder, C. (2018). *Geogames and geoplay: Game-based approaches to the analysis of geo-information*. Springer.

Akbar, P. N. G., Maulidiyanti, M., Wiwesa, N. R., & Auliya, A. (2024). The use of gamification for participatory smart city planning of Indonesia's new capital. *International Journal of Urban Sciences*, *29*(1), 210–231. https://doi.org/10.1080/12265934.2024.2382699

Ampatzidou, C., Gugerell, K., Constantinescu, T., Devisch, O., Jauschneg, M., & Berger, M. (2018). All Work and No Play? Facilitating serious games and gamified applications in participatory urban planning and governance. *Urban Planning*, *3*(1), 34–46.

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Planning Association*, *35*(4), 216–224.

Balbin, S. (2024). Integration of SimCity in learning urban geography. *Diversitas Journal*, *9*(2), 575–592. https://doi.org/10.48017/dj.v9i2.2972

Baušys, R., Leščauskienė, I., & Semėnas, R. (2021). Participant trustworthiness analysis in the game-based urban planning processes by PROMETHEE-mGqNN approach. *Journal of Civil Engineering and Management*, *27*(6), 427–440. https://doi.org/10.3846/jcem.2021.15263

Bereitschaft, B. (2021). Commercial city building games as pedagogical tools: What have we learned? *Journal of Geography in Higher Education*, *47*(2), 161–187.

Berlinski, D. (1976). Systems analysis. *Urban Affairs Review*, *6*(1), 104–126.

Bhardwaj, R., & Upadhyay, A. (2017). Cellular automata: Elementary cellular automata. *Journal of Organizational and End User Computing*, *29*(1), 42–50.

Bishop, J. (2015). *The craft of collaborative planning*. Routledge.

Bogost, I. (2007). *Persuasive games: The expressive power of videogames*. MIT Press.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience*, *59*(11), 977–984.

Bulkeley, H. (2022). Climate changed urban futures: Environmental politics in the Anthropocene city. In

G. Hayes, S. Jinnah, P. Kashwan, D. M. Konisky, S. Macgregor, J. M. Meyer, & A. R. Zito (Eds.), *Trajectories in environmental politics* (pp. 263–281). Routledge.

Burnett, K., Endress, L., Ravago, M. L., Rousmasset, J., & Wada, C. A. (2013). "Islands of sustainability in time and space." *International Journal of Sustainable Society*, *6*(1/2), 9–27.

Carrasco, C. A., Lombillo, I., Sánchez-Espeso, J. M., & Balbás, F. J. (2022). Quantitative and qualitative analysis on the integration of geographic information systems and building information modeling for the generation and management of 3D models. *Buildings*, *12*(10), Article 1672.

Chen, L. (2012). Agent-based modelling in urban and architectural research: A brief literature review. *Frontiers of Architectural Research*, *1*(2), 166–177. https://doi.org/10.1016/j.foar.2012.03.003

Christodoulou, N., Papallas, A., Kostic, Z., & Nacke, L. E. (2018). Information visualisation, gamification and immersive technologies in participatory planning. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 1–4). Association for Computing Machinery.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686.

Cranshaw, J., Schwartz, R., Hong, J., & Sadeh, N. (2012). The livehoods project: Utilizing social media to understand the dynamics of a city. *Proceedings of the International AAAI Conference on Web and Social Media*, *6*(1), pp. 58–65. https://doi.org/10.1609/icwsm.v6i1.14278

Crilly, M., Varna, G., Vemury, C. M., Lemon, M., & Mitchell, A. (2023). Building equality: A "litmus test" for recognising and evidencing inequalities and segregation in the built environment. *Urban Planning*, *8*(1), 372–387.

Crooks, A. T., & Heppenstall, A. J. (2012). Introduction to agent-based modelling. In A. Heppenstall, A. Crooks, L. See, & M. Batty (Eds.), *Agent-based models of geographical systems* (pp. 85–105). Springer.

Damerow, J. (2010). *John von Neumann's cellular automata*. Arizona State University. https://embryo.asu.edu/pages/john-von-neumanns-cellular-automata

Davidsson, O., Peitz, J., & Björk, S. (2004). *Game design patterns for mobile games*. Nokia Research Center.

de Sena, Í. S., Poplin, A., & de Andrade, B. (2021). GeoMinasCraft: A serious geogame for geographical visualization and exploration. In S. C. M. Geertman, C. Pettit, R. Goodspeed, & A. Staffans (Eds.), *Urban informatics and future cities: The urban book series* (pp. 613–632). Springer.

Delaney, J. (2022). Minecraft and playful public participation in urban design. *Urban Planning*, *7*(2), 330–342.

Devisch, O. (2008). Should planners start playing computer games? Arguments from SimCity and Second Life. *Planning Theory & Practic*, *9*(2), 209–226.

Devisch, O., Poplin, A., & Sofronie, S. (2016). The gamification of civic participation: Two experiments in improving the skills of citizens to reflect collectively on spatial issues. *Journal of Urban Technology*, *23*(2), 81–102.

Di Renzo, G. C., Tosto, V., & Tsibizova, V. (2021). The island of research (do not block the path of enquiry). In G. C. Di Renzo (Ed.), *Essential writing, communication and narrative skills for medical scientists before and after the Covid era* (pp. 1–17). Springer.

Donovan, T. (2010). *Replay: The history of video games*. Yellow Ant.

Dörner, R., Göbel, S., Effelsberg, W., & Wiemeyer, J. (2016). *Serious games: Foundations, concepts and practice*. Springer.

Dreith, B. (2023, June 1). Epic Games creates virtual model that realises Moshe Safdie's full vision for Habitat 67. *Dezeen*. https://www.dezeen.com/2023/06/01/epic-games-safdie-habitat-67-unbuilt-visualisation

Engelen, G. (1988). The theory of self-organization and modelling complex urban systems. *European Journal of Operational Research*, *37*(1), 42–57.

Evans, J. (2016). Trials and tribulations: Problematizing the city through/as urban experimentation. *Geography Compass*, *10*(10), 429–443. https://doi.org/10.1111/gec3.12280

Evans, J., Karvonen, A., & Raven, R. (2016). *The experimental city*. Routledge.

Feneri, A. M. (2016). *Digital urban planning tools for an on-going and interactive decision-making process* [Unpublished doctoral dissertation]. University College London.

Fox, N., Campbell-Arvai, V., Lindquist, M., Van Berkel, D., & Serrano-Vergel, R. (2022). Gamifying decision support systems to promote inclusive and engaged urban resilience planning. *Urban Planning*, *7*(2), 239–252.

Fuchs, M., Fizek, S., Ruffino, P., & Schrape, N. (2014). *Rethinking gamification*. Meson Press.

Galderisi, A. (2014). Urban resilience: A framework for empowering cities in face of heterogeneous risk factors. *A| Z ITU Journal of the Faculty of Architecture*, *11*(1), 36–58.

Gardner, M. (1970). The fantastic combinations of John Conway's new solitaire game "life." *Scientific American*, *224*(4), 129–123.

Gingold, C. (2024). *Building SimCity: How to put the world in a machine*. MIT Press.

Göçmen, Z. A., & Ventura, S. J. (2010). Barriers to GIS use in planning. *Journal of the American Planning Association*, *76*(2), 172–183.

Goodspeed, R. (2015). Smart cities: Moving beyond urban cybernetics to tackle wicked problems. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 79–92.

Gordon, E., & Baldwin-Philippi, J. (2014). Playful civic learning: Enabling reflection and lateral trust through game-based public participation. *International Journal of Communication*, *8*, 759–786.

Gray, C. M., Kou, Y., Battles, B., Hoggatt, J., & Toombs, A. L. (2018). The dark (patterns) side of UX design. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (pp. 1–14). Association for Computing Machinery. https://doi.org/10.1145/3173574.3174108

Green, B. (2019). *The smart enough city: Putting technology in its place to reclaim our urban future*. MIT Press.

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to sustainable development: New directions in the study of long-term transformative change*. Routledge.

Grinberger, A. Y., & Felsenstein, D. (2014). Bouncing back or bouncing forward? Simulating urban resilience. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *167*(3), 115–124.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *Proceedings of the 47th Hawaii International Conference on System Sciences* (pp. 3025–3034). IEEE Xplore.

Harbury, E. (1966). *The island of research - One rule: Do not block the path of inquiry* [Map]. Persuasive Cartography: The PJ Mode Collection (Division of Rare and Manuscript Collections, 8548). Cornell University Library, Ithaca, NY, USA. https://digital.library.cornell.edu/catalog/ss:19343399

Hargittai, E. (2002). Second-level digital divide: Differences in people's online skills. *First Monday*, *7*(4). https://doi.org/10.5210/fm.v7i4.942

Hartt, M., Hosseini, H., & Mostafapour, M. (2020). Game on: Exploring the effectiveness of game-based learning. *Planning Practice & Research*, *35*(5), 589–604.

Healey, P. (2006). *Collaborative planning: Shaping places in fragmented societies*. Palgrave Macmillan.

Heylighen, F., & Joslyn, C. (1992). *What is systems theory?* Principia Cybernetica Web. http://pespmc1.vub.ac.be/SYSTHEOR.html

Hügel, S., & Davies, A. R. (2022). Playing for keeps: Designing serious games for climate adaptation planning education with young people. *Urban Planning*, *7*(2), 306–320.

Hull, D. (1969). Analysis on the role of models in comprehensive urban planning. In *Record of the IEEE Systems Science and Cybernetics Conference* (pp. 172–179). IEEE.

Hussnain, M. Q., Waheed, A., Anjum, G. A., Naeem, M. A., Hussain, E., Wakil, K., & Pettit, C. J. (2020). A framework to bridge digital planning tools' utilization gap in peri-urban spatial planning; lessons from Pakistan. *Computers, environment and urban systems*, *80*, Article 101451. https://doi.org/10.1016/j.compenvurbsys.2019.101451

Jenney, S. L., Mühlhaus, M., & Petzold, F. (2018). Connect, motivate, communicate: A foundation for gamification in planning communication. *Sigradi Technopoliticas*, *22*, 42–60.

Johnson, P. A., & Robinson, P. J. (2014). Civic hackathons: Innovation, procurement, or civic engagement? *Review of Policy Research*, *31*(4), 349–357.

Jolly, R., & Budke, A. (2023). Assessing the extent to which players can build sustainable cities in the digital city-builder game "Cities: Skylines." *Sustainability*, *15*(14), Article 10780.

Juul, J. (2005). *Half-real: Video games between real rules and fictional worlds*. MIT Press.

Kahma, N., & Matschoss, K. (2017). The rejection of innovations? Rethinking technology diffusion and the non-use of smart energy services in Finland. *Energy Research & Social Science*, *34*, 27–36.

Karvonen, A., & van Heur, B. (2014). Urban laboratories: Experiments in reworking cities. *International Journal of Urban and Regional Research*, *38*(2), 379–392.

Kazhamiakin, R., Marconi, A., Perillo, M., Pistore, M., Valetto, G., Piras, L., Avesani, F., & Perri, N. (2015). Using gamification to incentivize sustainable urban mobility. In *Proceedings of the 2015 IEEE First International Smart Cities Conference* (pp. 1–6). IEEE.

Kelly, R. F. (1974). *Simulating a complex urban system*. Elsevier.

Kim, M., & Shin, J. (2015). The pedagogical benefits of SimCity in urban geography education. *Journal of Geography*, *115*(2), 39–50.

Klosterman, R. E., & Landis, J. D. (1988). Microcomputers in US planning: Past, present, and future. *Environment and Planning B: Planning and Design*, *15*(3), 355–367.

Koens, K., Klijs, J., Weber-Sabil, J., Melissen, F., Lalicic, L., Mayer, I., Önder, I., & Aall, C. (2020). Serious gaming to stimulate participatory urban tourism planning. *Journal of Sustainable Tourism*, *30*(9), 2167–2186. https://doi.org/10.1080/09669582.2020.1819301

Kontokosta, C. (2021). Urban informatics in the science and practice of planning. *Journal of Planning Education and Research*, *41*(4), 382–395.

Ladany, N., Thompson, B. J., & Hill, C. E. (2012). Cross-analysis. In C. E. Hill (Ed.), *Consensual qualitative research: A practical resource for investigating social science phenomena* (pp. 117–134). American Psychological Association.

Larson, K., & Gruen, D. (2013). CityScope: A data-driven interactive simulation tool for urban design. Use case: Kendall Square. In L. O'Brien, B. Gunay, & A. Khan (Eds.), *Proceedings of the Symposium on Simulation for Architecture & Urban Design* (pp. 1–8). SimAUD.

Latifi, G. R., Monfared, M. P., & Khojasteh, H. A. (2022). Gamification and citizen motivation and vitality in smart cities: A qualitative meta-analysis study. *GeoJournal*, *87*(2), 1217–1230.

Lehmann, S. (2023). *The unplanned city: Public space and the spatial character of urban informality*. Emerald Open Research, *1*(5). https://doi.org/10.1108/EOR-05-2023-0007

Li, X. (2008). Simulating urban dynamics using cellular automata. In L. Liu & J. Eck (Eds.), *Artificial crime analysis systems: Using computer simulations and geographic information systems* (pp. 125–139). IGI Global.

Li, X., & Liu, X. (2007). Defining agents' behaviors to simulate complex residential development using multicriteria evaluation. *Journal of Environmental Management*, *85*(4), 1063–1075.

Li, Y., & Li, X. (2022). The giant in the niche: Planning green metaprojects as urban experimentation. Planning Theory and Practice, *25*(3), 352–370.

Liu, H. X. (2022). Building the "complete game": An overview study of a development strategy for geo AR mobile games. In G. Meiselwitz, A. Moallem, P. Zaphiris, A. Ioannou, R. A. Sottilare, J. Schwarz, & X. Fang (Eds.), *HCI International 2022 - Late breaking papers. Interaction in new media, learning and games* (pp. 604–622). Springer.

Lobo, D. G. (2004). Playing with urban life: How SimCity influences planning culture. *Technology & Cities*, *6*. https://web.archive.org/web/20041211091031/http://www.americancity.org/article.php?id_article=21

Lobo, D. G. (2007). Playing with urban life: How SimCity influences planning culture. In F. V. Borries, S. P. Walz, & M. Böttger (Eds.), *Space time play: Computer games, architecture, and urbanism: The next level* (pp 206–213). Birkhauser Verlag AG.

Long Now Foundation. (2006, April 7). *Playing with time | Brian Eno and Will Wright* [Video]. YouTube. https://www.youtube.com/watch?v=Dfc-DQorohc

Lubove, R. (1967). The urbanization process: An approach to historical research. *Journal of the American Institute of Planners*, *33*(1), 33–39.

Macal, C. M. (2016). Everything you need to know about agent-based modelling and simulation. *Journal of Simulation*, *10*(2), 144–156.

Mahizhnan, A. (1999). Smart cities: The Singapore case. *Cities*, *16*(1), 13–18.

Mann, S., Saddik, A. E., Yuan, Y., Thawonmas, R., Lamberti, F., & Pratticò, F. G. (2023). eXtended meta-uni-omni-Verse (XV): Introduction, taxonomy, and state-of-the-art. *IEEE Consumer Electronics Magazine*, *13*(3), 27–35. http://doi.org/10.1109/MCE.2023.3283728

Matheus, R., Janssen, M., & Maheshwari, D. (2020). Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities. *Government Information Quarterly*, *37*(3), Article 101284.

Meijer, S. A., & Perpinya, X. (2012). Gaming simulations for railways: Lessons learned from modeling six games for the Dutch infrastructure management. In *Infrastructure design, signaling and security in railway* (pp. 275–294). IntechOpen.

Montgomery, C. (2015). *Happy city: Transforming our lives through urban design*. Penguin.

Morozov, E. (2013). *To save everything, click here: The folly of technological solutionism*. PublicAffairs.

Muehlhaus, S. L., Eghtebas, C., Seifert, N., Schubert, G., Petzold, F., & Klinker, G. (2022). Game.UP: Gamified urban planning participation enhancing exploration, motivation, and interactions. *International Journal of Human–Computer Interaction*, *39*(2), 331–347.

Mueller, C., Klein, U., & Hof, A. (2018). An easy-to-use spatial simulation for urban planning in smaller municipalities. *Computers, Environment and Urban Systems*, *71*, 109–119.

Mukhija, V., & Loukaitou-Sideris, A. (2015). Reading the informal city: Why and how to deepen planners' understanding of informality. *Journal of Planning Education and Research*, *35*(4), 444–454.

Nomura, H., John, P. C., & Cotterill, S. (2011). The use of feedback to enhance environmental outcomes: A randomised controlled trial of a food waste scheme. *Local Environment*, *16*(7), 637–653.

Numberphile. (2015, March 6). *Inventing game of life (John Conway) - Numberphile* [Video]. YouTube. https://www.youtube.com/watch?v=R9Plq-D1gEk

O'Sullivan, D., & Perry, G. L. (2013). *Spatial simulation: Exploring pattern and process*. John Wiley & Sons.

Olsson, T., Jarusriboonchai, P., Woźniak, P., Paasovaara, S., Väänänen, K., & Lucero, A. (2020). Technologies for enhancing collocated social interaction: Review of design solutions and approaches. *Computer Supported Cooperative Work*, *29*(1), 29–83.

Oswell, D., & Varna, G. (2024). Chain reactions: Can experimental urbanism provide the formula for productive, place-based, change? *Town Planning Review*, *95*(4), 435–447.

Özden, S., Arslantürk, E., Senem, M., & As, I. (2023). Gamification in urban planning—Experiencing the future city. *Architecture and Planning Journal*, *28*(3), Article 44.

Pagáč, T. (2022). *Simulating game worlds using cellular automata* [Unpublished doctoral dissertation]. Masaryk University Faculty of Informatics. https://theses.cz/id/7yx1i3

Paine, T. O. (1969). Space age administration. *Ordnance*, *54*(296), 164–166. https://www.jstor.org/stable/45362030

Pearson, L. C. (2020). A machine for playing in: Exploring the videogame as a medium for architectural design. *Design Studies*, *66*, 114–143.

Pena, E., & Sayama, H. (2021). Life worth mentioning: Complexity in life-like cellular automata. *Artificial Life*, *27*(2), 105–112.

Pilote, B., & Chiniara, G. (2019). The many faces of simulation. In G. Chiniara (Ed.), *Clinical simulation: Education, operations and engineering* (pp. 17–32). Academic Press.

Piras, G., Agostinelli, S., & Muzi, F. (2024). Digital twin framework for built environment: A review of key enablers. *Energies*, *17*(2), Article 436.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, *50*(4), 258–283.

Potts, R., & Milz, D. (2024). A culture of digital planning? An international comparison of culture, planning and technology. *International Planning Studies*, *29*(4), 327–341.

Resek, C. L., Siniscalchi, P. P., Caetano, B. P., Oliveira, K. W., Paula, M. M., & Souza, J. M. (2022). Gamification of citizen participation: A systematic mapping. *IEEE Transactions on Games*, *16*(1). https://doi.org/10.1109/TG.2022.3216750

Robinson, G. M., Hardman, M., & Matley, R. J. (2021). Using games in geographical and planning-related teaching: Serious games, edutainment, board games and role-play. *Social Sciences & Humanities Open*, *4*(1), Article 100208.

Salesses, P., Schechtner, K., & Hidalgo, C. A. (2013). The collaborative image of the city: Mapping the inequality of urban perception. *PloS one*, *8*(7), Article e68400.

Sante, I., Garcia, A. M., Miranda, D., & Crecente, R. (2010). Cellular automata models for the simulation of real-world urban processes: A review and analysis. *Landscape and Urban Planning*, *96*(2), 108–122.

Schmierbach, M. (2009). Content analysis of video games: Challenges and potential solutions. *Communications Methods and Measures*, *3*(3), 147–172.

Seelow, D. (2022). *Games as transformative experiences for critical thinking, cultural awareness, and deep learning: Strategies & resources*. CRC Press.

Sheppard, E., Couclelis, H., Graham, S., Harrington, J. W., & Onsrud, H. (1999). Geographies of the information society. *International Journal of Geographical Information Science*, *13*(8), 797–823.

Shi, Y., Zhai, G., Xu, L., Zhou, S., Lu, Y., Liu, H., & Huang, W. (2021). Assessment methods of urban system resilience: From the perspective of complex adaptive system theory. *Cities*, *112*, Article 103141.

Sintoris, C. (2015). Extracting game design patterns from game design workshops. *International Journal of Intelligent Engineering Informatics*, *3*(2/3), 166–185.

Sousa, M. (2020). A planning game over a map: Playing cards and moving bits to collaboratively plan a city. *Frontiers in Computer Science*, *2*, Article 37.

Stern, M. J., Adams, A. E., & Elsasser, S. (2009). Digital inequality and place: The effects of technological diffusion on internet proficiency and usage across rural, suburban, and urban counties. *Sociological Inquiry*, *79*(4), 391–417.

Sun, J., Zhai, N., Mu, H., Miao, J., Li, W., & Li, M. (2024). Assessment of urban resilience and subsystem coupling

coordination in the Beijing-Tianjin-Hebei urban agglomeration. *Sustainable Cities and Society*, *100*, Article 105058.

Syed, A. S., Sierra-Sosa, D., Kumar, A., & Elmaghraby, A. (2021). IoT in smart cities: A survey of technologies, practices and challenges. *Smart Cities*, *4*(2), 429–475.

Szot, J. (2024). Video games in civic engagement in urban planning, a methodology for effective and informed selection of games for specific needs. *Sustainability*, *16*(23), Article 10411. https://doi.org/10.3390/su162310411

Talen, E. (2014). Do-it-yourself urbanism: A history. *Journal of Planning History*, *14*(2), 135–148.

Tan, E., & Portugali, J. (2012). The responsive city design game. In J. Portugali, H. Meyer, E. Stolk, & E. Tan (Eds.), *Complexity theories of cities have come of age* (pp. 369–390). Springer.

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. Yale University Press.

Thiel, S. K., Ertiö, T. P., & Baldauf, M. (2017). Why so serious? The role of gamification on motivation and engagement in e-participation. *IxD&A*, *35*, 158–181.

Tonne, C., Adair, L., Adlakha, D., Anguelovski, I., Belesova, K., Berger, M., & Adli, M. (2021). Defining pathways to healthy sustainable urban development. *Environment International*, *146*, Article 106236.

Trevisan, F. (2022). Beyond accessibility: Exploring digital inclusivity in US progressive politics. *New Media & Society*, *24*(2), 496–513.

van Noorden, R. (2014). Online collaboration: Scientists and the social network. *Nature*, *512*, 126–129.

Vanolo, A. (2018). Cities and the politics of gamification. *Cities*, *74*, 320–326.

Vaz de Carvalho, C., Escudeiro, P., & Coelho, A. (2016). *Serious games, interaction, and simulation: 5th International Conference, SGAMES 2015*. Springer.

von Bertalanffy, L. (1968). *General systems theory*. George Braziller.

von Neumann, J., & Morgenstern, O. (1944). *Theoy of games and economic behavior*. Princeton University Press.

Waddell, P., Ulfarsson, G. F., Franklin, J. P., & Lobb, J. (2007). Incorporating land use in metropolitan transportation planning. *Transportation Research Part A: Policy and Practice*, *41*(5), 382–410.

Webb, D. (2018). Tactical urbanism: Delineating a critical praxis. *Planning Theory & Practice*, *19*(1), 58–73.

Wilson, A., Tewdwr-Jones, M., & Comber, R. (2019). Urban planning, public participation and digital technology: App development as a method of generating citizen involvement in local planning processes. *Environment and Planning B: Urban Analytics and City Science*, *46*(2), 286–302.

Wilson, E. (2022). *Guerilla urbanism: A guide to bottom-up activism in urban spaces* [Unpublished honors thesis]. Texas State University.

Wolfram. (n.d.). *Wolfram demonstrators project*. https://demonstrations.wolfram.com

Yeh, A. G. O., & Li, X. (2006). Errors and uncertainties in urban cellular automata. *Computers, Environment and Urban Systems*, *30*(1), 10–28.

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ARTICLE

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A Gaia-Inspired Framework for Geogames: Bridging Theory and Practice to Design and Assess Games

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Abstract

The field of geogames, positioned at the intersection of serious games and geographic information systems (GIS), remains theoretically fragmented and underexplored. This article addresses that gap by introducing a novel framework that integrates game studies with the Gaia hypothesis, as proposed by Lovelock and Margulis and expanded through post-humanist perspectives. While game studies provide valuable insights into mechanics, narratives, and player engagement, they often overlook the spatial, ecological, and systemic dimensions essential to geogames. Gaia theory, which conceptualizes Earth as a self-regulating system of interdependent components, offers a systems-thinking approach that aligns with the ecological and urban complexities modeled in geogames. This article critiques the anthropocentric bias in current geogame design, advocating for an ecocentric paradigm. To this end, based on the theoretical foundation, we propose four lenses of geogames (Gaia + Games): feedback mechanisms, co-evolutionary dynamics, multispecies interactions, and planetary thresholds. These four lenses are then further explained and operationalized into a Gaia Design Framework—a toolbox for both geogame design and assessment. By synthesizing Gaia's principles with urban and architectural analysis, our framework illustrates how geogames can serve as powerful tools to foster collaborative design, model human and non-human complexities, and explore regenerative solutions to pressing urban and planetary challenges. Our study challenges scholars and practitioners to rethink the role of games in shaping sustainable futures, positioning geogames as critical methods and tools for addressing the intertwined crises of urbanization and ecological and climate degradation.

Keywords

Gaia theory; game assessment; game design; geogames; urban regeneration

1. Introduction

Geogames—operating at the nexus of serious games and geographic information systems (GIS)—are defined as digital and analog games that embed real-world geospatial data and dynamics to model complex environments, serving as vital instruments for urban planning, ecological modeling, and participatory governance (Ahlqvist & Schlieder, 2018; Poplin et al., 2020). More than mere playful simulations, they function as volatile hybrids of simulation model, participatory platform, and speculative design instrument that render urban complexity playable, where every rule, resource counter, or growth threshold inscribes a politics of futurity and a reflection of urban power dynamics. In the context of urban planning, they are recognized for their potential to facilitate co-creation, learning processes, and collaborative exploration of contested futures in a way that traditional methods often fail to capture. Yet, as cities grapple with climate breakdown, biodiversity collapse, and infrastructural precarity, the limitations of conventional serious games and geogames design become starkly apparent.

Too often, these games reproduce the very anthropocentric logic that has precipitated planetary crisis: They treat space as an inert canvas for human intervention rather than a contested, dynamic, and more-than-human system (Haraway, 2016; Latour, 2017). The result is a paradox: games capable of simulating urban complexity, yet incapable of confronting the political-ecological entanglements that define the Anthropocene, such as climate-driven displacement, fossil-fuel lock-ins embedded in urban infrastructures, biodiversity collapse linked to land-use change, and the unequal distribution of environmental risks across marginalized communities.

This article argues that the Gaia concept, when critically reframed beyond Lovelock and Margulis' original hypothesis, offers a radical lens for reimagining geogames. While Lovelock and Margulis (1974) pioneered the idea of Earth as a self-regulating system, their framework risks depoliticizing ecological relations, reducing planetary dynamics to a closed feedback loop devoid of human agency, conflict, or power asymmetries (Doolittle, 2019). Such a view is insufficient for geogames, which must engage with the messy realities of urban climate adaptation, multispecies coexistence, and contested futures. Instead, we turn to post-humanist reinterpretations of Gaia—Latour's (2017) warrior Gaia, Stengers' (2015) unpredictable intruder, and Haraway's (2016) "sympoietic collaborator"—to confront the omissions in current geogame theory and practice.

Latour's (2017) Gaia is no harmonious superorganism but a politicized force that resists human mastery, exposing the futility of solutions that ignore power relations (e.g., climate policies that exacerbate inequality). Stengers (2015), in contrast, warns against instrumentalizing Gaia altogether, framing it as a process of becoming that defies human control, a necessary corrective to gamified fixes for wicked problems. Haraway (2016), meanwhile, reorients Gaia as a practice of sympoiesis (making-with), emphasizing the embodied, uneven collaborations between species, technologies, and infrastructures. Together, these perspectives demand a geogame paradigm shift that does not merely simulate ecosystems but stages their contested realities: where zoning decisions provoke ecological backlash, where non-human actors disrupt human plans, and where winning requires negotiating with, rather than dominating, planetary systems.

Our project is both theoretical and pragmatic, offering a critical examination of the anthropocentric assumptions embedded in serious games and geogames scholarship. These include the neglect of

political-ecological feedback and the erasure of more-than-human agency. To address these gaps, we propose a Gaia Design Framework that redefines geogames as critical media for Gaia politics, integrating three interconnected dimensions from post-humanist perspectives. First, antagonistic feedback draws on Latour's (2017) concept of political Gaia, modeling dynamic systems where urban interventions provoke ecological counter-actions—such as flood defenses failing due to policy loopholes or carbon trading schemes destabilizing ecosystems—underscoring the futility of unilateral human control. Second, unpredictable emergence reflects Stengers' (2015) notion of Gaia intrusions, incorporating non-linear systems that defy player mastery, such as urban heat islands disrupting energy grids or pollinator collapses unraveling food systems, revealing the unpredictable logics of ecological systems that challenge anthropocentric planning. Finally, sympoietic design actualizes Haraway's (2016) making-with philosophy through interdependent gameplay systems, where players collaborate with pollinator colonies or adapt infrastructure to tidal patterns, illustrating that sustainable urban futures depend on mutual adaptation between human and more-than-human actors rather than human dominance. Together, these dimensions position geogames as vital tools for rethinking the relationship between urbanization and ecological resilience.

This is not a call for escapist fiction but for speculative rigor, games that encourage players to confront the consequences of their decisions beyond human-centric metrics. We propose a framework where success hinges on satisfying both corporate developers and lichen colonies, or where algorithmic climate models rebel against simplistic policy inputs. Such games would not just teach systems thinking; they would render planetary tensions sensorially and politically palpable, impossible to ignore any longer. The stakes extend beyond academia. If urban and regional planning is to navigate the Anthropocene's turbulence, it needs tools that reject the illusion of human sovereignty. Geogames, reworked through a critical Gaia lens, could be those tools, not because they offer answers, but because they refuse simplistic ones. This article charts a path forward, one where play becomes a mode of thinking-with the planet's unruly, politicized, and collaborative futures.

2. Theoretical Foundation

Geogames inhabit an uneasy territory between serious gaming and geospatial technology—neither emancipatory planning panacea nor trivial digital toy, but volatile hybrids that render urban complexity playable (Ahlqvist & Schlieder, 2018). Every zoning rule, resource counter, or growth threshold inscribes a politics of futurity, transforming Batty's (2007) nonlinear urban models into procedural form. Early analog experiments such as Design Games (Sanoff, 1979) and Metropolis (Duke, 1974) promised participatory insight yet often concealed power asymmetries beneath consensus rhetoric, a critique that resurfaces in contemporary board-game revivals (Sousa, 2024). The digital turn only deepened these contradictions: Play the City (Tan, 2017) showed how role-play can expose conflict more vividly than algorithmic dashboards, while analyses of Block by Block and classroom Minecraft designs (Andrade et al., 2024) reveal how inclusive platforms frequently privilege the digitally fluent and institutionally endorsed. As Mayer et al. (2005) warned, the ruleset itself is the battleground where fairness is coded or denied.

Two dominant lineages now shape the geogames genre. The first is the sanitised SimCity clone, reducing urbanism to supply-chain optimisation and population growth (Juul, 2005); the second is the co-optative serious game that gamifies austerity planning in the language of participation (Poplin et al., 2017). Yet critical counter-currents exist. These outliers fundamentally challenge the anthropocentric assumptions of the

dominant lineages by procedurally embedding ecological complexity and non-human agency into their core mechanics. RElastiCity: An Urban Resilience Game (TU Delft Gamelab, 2021) challenges players to maintain urban resilience by managing resources and responding to ecological shocks, a stance that prioritizes long-term stability over short-term optimization; Block'hood (Plethora Project, 2017) visualises metabolic feedback loops; Eco (Strange Loop Games, 2018) encodes escalating climate regulation into server law; and Planet Zoo (Frontier, 2019) centres non-human welfare as a scoring metric, directly subverting the conventional prioritization of human progress metrics. Hybrid projects such as Sousa's (2024) stakeholders' clash game for urban planning or the Cosmopolitical Board Game for cultural heritage (Andrade et al., 2024) demonstrate how analog mechanics can destabilise digital determinism. Such a shift requires moving beyond both analog nostalgia and digital fetishism to embrace critical play (Flanagan, 2009) that weaponizes game systems against contemporary urban and planetary issues. These outliers prefigure the Gaia lenses elaborated in our methodology, yet most existing titles still sidestep the ecological politics they visualise.

The canon of game studies remains trapped in a "human-exceptionalist" paradigm (Haraway, 2016), brilliantly deconstructing play's formal structures (Aarseth, 1997; Juul, 2005) while remaining blind to spatial and ecological agency. This theoretical lacuna manifests in three fatal assumptions that constrain geogame potential. First, the player-centric fallacy reduces environments to narrative backdrops rather than active systems (Frasca, 2003), mirroring the Cartesian divide that enables ecological crisis. For example, Adams' (2014) framing of game worlds as "containers for gameplay" replicates what Latour (2017) critiques as the modernist illusion of passive space awaiting human design. In contrast, Brković Dodig and Chiles' (2016) Spector game engages pupils in co-creating sustainability knowledge within their schools, prioritizing experiential, context-based education while leaving room for future iterations. Second, procedural reductionism reflects the field's obsession with universal mechanics (Juul, 2005), ignoring what Haraway (2016) calls "situated knowledge."

Urban systems rarely follow neat, rule-based patterns; instead, they unfold in complex, place-specific ways. Tan's (2017) analog role-playing games capture this urban messiness, while digital designs often flatten such complexity into rigid frameworks. The Cosmopolitical Board Game (Andrade et al., 2024) offers a compelling alternative by positioning sacred trees as active political agents, requiring players to negotiate with waterways and green spaces as stakeholders in the city of Salvador, Brazil. Yet, victory condition myopia distorts urban complexity by reducing it to win/lose binaries (Juul, 2005). As Fernández Galeote and Hamari (2021) observe, while gamification and game-based learning can enhance engagement with climate change, they also risk simplifying or obscuring the slow, cumulative impacts that characterize phenomena like Nixon's (2011) "slow violence." This helps explain why most urban planning games reward growth over resilience (Poplin et al., 2020), whereas Andrade and Pereira Roders' (2022) heritage games challenge players to address heritage vacancy crises by exploring nature-based solutions that integrate ecological strategies into revitalizing abandoned buildings and sites.

Even the foundational debate in game studies—ludology's rules versus narratology's stories (Aarseth, 1997; Frasca, 2003)—fails to engage ecological thought. Both sides assume a human protagonist: Whether players conquer systems (ludology) or interpret meanings (narratology), the environment remains a stage. The consequences of anthropocentrism are palpable. Games often misrepresent feedback loops (e.g., portraying pollution as a debuff rather than a cascading threshold breach), erase more-than-human stakeholders (e.g., zoning games where soil health has no procedural representation), and prioritize speed

over deliberation (e.g., real-time strategy mechanics applied to decades-long urban transitions). Addressing these flaws requires dismantling foundational assumptions. Frasca's (2003) simulation theories could integrate Latour's (2017) actor-networks, and Aarseth's (1997) cybertext framework could embrace Haraway's (2016) sympoiesis. The tools exist, but the geogames field lacks the cosmovision to use them, or a worldview that includes non-Western, non-anthropocentric conceptions of human–nature relationships.

The original Gaia hypothesis (Lovelock & Margulis, 1974) conceptualized Earth as a self-regulating superorganism, but its vision of planetary homeostasis feels dangerously anachronistic in the age of climate breakdown. Its greatest flaw lies in its inability to account for the Capitalocene—a term used to describe the violent entanglement of human industry, colonial extraction, and ecological rupture driven by capitalism—which is a more precise term for referring to power asymmetries than the Anthropocene. Lovelock and Margulis' Gaia lacks a vocabulary for the power asymmetries that determine whose cities get seawalls and whose communities drown. Post-humanist reworkings of Gaia by Latour, Stengers, and Haraway confront these political, unpredictable, and collaborative dimensions of planetary life, offering the conceptual notions needed to revolutionize geogames. Latour (2017) reframes Gaia, conceptualizing the planet as a battlefield where climate change is not a system malfunction but Gaia's general strike. For geogames, this means designing mechanics that model conflict and resistance, such as zoning policies that trigger algorithmic revolts from urban forests or infrastructure projects that mobilize digital floods to reclaim watersheds. Conversely, Stengers (2015) warns against reducing Gaia to an adversary, emphasizing its radical unpredictability. This demands game mechanics that actively undermine player control, where rising seas mutate in response to player actions and solutions generate unintended consequences. Haraway's (2016) concept of sympoiesis offers a third path, envisioning Gaia as a collaborative process of multispecies world-making. Geogames inspired by this approach demand a design methodology that actively integrates the interests and agency of more-than-human beings into the core game flow, mechanics, and design logic, thereby emphasizing co-creation over unilateral human control.

Together, these thinkers provide a new paradigm for geogame design: urban spaces as negotiation arenas with agentic ecologies, game systems embracing radical uncertainty, and play as an exercise in co-creation. This paradigm is no mere theoretical exercise. These conceptual shifts anchor the Gaia Design Framework developed in the Methodology section and deployed in the Results. By coupling feedback mechanisms, co-evolutionary dynamics, multispecies interactions, and planetary thresholds to specific visual, narrative, procedural, temporal, and incentive levers, the framework translates theory into design practice. In doing so, it positions geogames as Latourian diplomatic assemblies where floodwaters, mushrooms, and disenfranchised residents negotiate sustainable urban futures, not abstractly, but through the very rules that constitute play.

3. Methodology

The methodology for this study is grounded in a critical examination of contemporary geogames, which often perpetuate anthropocentric paradigms and fail to address the complexities of urban–ecological systems. Drawing on Gaia theory and post-humanist thought, this research proposes a transformative framework for both geogame design and assessment, structured around four Gaia-inspired lenses: feedback mechanisms, co-evolutionary dynamics, multispecies interactions, and planetary thresholds. These lenses, derived from the theoretical framework, aim to dismantle the "modernist divide" (Latour, 2017) between society and nature, embedding ecological complexity and more-than-human agency into game systems.

3.1. Gaia Lenses for Geogame Design

Our Gaia Design Framework offers a provocative and transformative framework for reimagining geogames as tools for navigating the intertwined crises of urban degradation and ecological collapse. Rooted in Gaia theory, the framework challenges the anthropocentric logic that has long dominated game design. It shifts the focus from human-centered simulations to systems of more-than-human negotiation, where the agency of non-human actors—trees, cats, ancestors—becomes central to gameplay. This approach not only reflects the complexity of planetary systems but also compels players to confront the ethical and cosmopolitical dimensions of living within ecological limits, resisting the fatalism of the coming barbarism Stengers (2015) warns against.

At its core, the framework integrates four lenses—feedback mechanisms, co-evolutionary dynamics, multispecies interactions, and planetary thresholds—into a unified framework, each addressing critical aspects of planetary systems. Feedback mechanisms focus on systemic interconnections, using tools like heat maps, delayed smog effects, and air-quality recovery to visualize cascading impacts. Co-evolutionary dynamics explore the interplay between human and ecological systems, with mechanics like construction freezes and flash-forwards simulating long-term consequences. Multispecies interactions foreground non-human agency, featuring elements like bee corridors, tree agents, and rivers narrating their histories to challenge anthropocentric perspectives. Finally, planetary thresholds emphasize the fragility of Earth's systems, with mechanics such as CO_2 limits, shoreline loss, and flood-damaged land recovery highlighting the stakes of crossing critical boundaries. Together, these lenses transform geogames into tools for critical reflection and systemic thinking, fostering a deeper understanding of ecological interdependence.

The framework's critical potential lies in its ability to provoke reflection and resistance. By embedding Gaia principles into game architectures, it challenges players to rethink their relationship with the Earth, moving beyond the extractive logic of the Anthropocene. Yet, as Stengers reminds us, the intrusion of Gaia is not a call for despair but an invitation to imagine alternative futures rooted in care, humility, and collective action. The framework embodies this ethos, transforming geogames into spaces of critical experimentation where players can explore the ethical dilemmas and systemic consequences of their decisions. It resists the illusion of control, instead fostering a sense of accountability that transcends individual lifetimes and geographic boundaries.

Our Gaia Design Framework (Figure 1) was developed through a systematic, two-step iterative process: literature triangulation and framework synthesis. First, we cross-mapped four core Earth-system processes—nonlinear feedbacks, co-evolutionary dynamics, multispecies interactions, and planetary thresholds—with the socio-ecological questions central to contemporary urban research (Batty, 2013; Beatley, 2012; Rockström et al., 2009). Simultaneously, insights from game studies (Aarseth, 1997; Flanagan, 2009) clarified which ecological dynamics are often overlooked in city-building simulations. This process yielded a shortlist of "design-critical" concepts that a Gaia-aligned geogame should address, transforming abstract theory into procedural concerns. The selection of these four lenses is not arbitrary. They integrate the core post-humanist perspectives of Gaia (Latour's antagonism, Stengers' unpredictability, Haraway's sympoiesis) with the necessity of modeling Earth-system limits. They collectively address the fatal anthropocentric assumptions in current geogame design, ensuring that complexity, agency distribution, and irreversibility are integrated into the core game mechanics.

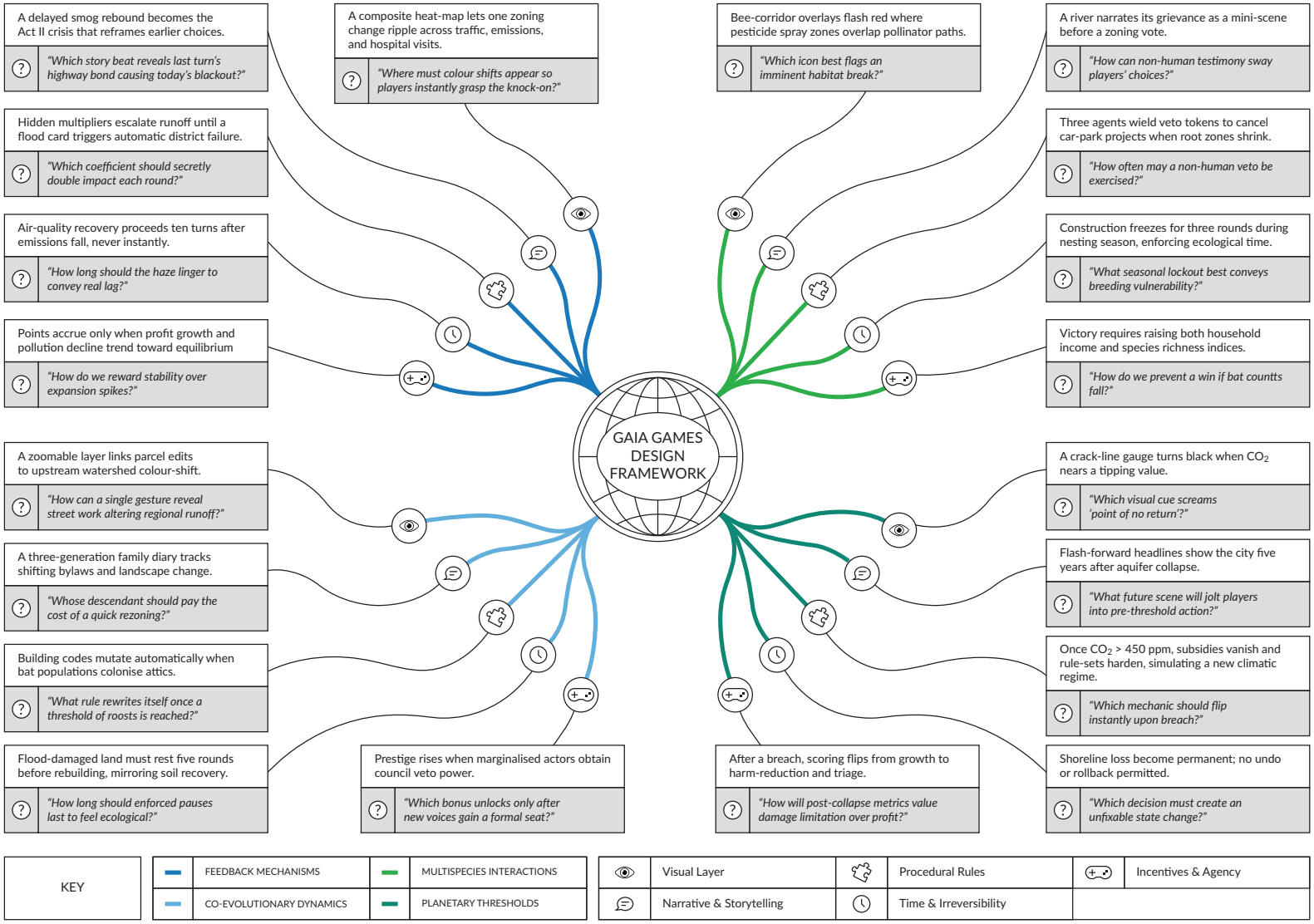

Figure 1. Four-lenses conceptual framework for geogames (Gaia + Games) design.

3.1.1. Feedback Mechanisms: Nonlinear Urban--Ecological Loops

Feedback mechanisms emphasize the interconnectedness of urban and ecological systems, focusing on nonlinear dynamics, delays, and cascading effects. This lens challenges the linear cause–effect logic of traditional geogames, instead modeling complex loops where small actions can trigger disproportionate consequences. Drawing on Batty's (2007) exploration of complexity in urban systems and Lovelock's (2000, 2006) Gaia theory, feedback mechanisms highlight the dynamic interplay between amplifiers (positive feedback) and dampers (negative feedback) in regulating urban–ecological systems. Batty's work on cellular automata, agent-based models, and fractals underscores how small, localized changes can propagate through systems, creating emergent patterns and unexpected outcomes.

For example, urban sprawl may initially improve housing availability but later destabilize ecosystems through deforestation and water table depletion. Similarly, algal blooms in water bodies can amplify global warming by releasing methane, while urban green spaces can dampen heat island effects, demonstrating the dual nature of feedback loops. Geogames mechanics could incorporate delayed smog effects, where pollution accumulates invisibly before triggering health crises, or composite heat maps that visualize cascading urban heat impacts. Hidden multipliers, such as methane release from wetlands or the compounding effects of deforestation, could challenge players to anticipate long-term consequences rather than focusing on immediate rewards. Additionally, zoomable layers could allow players to explore feedback loops at different scales, from local neighborhoods to regional ecosystems.

To effectively address feedback mechanisms and guide geogame design projects, the following questions can serve as critical triggers: How can delayed feedback loops, such as groundwater depletion or air-quality recovery, be visualized to make invisible processes tangible to players? What dynamics emerge when players are rewarded for short-term gains but penalized for long-term ecological overshoot, and how can this tension be embedded into gameplay mechanics? How might hidden multipliers, like methane release from wetlands or cascading effects of shoreline loss, challenge players to rethink resource management and urban and regional planning strategies? Finally, how can visual storytelling—such as a river narrating its pollution history—help players grasp the systemic and far-reaching consequences of their actions?

3.1.2. Co-Evolutionary Dynamics: Mutual Transformation Across Scales

Co-evolutionary dynamics explore the reciprocal and iterative relationship between built environments and biophysical systems, emphasizing how they reshape one another over time and across spatial scales. This lens draws on Margulis' (1998) work on symbiosis, which highlights mutualistic relationships as drivers of evolutionary processes, and Latour's (2017) actor-network theory, which emphasizes the entanglement of human and non-human agents in shaping socio-ecological systems. For example, light pollution disrupts nocturnal animal behavior, which in turn alters vegetation patterns and urban biodiversity, demonstrating the cascading effects of human interventions. Similarly, urban heat islands influence local weather patterns, which feed back into urban planning decisions, creating a dynamic co-evolutionary loop. Batty's (2007) exploration of complexity in urban systems further underscores how small, localized actions—such as zoning changes or tree planting—can ripple outward, producing emergent patterns that reshape entire communities.

Geogames mechanics can operationalize co-evolutionary dynamics by simulating the mutual transformation of urban and ecological systems. For instance, tree agents could influence urban planning decisions by

altering soil stability, shading, or air quality, evolving over time to reflect the long-term impacts of urban development. Seasonal migrations or ecological thresholds could trigger construction freezes, forcing players to adapt their strategies to accommodate non-human needs. Flash-forward mechanics could reveal the long-term consequences of short-term urban policies, such as the impact of unchecked urban sprawl on regional ecosystems. Additionally, dynamic governance systems could evolve in response to ecological changes, such as floodplain zoning regulations adapting after a major storm, challenging players to think beyond immediate outcomes and consider broader, long-term implications.

To guide the design of geogames that incorporate co-evolutionary dynamics, several critical questions arise: How can governance systems in games evolve dynamically in response to ecological changes, such as floodplain zoning after a major storm or the introduction of invasive species? What happens when players must negotiate with non-human agents, such as bee colonies or migrating birds, to unlock urban development options? How can flash-forward mechanics be used to reveal the long-term consequences of short-term urban policies, such as the effects of deforestation or wetland destruction on regional ecosystems? Finally, how might visual storytelling—such as a tree narrating its growth and decline in response to urbanization—help players grasp the systemic and far-reaching consequences of their actions?

3.1.3. Multispecies Interactions: More-Than-Human Agency in Urban Systems

Multispecies interactions foreground the agency and stakes of non-human actors in urban systems, reimagining them as active participants rather than passive resources. This lens challenges anthropocentric paradigms by embedding non-human entities—such as rivers, pollinators, and mushrooms—into decision-making processes, drawing on Haraway's (2016) concept of sympoiesis, which emphasizes collaborative and interdependent systems. Tsing (2015) further highlights the entangled survival strategies of human and non-human actors in precarious environments, while Despret (2016) explores the relational and performative dimensions of non-human agency. These works underscore the need to rethink urban systems as multispecies assemblages, where rivers narrate their histories of pollution, bee corridors shape agricultural zones, and mushroom communities influence soil health. Such interactions reveal the profound interdependence between human and non-human beings, compelling players to confront the ethical implications of their decisions.

Geogames can operationalize multispecies interactions by introducing mechanics that give non-human agents tangible roles in gameplay. For instance, tree agents could influence urban planning by altering soil stability or air quality, evolving over time to reflect the long-term impacts of urbanization. Bee corridors could serve as critical pathways for pollination, requiring players to maintain biodiversity to ensure agricultural productivity. Visual storytelling could further enhance these interactions, with rivers narrating their pollution histories or mushrooms responding dynamically to player actions. These mechanics shift the focus from human control to multispecies negotiation, encouraging players to consider the needs, agency, and resilience of non-human actors in urban systems. By doing so, geogames can challenge players to think critically about the shared futures of human and non-human communities.

To guide the design of geogames that incorporate multispecies interactions, several critical questions arise: How can non-human testimony, such as a river narrating its pollution history, be integrated into gameplay to make ecological processes more tangible? What ethical dilemmas emerge when players must prioritize the

needs of non-human agents over human development goals? How can multispecies victory conditions, such as biodiversity thresholds or pollination success rates, redefine success in geogames? Finally, how might visual and procedural storytelling help players grasp the systemic and far-reaching consequences of their actions on more-than-human systems?

3.1.4. Planetary Thresholds: A Critical Framework for Sustainability

Planetary thresholds represent the critical boundaries within Earth's systems that, if crossed, could lead to irreversible ecological collapse. Rockström et al. (2009) conceptualized these thresholds as limits to processes like climate regulation, biodiversity loss, and biogeochemical cycles, which collectively maintain the planet's stability. We acknowledge that the concept of planetary boundaries has faced significant critique, particularly concerning the risk of its instrumentalization, which can obscure the profound social and political inequalities that underpin ecological crises. However, Stengers (2015) argues that these thresholds are not neutral scientific markers but sites of profound ethical and political struggle. The author critiques the framing of Gaia as a vengeful force, warning against narratives that reduce ecological collapse to an inevitable punishment for human hubris. Instead, she calls for a radical rethinking of our relationship with Gaia—not as a deity to appease but as a force that demands humility, care, and resistance to the fatalism of modernity. This perspective challenges the illusion of control over planetary systems, urging us to confront the systemic violence and inequalities that underpin urban–ecological crises.

Planetary thresholds are operationalized as dynamic constraints that shape gameplay and decision-making. Mechanics like "Once $CO_2 > 450$ ppm" or "Flood-damaged land must rest" simulate the cascading effects of crossing critical boundaries, forcing players to grapple with the fragility of Earth's systems. Still, as Stengers (2015) reminds us, these mechanics must go beyond mere simulations of control to provoke critical reflection on the limits of human agency. Geogames mechanics must emphasize systemic thinking—where every action reverberates across ecological networks—as a call to resist the reduction of Gaia to a manageable system. By embedding planetary thresholds into gameplay, players are compelled to confront the irreversible tipping points and systemic risks, where the consequences of inaction or mismanagement are not abstract but visceral and immediate. Hence, this lens emphasizes sustainability, resilience, and the cascading hazards of breaching ecological limits, rejecting the resettable failure states of conventional games.

Critically, the integration of planetary thresholds into geogame design raises urgent questions about responsibility and resistance against a descent into ecological collapse marked by apathy and the abandonment of collective care. This is particularly vital given the historical critique that the narrative of planetary limits risks being mobilized to justify exclusionary or anti-democratic policies, potentially reinforcing social hierarchies and systemic inequalities, rather than dismantling them. How can geogames foster a sense of accountability that transcends individual lifetimes and geographic boundaries? What ethical dilemmas arise when players must prioritize planetary health over immediate human needs? By situating planetary thresholds at the heart of gameplay, players are challenged to resist the fatalism of ecological collapse and imagine alternative futures rooted in systemic accountability, ethical governance, and regenerative solutions. This reflexive engagement transforms planetary thresholds from static limits into dynamic opportunities for learning, resistance, and transformation.

3.2. Geogames Assessment Tool

To evaluate and audit existing geogames, the study employs a rigorous methodology based on the Gaia lenses and their associated analytical categories. We created and structured an assessment tool for this analysis, categorizing games according to their alignment with the lenses and their ability to model urban–ecological dynamics. To ensure a rigorous and diverse selection of games, the methodology involved a systematic search across online platforms such as Games for Change, Games for Cities, Games4Sustainability, and Board Game Geek. Five illustrative examples were chosen for each category, reflecting a wide range of possibilities in terms of gameplay mechanics, thematic focus, and educational potential. These games were selected based on their alignment with the Gaia lenses, their ability to exemplify the Gaia-inspired analytical categories, and their relevance to real-world challenges in urban and regional planning.

The objective of our assessment tool is to move beyond conventional metrics—such as simple usability or engagement—to diagnose how effectively games embody the complexity of planetary systems. The chosen games were rigorously selected for diversity across three criteria: platform type (digital vs. analog), thematic focus (e.g., climate change, biodiversity, urban resilience), and their capacity to prefigure the Gaia lenses. This process ensured the selection of outliers that showcase alternative design philosophies, rather than the dominant SimCity-style clones. The resulting audit protocol aims to prioritize three key factors: (a) agency distribution, assessing the extent to which non-human systems influence game events; (b) temporal fidelity, evaluating how accurately ecological timescales are represented; and (c) threshold representation, examining whether collapse points are modeled as systemic rather than localized. This tool thus transforms subjective commentary into a reproducible audit protocol for diagnosing ecological coherence in games.

4. Results

The application of Gaia theory to games in architecture, urban, and regional planning marks a transformative shift in both conceptualization and practice. By embedding Gaia's systemic principles, the proposed framework directly addresses the anthropocentric limitations of conventional planning games, foregrounding the emergent, interconnected nature of urban–ecological systems. Most existing games privilege static, human-driven decision-making, often neglecting the nonlinear, co-evolutionary dynamics that characterize real-world urban environments. For example, in widely adopted city-builders like Cities: Skylines, non-human agency is often absent, and ecological collapse is modeled as a local event rather than a systemic consequence. The Gaia-inspired framework intervenes by structuring ecological complexity into the core of game design, compelling players to grapple with the ethical and systemic consequences of their actions. Equally, the same lens-lever grid can be deployed as an evaluative rubric, allowing scholars to diagnose where existing planning games illuminate—or ignore—crucial feedbacks, multispecies agencies, and planetary limits, and to quantify those omissions with reproducible metrics.

Assessing Gaia-aligned geogames requires moving beyond conventional usability metrics to evaluate how effectively they embody the complexity of planetary systems. The Gaia Assessment Tool (Table 1) aims to prioritize three key factors: (a) agency distribution, assessing the extent to which non-human systems influence game events; (b) temporal fidelity, evaluating how accurately ecological timescales are represented; and (c) threshold representation, examining whether collapse points are modeled as systemic rather than localized. While the table highlights 20 games, it acknowledges the existence of many other

relevant titles, emphasizing the breadth of this emerging field. This rigorous approach ensures that the selected games not only represent the diversity of possibilities but also serve as valuable tools for exploring the complex interdependencies between built environments and ecological systems.

Table 1. Detailed Gaia Assessment Tool.

Main Gaia Lenses	Gaia-Inspired Analytical Categories	Illustrative Games
Feedback Mechanisms: Urban–ecological loops that amplify, damp, or cascade.	Systemic Interconnectedness: Reveals the knock-on links among built and ecological environments. Feedback Loops: Tracks non-linear cause-and-effect, surfacing delayed blow-back. Resource Flow & Balance: Gauges energy/material cycles and consequences of overshoot.	Block'Hood (Plethora Project, 2017) explores intricate relationship between neighborhood influences and land use. Flood Resilience Game (Centre for Systems Solutions, 2017) simulates planning decisions and flood risks. Eco (Strange Loop Games, 2018) tracks resource cycles and ecological feedback. Underwater Cities (Delicious Games, 2018) imagines a collapsed future where humanity must master living beneath the sea. Pandemic (Z-Man Games, 2008) models global disease spread and its systemic consequences.
Co-evolutionary Dynamics: Built form & biophysical systems reshape one another over time and scale.	Temporal & Spatial Scales: Situates decisions from parcel to watershed, minute to decade. Governance & Policy Simulation: Tests how rules mutate alongside evolving ecologies. Socio-Political Agency: Who holds, shares, or loses decision-making power as urban–ecological systems evolve.	Urban Climate Architect (CliSAP, 2016) focuses on adaptive strategies for climate risks like heat islands and flooding. Play the City (Tan, 2017) simulates co-design and governance over a monopoly-like board. Videogame Urbanism (Pearson & Youkhana, 2020) fosters speculative scenarios to question power forces that shape cities. SimCity (Electronic Arts, 2013) shows policy impacts on urban growth and environment. RElastiCity (TU Delft Game Lab, 2021) emphasizes protecting cities against stresses and adapt them to become more resilient.
Multispecies Interactions: More-than-human agents hold political stakes in the city.	Biodiversity & Ecosystem Health: Values habitat networks and services within the urban fabric. Anthropocentric ↔ Ecocentric Paradigms: Challenges human-exceptionalist world-views. Ethics & Moral Implications: Foregrounds responsibility and justice across species lines.	Planet Zoo (Frontier, 2019) centres habitat design for species well-being. Tree (New Reality Company, 2017) immerses players in a tree's lifecycle. Ubuntu (Traficantes de Sueños, 2022) makes humans negotiate territory with beavers and oaks. Ego City (The Why Factory, 2014) forces densification choices under strict carbon-and-biodiversity caps. Beecarbonize (Charles Games, 2023) explores non-human agency for climate action.

Table 1. (Cont.) Detailed Gaia Assessment Tool.

Main Gaia Lenses	Gaia-Inspired Analytical Categories	Illustrative Games
Planetary Thresholds: Irreversible tipping points that bound urban futures.	Sustainability & Resilience: Probes capacity to stay within or adapt to hard limits. Planetary-Limit Focus: Monitors CO_2, groundwater, or nitrogen levels that trigger collapse states. Irreversibility & Risk: One-way tipping points and the cascading hazards that follow threshold breaches.	TRADEOFF! (Natural Capital Project, 2015) ends scenarios once nutrient thresholds break. Cities: Skylines—Natural Disasters (Paradox Interactive, 2016) tests planning under escalating shocks. Ecocraft (Hettinga et al., 2021) simulates the pursuit of clean energy. Carbon City Zero (Possible, 2020) builds carbon-neutral cities. Daybreak (CMYK, 2024) deploys policies and technologies as climate actions to dismantle the engine of global heating and to build resilient societies.

Our proposed detailed framework (Table 2) was developed through a two-step process: literature triangulation and framework synthesis. First, we cross-mapped four core Earth-system processes—nonlinear feedbacks, co-evolutionary dynamics, multispecies interactions, and planetary thresholds—with the socio-ecological questions central to contemporary urban research (Batty, 2013; Beatley, 2012; Rockström et al., 2009). Simultaneously, insights from game studies (Aarseth, 1997; Flanagan, 2009) clarified which ecological dynamics are often overlooked in city-building simulations. This triangulation produced a shortlist of "design-critical" concepts, such as delayed feedback, role symmetry between humans and non-humans, and irreversible state changes, which any Gaia-aligned geogame should address.

To ensure usability in tight design cycles, the framework was structured as a 4 × 5 grid, with four Gaia lenses (feedback mechanisms, co-evolutionary dynamics, multispecies interactions, and planetary thresholds) intersecting with five design levers (visual layer, narrative framing, procedural rules, temporal/irreversible pacing, and incentives/agency). Each cell in the framework includes a guiding sentence and an open-ended design question, inspired by Schell's (2020) "lens" strategy for rapid ideation. This approach allows the framework to function as a flexible, context-specific tool for sparking creative solutions without sacrificing theoretical depth. Additionally, an overarching educational and transformative layer evaluates how effectively gameplay reshapes real-world understanding and behavior around ecological interdependence and sustainable planning.

The detailed framework's structure is summarized in Table 2, which contrasts conventional geogames with Gaia-aligned designs.

Table 2. Detailed Gaia Design Tool.

Gaia Lens & Analytical Categories	Visual Layer (Maps, dashboards, AR overlays that make hidden flows legible)	Narrative & Storytelling (Quests, cut-scenes, or news flashes that contextualise systemic change)	Procedural Rules (Code or board mechanics that enact coupling, veto, or mutation)	Time & Irreversibility (Pacing tools that stretch or lock decisions to mirror real delays)	Incentives & Agency (Point systems, veto tokens, or playable roles that redistribute power)
Feedback Mechanisms (Systemic Interconnectedness – Feedback Loops – Resource Flow & Balance)	A composite heat-map lets one zoning change ripple across traffic, emissions, and hospital visits. "Where must colour shifts appear so players instantly grasp the knock-on?"	A delayed smog rebound becomes the Act II crisis that reframes earlier choices. "Which story beat reveals last turn's highway bond causing today's blackout?"	Hidden multipliers escalate runoff until a flood card triggers automatic district failure. "Which coefficient should secretly double impact each round?"	Air-quality recovery proceeds 10 turns after emissions fall, never instantly. "How long should the haze linger to convey real lag?"	Points accrue only when profit growth and pollution decline trend toward equilibrium. "How do we reward stability over expansion spikes?"
Co-Evolutionary Dynamics (Temporal & Spatial Scales – Governance/ Policy – Socio-Political Agency)	A zoomable layer links parcel edits to upstream watershed colour-shift. "How can a single gesture reveal street work altering regional runoff?"	A three-generation family diary tracks shifting bylaws and landscape change. "Whose descendant should pay the cost of a quick rezoning?"	Building codes mutate automatically when bat populations colonise attics. "What rule rewrites itself once a threshold of roosts is reached?"	Flood-damaged land must rest five rounds before rebuilding, mirroring soil recovery. "How long should enforced pauses last to feel ecological?"	Prestige rises when marginalised actors obtain council veto power. "Which bonus unlocks only after new voices gain a formal seat?"
Multispecies Interactions (Biodiversity & Ecosystem Health – Anthro ↔ Eco Paradigms – Multispecies Ethics & Justice)	Bee-corridor overlays flash red where pesticide spray zones overlap pollinator paths. "Which icon best flags an imminent habitat break?"	A river narrates its grievance as a mini-scene before a zoning vote. "How can non-human testimony sway players' choices?"	Tree agents wield veto tokens to cancel car-park projects when root zones shrink. "How often may a non-human veto be exercised?"	Construction freezes for three rounds during nesting season, enforcing ecological time. "What seasonal lockout best conveys breeding vulnerability?"	Victory requires raising both household income and species richness indices. "How do we prevent a win if bat counts fall?"
Planetary Thresholds (Sustainability & Resilience – Planetary-Limit Focus – Irreversibility & Risk)	A crack-line gauge turns black when CO_2 nears a tipping value. "Which visual cue screams 'point of no return'?"	Flash-forward headlines show the city five years after aquifer collapse. "What future scene will jolt players into pre-threshold action?"	Once $CO_2 > 450$ ppm, subsidies vanish and rule-sets harden, simulating a new climatic regime. "Which mechanic should flip instantly upon breach?"	Shoreline loss becomes permanent; no undo or rollback permitted. "Which decision must create an unfixable state change?"	After a breach, scoring flips from growth to harm-reduction and triage. "How will post-collapse metrics value damage limitation over profit?"

4.1. Employing the Framework as an Assessment Tool

The framework is intended to transform subjective commentary into a reproducible audit protocol. The procedure is initiated with scoping, during which the Detailed Gaia Assessment Tool (Table 1) is used as the core assessment matrix. The evaluation focuses on the smallest self-contained gameplay loop—one fiscal year in Cities: Skylines, for example—and the principal interface layer (map, board, or VR scene) is selected. Subsequently, the 20 lens-lever cells are traversed and evidence for each linkage is coded as present, partial, or absent. Visual assets (heat-maps), rule artefacts (code or card text), and behavioural logs (player choices) are employed as evidence sources. Thereafter, relevance weights (1–3) are assigned to every cell in accordance with the study brief; coastal investigations, for instance, are often weighted toward Planetary Thresholds rows. Presence scores are then multiplied by weights, and a radar plot is generated that exposes over- and under-represented ecological logics, supplemented by qualitative notes referencing the mechanics that produced each score.

When this protocol is applied to Cities: Skylines—Natural Disasters (Paradox Interactive, 2016), strong performance is recorded in Feedback-Mechanisms, because zoning changes instantly recolour congestion and pollution layers, whereas all Multispecies Interactions rows are marked absent, indicating that no agency is granted to non-human actors. By contrast, Eco (Strange Loop Games, 2018) registers high Feedback–Mechanisms scores through progressive climate loops encoded in server rules, but only partial performance in Co-Evolutionary Dynamics, given that governance statutes are not mutated by ecological change. A tabletop audit of Ubuntu (Gaidet, 2024) highlights complete Multispecies Interactions coverage via tree and beaver veto tokens, yet weak visual layers are flagged, suggesting that richer habitat overlays could be incorporated. With its live block-level input-output ledger and colour-coded flow icons that lay energy-waste links bare (strong Feedback-Mechanisms), Block'hood makes systems couplings instantly legible while its deliberately minimal story and rewards leave room for added incentive layers to deepen learning (Sánchez, 2015). In this fashion, the framework enables concrete affordances to be retained, adapted, or invented in subsequent production cycles.

Each populated cell forms a testable design claim (e.g., visible feedback loops), enabling direct evaluation via: interface logs for mechanic verification (veto triggers), pre/post concept mapping for systems thinking (Novak & Cañas, 2008), and policy support measures for Planetary Thresholds (Weber, 2015). Games strong in time-irreversibility mechanics warrant longitudinal tracking given their theorized attitudinal persistence (Bosman, 2019). By coupling clear design prompts with diagnosable outcome statements, the framework aligns with design-based-research standards (Barab & Squire, 2004) and transdisciplinary sustainability frameworks (Lang et al., 2012). This ensures that every mechanic is justified by its capacity to shift real-world understanding, aligning the tool with broader goals of durable, transformative change in urban governance.

4.2. Employing the Framework as a Design Tool

When used prospectively, the Gaia Design Tool (Table 2) is intended to function as a generative checklist that guides teams from abstract ecological concerns to concrete mechanics. A design cycle is normally initiated by the selection of a primary Gaia lens—Multispecies Interactions, for example—based on the environmental question or site context. Designers are then asked to examine the five design levers and to

draft at least one mechanic for every intersection cell. Under Multispecies Interactions, the prompt "Which non-human agent wields a veto?" may be translated into an oak-root algorithm that cancels parking garages encroaching on riparian zones. When a first sweep has been completed, a reinforcement pass is conducted to ensure that mechanics introduced by one lever are supported by complementary levers; the oak veto is thus coupled with a narrative scene in which the tree "speaks" and a visual overlay that flashes red when root zones contract.

The weighting column described in the audit protocol is subsequently reused as a development triage: High-priority yet empty cells are targeted immediately, thereby preventing feature sprawl and focusing effort on the intersections deemed essential for expressing chosen Gaia dynamics. The value of this disciplined focus is illustrated by published titles. In Planet Zoo (Frontier, 2019), a coherent Multispecies Interactions vision is achieved because mechanics, interface panels, and scoring systems all reinforce habitat welfare; in Surviving Mars (Haemimont, 2018), planetary thresholds are visualised but the procedural and incentive levers required to render dust-storm damage irreversible are absent, a gap that would have been illuminated had the framework been consulted during early concept development.

The framework can also be rotated mid-project to integrate under-represented dynamics. If a prototype is strong in Feedback Mechanisms loops, a later sprint can be devoted to Planetary-Threshold regarding limitations of time, implementing an irreversible aquifer-depletion mechanic. Because each prompt is formulated generically, the tool is transferable across media—from VR flood simulations to cardboard zoning games—consistent with Brandt's (2006) assertion that serious-game mechanics must be tailored to project goals.

An educational-and-transformative layer is intended to overarch the grid, ensuring that every mechanic is justified by its capacity to shift real-world understanding or behaviour concerning ecological interdependence and sustainable planning (Brković Dodig & Groat, 2019). Accordingly, the framework is advanced not as a rigid checklist but as a flexible, theory-rich prompt set that can be deployed for rigorous evaluation or for the construction of new, Gaia-aligned geogames.

5. Discussion

The Gaia-inspired framework marks a measurable advance in the field of geogames, moving beyond the limitations of conventional planning tools to offer a genuinely systemic and reflexive approach to urban and regional challenges. By operationalizing Gaia theory through our design framework, we foreground the entanglement of social, ecological, technological, and political processes, challenging the persistent anthropocentrism and reductionism that have long characterized both urban planning and serious game design. In doing so, we position geogames not merely as didactic simulations, but as experimental arenas where the consequences of policy, the agency of non-human actors, and the unpredictability of complex systems can be meaningfully explored and contested. This framework's critical contribution lies in its capacity to make visible and playable the feedbacks, co-evolutionary dynamics, multispecies interactions, and planetary thresholds that define contemporary urbanization. By embedding these lenses into the mechanics, narratives, and incentives of geogames, we enable designers and stakeholders to interrogate the cascading effects of decisions, the distribution of agency, and the ethical stakes of urban transformation. The framework thus serves as both a diagnostic and generative tool: It reveals where existing games

reinforce extractive, human-centered logics, and it guides the creation of new games that foreground interdependence, resilience, and justice.

Yet, the promise of the Gaia-inspired approach is matched by the complexity of its implementation. The technical demands of modeling urban–ecological systems with fidelity—integrating real data, simulating non-linear feedbacks, and representing more-than-human agency—require interdisciplinary collaboration and significant resources. Moreover, the participatory ambitions of geogames are often challenged by issues of inclusivity, accessibility, and power. While the framework can democratize planning by inviting diverse actors into the design process, it also risks reproducing existing inequities if marginalized voices are not meaningfully engaged or if the tools themselves remain inaccessible.

A further challenge lies in the translation of game-based insights into real-world planning outcomes. While geogames can foster systems thinking, scenario exploration, and stakeholder dialogue, their actual impact on policy and practice remains under-examined. To address this, we advocate for robust, mixed-methods evaluation protocols that move beyond engagement metrics to assess shifts in understanding, attitudes, and, crucially, support for systemic change. Longitudinal studies, process tracing, and comparative analyses with traditional planning methods are essential to determine whether Gaia-aligned geogames can catalyze durable change in urban governance, design, and community action.

The framework's limitations also demand critical reflection. While Gaia theory offers a powerful lens for reimagining urban systems, it may risk oversimplifying the social and political complexities that shape cities. Urban environments are not only ecological assemblages but also sites of contestation, shaped by histories of inequality, exclusion, and conflict. The Gaia metaphor, if uncritically applied, could obscure these dynamics or naturalize existing power relations. Addressing this requires ongoing theoretical innovation—integrating justice, participation, and historical consciousness into both the design and assessment of geogames.

Scalability remains another open question. While the framework has demonstrated value at the local and project scale, its application to regional or global challenges requires further methodological development. We acknowledge that governance fragmentation and ecological complexity are inherent to all scales, including the local. However, at regional and global scales, this challenge is intensified because ecological processes transcend administrative boundaries. Addressing this requires developing networked, federated game environments, and modular design strategies may offer pathways forward, but these approaches must be tested in practice.

Looking ahead, the integration of emerging technologies such as AI, virtual and augmented reality, and persistent digital twins holds promise for deepening the realism, immersion, and participatory potential of Gaia-aligned geogames. Equally, the development of accessible, non-digital formats can broaden participation and foster critical engagement beyond the digital divide. Ultimately, the true measure of this framework's success will be its capacity to provoke new forms of reflexivity, collaboration, and action among planners, designers, and communities, transforming geogames from illustrative tools into engines of urban and planetary transformation.

6. Conclusion

Our article has advanced the field of geogames by introducing the Gaia-inspired framework as both a critical lens and a practical methodology for the design and assessment of games in urban and regional planning. By embedding Gaia theory at the core of geogame development, we challenge the prevailing tendencies of planning simulations to privilege static, human-centered logics and to overlook the dynamic, interdependent realities of urban–ecological systems. The framework's insistence on systemic thinking, participatory engagement, and ecological adaptability offers a compelling pathway for addressing the urgent and intertwined crises of urban degradation, climate change, and sustainability.

Crucially, the integration of Gaia theory into geogame practice is not a mere theoretical exercise, but a necessary intervention in how we conceptualize, model, and ultimately shape urban environments. Gaia's focus on the mutual constitution of living and non-living systems reframes cities as complex, adaptive assemblages—spaces where human and more-than-human agencies are in constant negotiation. Through this lens, geogames become more than educational or participatory tools; they emerge as experimental platforms for exploring the cascading consequences of decisions, the distribution of agency, and the ethical dilemmas at the heart of urban transformation.

Yet, realizing the full potential of this framework demands a profound paradigm shift. The current geogame landscape remains fragmented, often constrained by reductionist models and short-term metrics. To confront the complexities of the Anthropocene, geogames must evolve—embracing interconnectedness, resilience, and co-evolutionary dynamics as foundational principles. This evolution is not solely a matter of technical refinement; it requires a reimagining of the cultural, institutional, and political contexts in which games are conceived and deployed. It calls for interdisciplinary collaboration, the genuine inclusion of marginalized voices, and a sustained commitment to equity and justice in both process and outcome.

As a living framework, the Gaia Design Framework is open to adaptation and expansion, evolving alongside the crises it seeks to address. Future developments could deepen its engagement with temporal scales, simulating the long-term impacts of short-term decisions, or explore more nuanced representations of multispecies agency. Beyond its immediate application to geogame design, the framework invites broader conversations about the role of geogames in shaping public discourse and urban policy. How can geogames serve as platforms for participatory urban and regional planning or as tools for fostering ecological literacy? Such questions underscore the transformative potential of the framework—not just as a design or assessment/auditing tool but as a catalyst for reimagining our cities within a fragile and interdependent world.

Ultimately, the Gaia-inspired framework is a call to action for the geogame community: to move beyond the limitations of traditional planning tools and to harness the transformative potential of play as a mode of inquiry, critique, and collective imagination. In an era defined by planetary crisis, the stakes for how we design, play, and learn from geogames could not be higher. The imperative is clear: Only by radically rethinking our approaches can we hope to foster the sustainable, resilient, and just urban futures our world so urgently requires.

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References

Aarseth, E. (1997). *Cybertext: Perspectives on ergodic literature*. Johns Hopkins University Press.

Adams, E. (2014). *Fundamentals of game design* (3rd ed.). New Riders.

Ahlqvist, O., & Schlieder, C. (2018). *Geogames and geoplay*. Springer. https://doi.org/10.1007/978-3-319-22774-0

Andrade, B., Braga, L. I., & Cunha, C. A. (2024). The city as a cosmopolitical board game: Candomblé terreiros in Bahia, atmospheres, and design games. In M. Boubezari, C. R. Duarte, & E. Pinheiro (Eds.), *Proceedings of the 5th International Congress on Ambiances—Sensory Explorations: Ambiances in a Changing World* (pp. 326–339). International Ambiances Network.

Andrade, B., & Pereira Roders, A. (2022). Value-based redesign in gamified learning environments. In R. Rocco, A. Thomas, & M. Novas-Ferradás (Eds.), *Teaching design for values: Concepts, tools & practices* (pp. 292–317). TU Delft OPEN Publishing.

Barab, S. A., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, *13*(1), 1–14. https://doi.org/10.1207/s15327809jls1301_1

Batty, M. (2007). *Cities and complexity: Understanding cities with cellular automata, agent-based models, and fractals*. MIT Press.

Batty, M. (2013). *The new science of cities*. MIT Press.

Beatley, T. (2012). *Biophilic cities: Integrating nature into urban design and planning*. Island Press.

Bosman, F. G. (2019). There is no solution!: "Wicked problems" in digital games. *Games and Culture*, *14*(4), 347–364.

Brandt, E. (2006). Designing exploratory design games: A framework for participation in participatory design? In *PDC '06: Proceedings of the Ninth Conference on Participatory Design: Expanding Boundaries in Design—Volume 1* (pp. 57–66). Association for Computing Machinery. https://doi.org/10.1145/1147261.1147271

Brković Dodig, M. B., & Chiles, P. (2016). 'Spector—The sustainability inspector': Participatory teaching, learning and evaluation game for architects, architecture students and pupils. *Facta Universitatis—Series: Architecture and Civil Engineering*, *14*(1), 1–20. https://doi.org/10.2298/FUACE1601001B

Brković Dodig, M. B., & Groat, L. (2019). *The Routledge companion to games in architecture and urban planning: Tools for design, teaching, and research*. Routledge.

Centre for Systems Solutions. (2017). *Flood Resilience Game* [Video game]. https://floodresilience.socialsimulations.org

Charles Games. (2023). *Beecarbonize* [Video game]. https://www.charlesgames.net/beecarbonize

CliSAP. (2016). *Stadt Klima Architekt* [Video game]. https://www.cen.uni-hamburg.de/press/entdecken/stadtklimaarchitekt.html

CMYK. (2024). *Daybreak*. https://www.daybreakgame.org

Delicious Games. (2018). *Underwater Cities*. Board Game Geek. https://boardgamegeek.com/boardgame/247763/underwater-cities

Despret, V. (2016). *What would animals say if we asked the right questions?* University of Minnesota Press.

Doolittle, W. F. (2019). Making evolutionary sense of Gaia. *Trends in Ecology & Evolution*, *34*(10), 889–894. https://doi.org/10.1016/j.tree.2019.05.001

Duke, R. D. (1974). *Gaming: The future's language*. Sage.

Electronic Arts. (2013). *SimCity* [Video game]. https://www.ea.com/games/simcity/simcity

Fernández Galeote, D., & Hamari, J. (2021). Game-based climate change engagement: analyzing the potential of entertainment and serious games. *Proceedings of the ACM on Human-Computer Interaction*, *5*(CHI PLAY), Article 226.

Flanagan, M. (2009). *Critical play: Radical game design*. MIT Press.

Frasca, G. (2003). Simulation versus narrative: Introduction to ludology. In M. J. P. Wolf & B. Perron (Eds.), *The video game theory reader* (pp. 221–235). Routledge.

Frontier. (2019). *Planet Zoo* [Video game]. https://www.planetzoogame.com

Gaidet, N. (2024). Composer un territoire de vie en commun entre humains et non-humains : l'exemple du jeu Ubuntu. In *Jeux & Enjeux Proceedings* (pp. 132–134). Maison des Sciences de l'Homme de Montpellier.

Haraway, D. J. (2016). *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press.

Hettinga, S., Boter, J., Dias, E., Fruijtier, S., de Vogel, B., & Scholten, H. (2021). Urban energy transition in a gaming context: The role of children. *Land Use Policy*, *111*, 104903.

Haemimont Games. (2018). *Surviving Mars* [Video game]. Paradox Interactive. https://www.haemimontgames.com/games/surviving-mars/

Juul, J. (2005). *Half-real: Video games between real rules and fictional worlds*. MIT Press.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science*, *7*(Suppl. 1), 25–43.

Latour, B. (2017). *Facing Gaia: Eight lectures on the new climatic regime*. Polity Press.

Lovelock, J. (2000). *Gaia: A new look at life on Earth* (3rd ed.). Oxford University Press.

Lovelock, J. (2006). *The revenge of Gaia: Earth's climate crisis & the fate of humanity*. Basic Books.

Lovelock, J., & Margulis, L. (1974). Atmospheric homeostasis by and for the biosphere: The Gaia hypothesis. *Tellus*, *26*(1/2), 2–10. https://doi.org/10.3402/tellusa.v26i1-2.9731

Margulis, L. (1998). *Symbiotic planet: A new look at evolution*. Basic Books.

Mayer, I. S., van Bueren, E. M., Bots, P. W. G., van der Voort, H., & Seijdel, R. (2005). Collaborative decisionmaking for sustainable urban renewal projects: A simulation–gaming approach. *Environment and Planning B: Planning and Design*, *32*(3), 403–423.

Natural Capital Project. (2015). *TRADEOFF!* [Video game]. https://tradeoffgames.naturalcapitalproject.org

New Reality Company. (2017). *Tree*. https://www.treeofficial.com

Nixon, R. (2011). *Slow violence and the environmentalism of the poor*. Harvard University Press.

Novak, J. D., & Cañas, A. J. (2008). *The theory underlying concept maps and how to construct and use them* (Technical Report IHMC CmapTools 2008-01). Institute for Human and Machine Cognition. https://cmap.ihmc.us/docs/theory-of-concept-maps

Paradox Interactive. (2016). *Cities: Skylines—Natural Disasters* [Video game]. https://www.paradoxinteractive.com/games/cities-skylines/add-ons/cities-skylines-natural-disasters

Pearson, L., & Youkhana, S. (2020). Videogame urbanism: Using game spaces to challenge the future of cities. *The Site Magazine*, *40*(3). https://www.thesitemagazine.com/read/videogame-urbanism

Plethora Project. (2017). *Block'hood* [Video game]. https://www.plethora-project.com/blockhood

Poplin, A., Andrade, B., & de Sena, Í. S. (2020). Geogames for change: Cocreating the future of cities with games. In D. Leorke & M. Owens (Eds.), *Games and play in the creative, smart and ecological city* (pp. 64–93). Routledge.

Poplin, A., Kerkhove, T., Reasoner, M., Roy, A., & Brown, N. (2017). Serious geogames for civic engagement in urban planning: Discussion based on four game prototypes. In C. Yamu, A. Poplin, O. Devisch, & G. De Roo (Eds.), *The virtual and the real in planning and urban design* (pp. 189–213). Routledge.

Possible. (2020). *Carbon City Zero*. Board Game Geek. https://boardgamegeek.com/boardgame/288179/carbon-city-zero

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., III, Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., . . . Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475.

Sánchez, J. L. S. (2015). Block'hood—Developing an architectural simulation video game. In B. Martens, G. Wurzer, T. Grasl, W. E. Lorenz, & R. Schaffranek (Eds.), *Real Time—Proceedings of the 33rd eCAADe Conference* (Vol. 1, pp. 89–97). Vienna University of Technology. https://doi.org/10.52842/conf.ecaade.2015.1.089

Sanoff, H. (1979). *Design games*. William Kaufmann.

Schell, J. (2020). *The art of game design: A book of lenses* (3rd ed.). CRC Press.

Sousa, M. (2024). The Stakeholders Clash Game: From Board game design to online collaborative platforms for urban planning. In A. Marto, R. Prada, P. Gouveia, R. Contreras-Espinosa, A. Gonçalves, E. Abrantes, & R. Ribeiro (Eds.), *International Conference on Videogame Sciences and Arts* (pp. 55–69). Springer Nature.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), Article 1259855.

Stengers, I. (2015). *In catastrophic times: Resisting the coming barbarism*. Open Humanities Press.

Strange Loop Games. (2018). *Eco* [Video game]. https://play.eco

Tan, E. (2017). *Play the city: Games informing the urban development*. Jap Sam Books.

The Why Factory. (2014). *Ego City*. https://thewhyfactory.com/output/ego-city

Traficantes de Sueños. (2022). *Ubuntu*. https://traficantes.net/libros/ubuntu

Tsing, A. L. (2015). *The mushroom at the end of the world: On the possibility of life in capitalist ruins*. Princeton University Press.

TU Delft Game Lab. (2021). *RElastiCity: An Urban Resilience Game* [Video game]. https://seriousgaming.tudelft.nl/games/relasticity

Weber, E. U. (2015). Climate change demands behavioral change: What are the challenges? *Social Research: An International Quarterly*, *82*(3), 561–580. https://doi.org/10.1353/sor.2015.0050

Z-Man Games. (2008). *Pandemic*. https://www.zmangames.com/game/pandemic

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ARTICLE

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Modern Board Games: Can They Be Geogames?

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Abstract

This article addresses the evolving concept of geogames, traditionally focused on digital and location-based experiences, and explores the potential of modern board games as an analogue form of geogame. While geogames have been defined by their use of real-world spatial information, often through GIS technology, there is a recognized need to include more abstract and imaginative representations of space, particularly in analogue formats. This study investigates how modern commercial entertainment board games, characterized by innovative game mechanics and spatial representation, connect with the concept of geogames. It employs a bibliometric analysis of geogame literature and a descriptive analysis of modern board games from the BoardGameGeek database. Key findings indicate a lack of research on analogue games within geogame specific literature, while revealing that modern board games effectively utilize spatial units, territory representation, and game mechanics to create virtual spatial worlds. The study concludes that modern board games align with the definition of geogame, advocating for their inclusion in the geogame research agenda.

Keywords

analogue games; bibliometric analysis; game design; geo-information; location-based games; serious games

1. Introduction

The broad concept of geogames—games in which the mechanics have a geographic context, often facilitated by digital means—has profited from the development and ease of digital technologies. However, as we enter the post-digital age, this concept is evolving. In this new age, some authors claim that analogue media are gaining popularity, as they are an escape from screens (Cramer, 2015; Lhowe, 2018). As such, to broaden the genre and concept of geogames—and inspired by the emergence of new game systems and experiences in analogue games (Arnaudo, 2023)—a fundamental design revolution is needed in the field. This revolution would transition from purely GIS-based or location-based to include more abstract and imaginative representations of space in geogames. Modern board games, in contrast to classic board games, employ game systems to deliver complexity through a combination of game mechanisms. As we will detail, there is currently limited broader exploration of new systems in modern board games, such as those supporting geogames, for non-entertainment purposes.

Ahlqvist and Schlieder (2018) define location-based games (LBGs) as those that use real-world space and location as a key element, yet they also acknowledge that geogames can be location-based while using non-spatial elements—like simulations and abstracted realities—to represent geographical information. This idea broadens the possibilities for geogames, extending them to include analogue games that represent geographical information through specific game mechanics. Furthermore, although the same authors explored converting a digital geogame into a traditional board game, there is a gap in the literature exploring modern board game design and how new techniques can both deliver engaging interactive systems to explore geographic context and facilitate how spatial abstraction takes place in analogue platforms.

Initially, Schlieder et al. (2006) worked on LBGs and referred to them as geogames, focusing on the use of positioning technology like GPS to integrate the player's physical location into a game logic. A broader concept was explored by Ahlqvist et al. (2012), who considered geogames to be those that use real-world spatial information and are mediated by GIS, with a focus on the creation of replicas of the real world based on geospatial data. In its essence, geogames overlaps with the concept of serious games (Abt, 1987) and pervasive games (Adanalı, 2021), as they are designed to achieve outcomes beyond purely entertainment.

While there is overlap and sometimes interchangeable use of terms in the literature, the concept of geogames evolved from an initial focus on LBGs involving physical movement and specific classic board game mapping constraints to a broader definition encompassing any game using real-world spatial information, often mediated by GIS technology. However, studies on analogue geogames, such as board games, are less common in the literature. Thus, we propose exploring manifestations of "geo" in modern commercial entertainment board games—especially in tabletop, card, and board games—to explore new play experiences.

Our primary objective is to examine the existing literature in geogames to understand the role of analogue games in defining geogame systems. Our second objective focuses on analysing modern board games to describe their connection with the concept of geogames. This study considers published scientific literature that specifically mentions "geogame" as a term, and commercial entertainment analogue games—in particular, the modern board games from the BoardGameGeek (BGG) database. In our results, we present a description of the trends within geogames studies through a bibliometric analysis and a comprehensive

summary of the design elements, mechanics, and physical components that underpin modern analogue geogames, thereby contributing to a redefinition of the overall concept of geogames to include non-digital applications.

2. Modern Board Games

A board game design revolution has occurred in the last two decades (Arnaudo, 2023). Despite the continuous innovations in digital game technologies, analogue games are changing how people play in person and with tangible game pieces. There is a fascination for game pieces and how to use them in interactive playable systems. Modern board gaming has elevated these engaging experiences to a new level (Rogerson et al., 2016, 2020). Besides the material dimensions, mechanical design innovations are core elements of modern board gaming. New game mechanics and mechanisms emerged in the last 20 years that allow game designers to mimic complex playable models (Engelstein & Shalev, 2019; Sousa, Oliveira, & Zagalo, 2021). We can identify recurring elements that contribute to success across highly regarded hobby board games, as selected by experts and hobby players (Sousa, 2023a).

These design trends build upon other hobby games (Woods, 2012) which niche publics have played, and they have gained popularity due to the rise of geek culture (Booth, 2021; Trammell, 2023). The popularity of narrative games like Dungeons & Dragons influenced how modern board games are built today. Within all the variety, there is a concern about the narrative and thematic coherence between mechanics and narratives (Shipp, 2024). Narrative analogue tabletop games have been exploring virtual and imaginary spaces without digital technologies (Arnaudo, 2018; Mizer, 2019), sometimes collectively (Nikolaidou, 2018). Modern board games have been exploring these virtual imaginary spaces while proposing elegant mechanical systems. Despite their robust mechanical characteristics, modern board games build consistent narratives that players can explore with more visual support (e.g., Pandemic Legacy Season 1; Sleeping Gods; Robinson Crusoe: Adventures on the Cursed Island) compared with purely narrative games which reply primarily on books as game materials (Arnaudo, 2023). These new designs go beyond the abstraction and ludonarrative (Hocking, 2009) of mass market and non-modern games, avoiding the disconnection of narrative and mechanical systems.

Exploring how modern board games are built, what mechanical game systems they rely on, and how they help create narratives that immerse players in the virtual world they propose is a necessary step to advance the discipline. These new systems allow the building of new games and forms of analogue simulation. Similar game mechanisms appear among the top games listed in the BGG database. BGG is the world's biggest and most prestigious board game platform, systematizing information about all analogue games. Recent studies indicate a trend away from certain game mechanisms, once common and dominant in older designs, suggesting their gradual abandonment. One example is the mass market games' roll and move mechanism (Samarasinghe et al., 2021). Among modern games, these mechanisms tend to be avoided by players (Nguyen et al., 2024). This change means this revolution is tightly connected to the mechanisms and ways games materialize space. Modern board game design engages a growing number of players worldwide. Among the reasons for this identified by players is the social interaction during engaging game experiences (Booth, 2021), highlighting that the overall game system—encompassing mechanical and narrative—is crucial in delivering new experiences that foster joyful interaction among participants.

As we have seen, board games have changed. However, despite this novelty and innovation, there seems to exist a lack of application of the new designs into spatial components in games (including serious games) like geographical space (Sousa et al., 2022b; Sousa & Bernardo, 2019). Modern board game design can help develop serious game approaches, where the games are used as engaging planning support tools, either for simulating complex systems where stakeholders can interact and test decisions or just as game-based learning methods to teach various related topics such as climate change and adaptation approaches (Sousa, 2023b, 2024). The use of analogue games has limitations and advantages. The limited number of participants and the need to be played in person can foster social interaction, and eases the development and adaptation of the games for specific applications (Ham, 2015; Sousa et al., 2022a). They are cost-effective and allow real-time adaptations. Considering the huge amount of board games published each year (Nand, 2021; technavio, 2022), we aim to find if significant and relevant modern commercial entertainment board games address geographical and spatial dimensions and can be considered a form of analogue geogames. Our proposal demonstrates how the current state of the art in modern board games can be applied to future geogames for purposes beyond entertainment, such as serious games and other bespoke applications related to geographic or spatial topics.

3. Methodology

To explore the context at the intersection of geogames and analogue modern games, a combination of bibliometric analysis and descriptive analysis was employed, using two data sources. For the first, a search on Scopus provided insights on the current trends in geogames research, while the second source was the online database of commercial board games BGG.

3.1. Bibliometric Analysis

In terms of databases for bibliometric analyses, two options are widely used: Scopus (Elsevier) and Web of Science Core Collection (Clarivate Analytics). It is worth noting that there are studies aimed at comparing the results obtained in the two databases. For example, Archambault et al. (2009) indicated R^2 correlation indices of 0.99 regarding the number of articles and the number of citations received by country. In any case, it is essential to consider that there are limitations in the catalogue of both platforms, especially with regard to publications prior to the 1990s (Mota et al., 2025).

The bibliometric analysis was conducted using the Scopus database, considering scientific articles and other documents published between 1900 and 2024. For the search routines, all the Scopus database was considered, without restricting it to specific scientific journals. The search routines included keywords with a direct or indirect relationship to geogames, LBGs and board games, identified through a previous qualitative literature review. The Boolean operators (e.g., "AND," "OR") were used to restrict or expand the search by combining keywords. The asterisk (*) was used to comprise variations of the words created by the addition of new characters from the original keyword. The selection of keywords was based on well-known literature about geogames intended to narrow our scope and allow for a more focused bibliometric analysis of how the term "geogame" has evolved since its first appearance. The search prompts applied to this research routine are presented below:

#1 TITLE-ABS-KEY = ("location-based gam*")

#2 TITLE-ABS-KEY = ("serious gam*")

#3 TITLE-ABS-KEY = (geogam*) OR TITLE-ABS-KEY = (geo-gam*) OR TITLE-ABS-KEY = (geogaming) OR TITLE-ABS-KEY = (geo-gaming)

The resulting data were exported from the Scopus database (in .csv format file), and the dataset was analysed using VOSviewer software from Leiden University (Eck & Waltman, 2010). According to the definition on the tool's official website (vosviewer.com), VOSviewer is a software for constructing and visualizing networks. In this specific case, it was used to design bibliometric networks. These networks can include keywords, journals, researchers, or countries with a construction based on citation, co-occurrence of keywords, bibliographic coupling, co-citation, or co-authorship relations. The data are spatially organized in the graph so that their distance indicates thematic affinity between the authors and keywords. In this research, the software's default configuration was used, considering an analysis focused on the co-occurrence of keywords.

The analysis of co-occurrence of keywords focuses on the content of publications (title, abstract, and/or author's keywords), establishing relationships between the occurrence of terms and enabling the delimitation of conceptual structures (Zupic & Čater, 2015). Resulting in semantic networks, the limitations of the technique are mainly linked to the subjectivity of choosing the terms used in the search and the fidelity of the indexers in recording the keywords. Considering such operational limitations, the use of keywords gives us clues about subfields of a discipline or research problems that are most prevalent within a sample.

In terms of graphical representation, VOSviewer allows three data visualization options: network visualization, overlay visualization, and density visualization. In this study, the presentation of the first option was prioritized. In network visualization it is possible to perform a cluster analysis (groups that are formed by affinity/proximity) where the thickness of the lines and the size of the points indicate the relevance of connections and occurrences, respectively.

To expand our results based on bibliometric analysis (quantitative), we also analysed the publications under a qualitative perspective, considering all the documents of the sample. We classified the documents in the sample by type of publication (article, conference proceedings, book chapters), type of study (theory, development, application), and definition of geogame. These classifications were performed by analysing the documents' metadata, such as used as an input in VOSviewer, and abstract screening. When the qualitative information to classify the type of study or the conceptual definition of geogame used in the document was missing from the abstract, a search in the full document was performed. To analyse the sample in relation to the research question of the present study, a general analysis of references to analogue games was performed within the sample.

3.2. Board Game Database Analysis

BGG is a website created in January 2000 by Scott Alden and Derk Solko (BGG, n.d.) as a community for players. The website has a database of more than 100,000 games and extensions, along with a rating system for users to contribute to the creation of a ranking. It is a widely recognized and comprehensive online

database and community for board game enthusiasts, making it a suitable source for analysing trends in modern board games.

To analyse the BGG database, we followed the Mechanics for Engagement Design Protocol (Sousa, Oliveira, Cardoso, et al., 2021), adapted to geospatial-related topics. The inclusion criteria were the top-ranked 100 games, based on a ranking system derived from the average of user-submitted ratings on BGG. Within this sample, another inclusion criterion was considered: games relating to one or more of the following context categories—Environmental, Exploration, Territory Building, and/or Travel. We considered these categories as most relevant to the broader scope of geogames. This selection ensures that the most popular games in the database relevant to the research question are included in the analysis.

The games were analysed based on their representation of geographical space and systems and the application of game mechanics and mechanisms in a spatial context. We considered the following geographical characteristics: spatial unit (e.g., hexes, networks, zones), type of map (e.g., abstract, realistic), scale (e.g., building, land plot, country), economy and social dimension, natural resources, and climate.

4. Results and Discussion

4.1. Bibliometric Analysis of Geogames

While exploring keywords for this study, based on common concepts used among well-known publications in the field of geogames, we noticed that when including solely "location-based game" in the search, 550 publications were available, which would be a large sample to analyse. When narrowing it by adding "serious games" to the search it reduced the total number of publications to 56. However, when adding "geogame" OR "geo-game" to the search, only one result was available. Therefore, to focus the search on capturing existing literature in the field we use the word "geogame" or its variations (geo-game, geogaming, geo-gaming), which yielded a total of 48 results, with three items being excluded from the sample after abstract screening, as being descriptions of conference proceedings. The final sample is 45 documents. Of this sample in question, 22 documents are conference papers, 16 articles, and seven book chapters. Eighteen of these documents discuss the use of LBGs as geogames, approximately 40% of the total documents in the sample.

While 11 documents refer to or discuss the use of analogue games (specifically classic board games) as a base to develop geogames, only one document focuses on board games as a core element of the study, which is the seminal paper written by Schlieder et al. (2006) who were among the first researchers to introduce the concept of "geogames." It explains that a straightforward mapping of board games onto the real world does not work, and introduces a framework based on player locations and resource distribution.

Regarding the publication date of the documents in the sample (Figure 1), the oldest document is from 2006, including the previously discussed work of Schlieder et al. (2006). The series remains stable, with one or two publications annually until 2016. In 2017 there was a significant increase in the number of publications, with six documents registered. However, the maximum in the sample would occur the following year, with 13 documents in 2018 potentially associated with the publication of *Geogames and Geoplay* (Ahlqvist & Schlieder, 2018). Publications have been decreasing since then, reaching a relative stability that extends until 2024, with values of four annual documents up to the date of this research.

Regarding the number of citations of the documents in the sample (Figure 1), the trend found is different. The highest citation values are more recent, reaching a maximum in the year 2023 (a year with a low number of documents published within the scope of this bibliometric research). Regarding the country of origin of the documents (Figure 2), there is a predominance of documents from Germany (15 documents), followed by the United States (13), Spain (4), Czech Republic (4), Ireland (3), Netherlands (3), and Portugal (3). Nine other countries are included in the sample, with representatives from South America, Africa, Asia, and Europe.

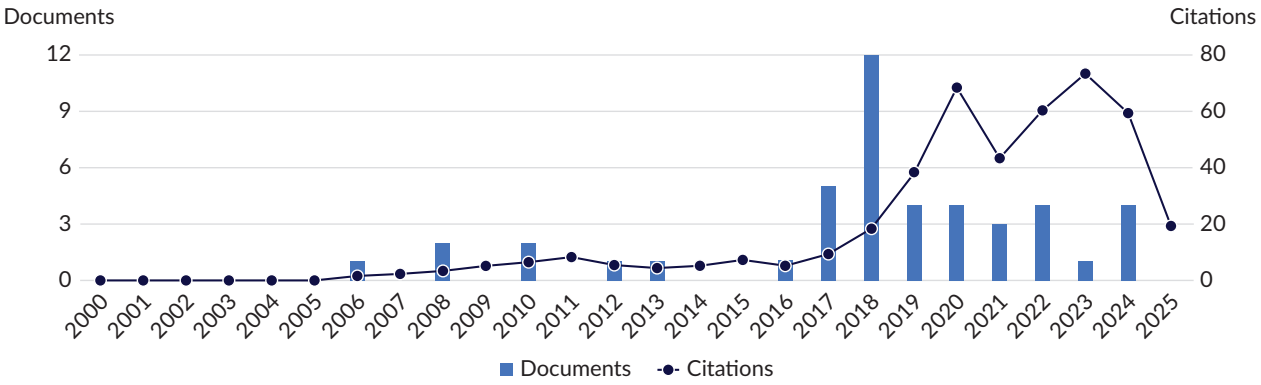

Figure 1. Citations over time compared with published documents per year ($N = 45$). Source: Scopus.

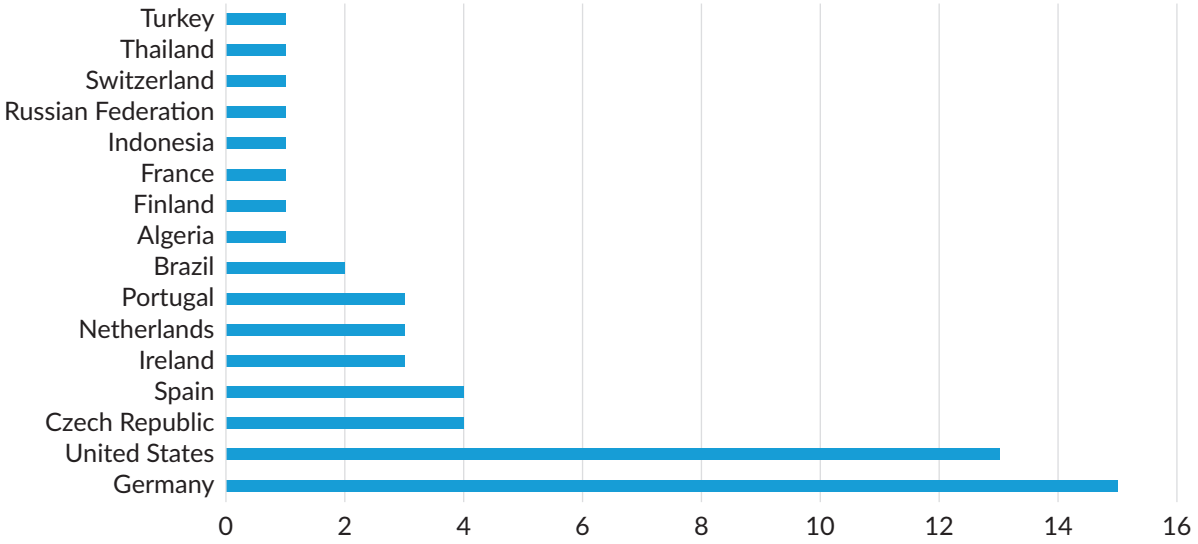

Figure 2. Total number of documents published per country that have "geogame" or its variations in the title, abstract, or keywords. Source: Scopus.

Finally, regarding the co-occurrence of keywords, only the keywords selected by the authors were considered, reaching a total of 140 terms recorded in the sample. However, only 19 of these keywords occur at least twice in the sample, demonstrating the diversity of approaches even in the face of a specific methodological theme and a relatively small sample of documents. The variants "geogame" and "geogames" are the most dominant in the sample, with seven records each, reinforcing the search parameters used. "Location-based games" (five records) can also be found among the most cited terms, followed by a larger list of those terms whose occurrence is three records: "game design," "education for sustainable development," "digital game-based learning," "Minecraft," and "education."

When the keyword co-occurrence metadata is graphically represented through VOSviewer bibliometric networks, four clusters are formed (Figure 3), represented by distinct colours. While "geogame" assumes a central position related to the "GPS" record, "serious games" and "urban planning" form an adjacent and restricted cluster. The two largest clusters are represented at opposite ends of the graph with "location-based games," "Minecraft," "geodiversity," "education," and "point of interest" (in red), and "game-based learning," "environmental education," "education for sustainable development," "game design," and "mobile learning" (in green). The opposing positions of "location-based games" and "game-based learning," two of the main approaches related to the use of games in education, are noteworthy. Being in different clusters and with different connections, the two keywords are directly linked to the central concept of "geogame." The connections between terms, forming clusters, allow the observation of conceptual and methodological affinities in the scientific documents selected by the sample. However, the small size of the sample is a limiting factor for a definitive correlation analysis.

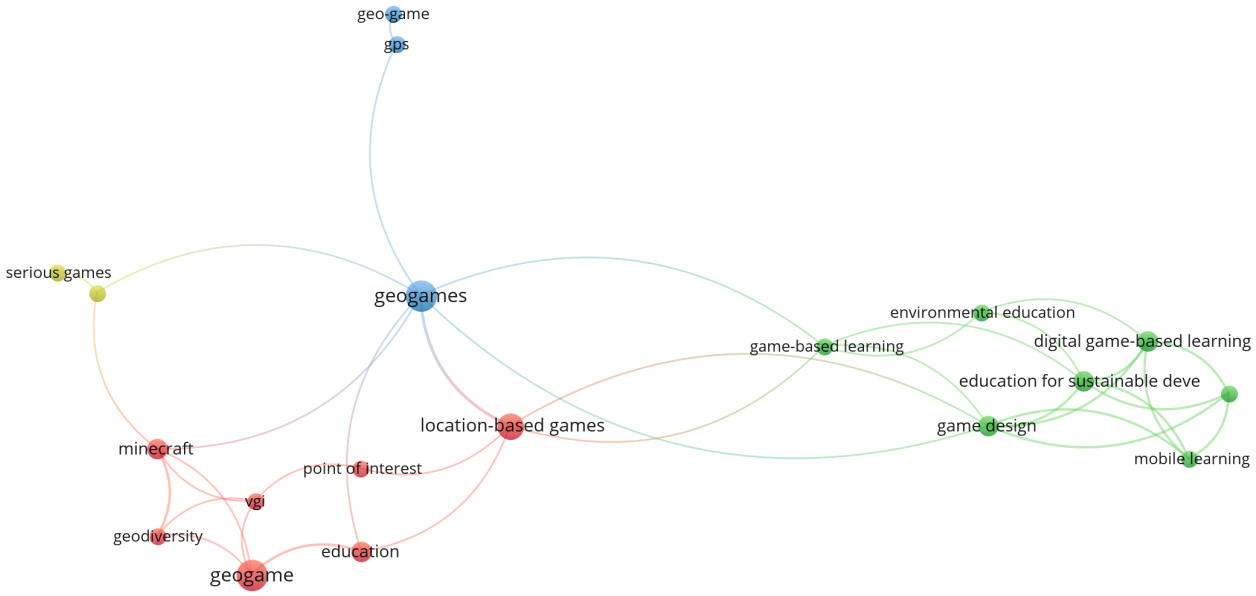

Figure 3. Identified links between keywords considering their co-occurrence ($N = 45$). Each colour represents clustering keywords departing from links to the word "geogames."

In general, 12 documents in the sample have a particular focus discussing the theory or foundations of the geogames concept, by presenting examples or defining the concept in the context of their studies. Many of the documents cite two other documents present in the sample to contextualize the definition of geogame, namely Schlieder et al. (2006) and Ahlqvist et al. (2012). These documents primarily define "geogame" itself and discuss related theoretical concepts or frameworks (like core geographic concepts, game patterns, pedagogical theories, GIS methodologies, modelling approaches) that inform geogames rather than defining different types of games and differentiating them. However, the sources do highlight that the term "geogame" is not used with perfect uniformity.

One of the most relevant sources is the book *Geogames and Geoplay*, edited by Ahlqvist and Schlieder (2018), which features 11 chapters discussing foundations and applications of game-based approaches in the context of geo-information. Three chapters appear in the sample collected from Scopus, namely chapters 2, 3, and 6. In chapter 2, the geogame genre is explored by providing a wide umbrella definition for geogames,

considering them as games and play using real geocontent mediated by geo-information technology (Ahlqvist et al., 2018). It examines elements that define the geographic and gaming dimensions of geogames, aligning spatial game patterns with core geographic concepts, while introducing the concept of GIS-MOG (Geographic Information System Multiplayer Online Games). In Chapter 3, Bartoschek et al. (2018) present the prototype of the OriGami, described as a mobile geogame developed for fostering spatial literacy. The authors also define mobile geogames as being based on player movement through real environments. In chapter 6, Schlieder et al. (2018) use the idea of a competitive LBG as a primary definition of geogame, played in an urban or natural environment. The focus on LBGs is shared among the three chapters, corroborating the trend identified in the bibliometric analysis of co-occurrence of keywords (Figure 3).

The term LBG is sometimes used interchangeably with geogames in the literature. Schlieder et al. (2006) present an initial "geogames" concept as a specific case of LBGs, characterized by the spatial and temporal coherence constraints from classic board games. Other documents mention LBGs in the context of using mobile, location-aware devices (Bartoschek et al., 2018) and designing them for learning (Oppermann et al., 2017). Similarly, the term "location-aware games" appears as a synonym for LBG in the context of the sample.

In regard to the relationship of board games and geogames in the documents, these are discussed in several contexts but primarily presented as historical precursors and foundational inspirations for geogames and related concepts. A key connection is highlighted by the work of Schlieder et al. (2006), who introduced the term "geogames" and discussed designing LBGs based on classic board games. Classic board games are used to illustrate fundamental game design concepts. For instance, chess and checkers are mentioned as examples of games that exhibit a full information pattern, where there is no hidden information, which can increase the combinatorial complexity and encourage strategic reasoning (Schlieder et al., 2018). In the context of modern board games, a few documents mention this. One example is the "genesis" of the GIS-MOG framework discussed by Ahlqvist et al. (2018), which originated from an independent study assignment to design a new board game map of Canada for the popular map game Ticket to Ride™. Matyas et al. (2008) describe how the design of the LBG CityExplorer was inspired by Carcassonne, a famous tile placement board game that uses modern game mechanisms. The CityExplorer adopted game rule features from Carcassonne, such as placing tokens on predefined categories of locations not known in advance. This highlights a direct link between a prominent modern board game and the design of a geogame.

In essence, the literature demonstrates that the term "geogame" has a broader scope than "location-based games." Geogames are defined as games that use or are mediated by geoinformation technology, with "geo" referencing "land" or "Earth." This genre includes games that heavily rely on geospatial data for their core mechanics, incorporating elements such as modelling, visualization, and simulation of real-world processes. The term can also apply to online games that utilize geographical information without requiring physical interaction from players. This key distinction allows for the inclusion of games where physical movement is not a prerequisite. Consequently, while all LBGs can be considered geogames, the latter term represents a wider genre that does not necessarily require real-world player movement. However, the consulted literature does not clarify if analogue games such as modern board games can be considered geogames.

4.2. The "Geo" Component in Modern Board Games

Thirty games emerged after applying the exclusion criteria in the sample collected from BGG. Although the sample supported the identification of games with spatial or geographical-related systems or contexts, we need to analyse each game in detail to find specific patterns. Only seven games use realistic and similar maps associated with game boards. All others use simplification, either dividing the spatial units into hexagons (17) or establishing relationships between the elements with a network/relationships of points and arcs (7) and a minority, dividing the maps into limited regions/zones (4). The scale elements express considerable variation. Independent of using hexagons, networks/relationships, or zones, there are games representing galaxies (3), continents (6), countries and regions (13), worlds (3), and facility/building/land plots (5). Fifteen games directly include natural and physical resources for the players to manage in their game economy and mechanical system. Considering other human geographic dimensions, 13 games identify human economic and social development as part of the game mechanical system. Other elements, like climate effects, are presented in six games.

In the game sample, we realized that most games rely on representing a territory, even those in categories like Environmental, Exploration, and Travel. The exception is Arkham Horror (Charlie et al., 1987), a card game with no clear physical world representation. All others represent territory, connections, and relationships between locations with distorted scales. In the case of Lost Ruis of Arnak (Elwen & Mín, 2020), the locations are only defined by their distance to the shore and the transportation you need to get there (representing accessibility). One of the standard ways to mimic other dimensions such as climate-related topics is the use of track bars. In Terraforming Mars, players play cards that allow them to modify the planet, adding and removing hexagon tiles and collecting resources, which then are tracked in bars representing the temperature, oxygen level and availability of liquid water (available ocean tiles). Terraforming Mars (Fryxelius, 2016) is an example of the complexity of a world and its geographical manifestations and elements resulting from the combination of different game mechanisms that complement the world map, demonstrating one of the typical manifestations of modern board games where the designers combine sets of mechanisms to simulate parts of reality (Engelstein & Shalev, 2019).

In a conventional geogame, players travel to a real location, motivated by the digital game system. In these analogue games, players can travel into real or imaginary territories, e.g., Tolkien's Middle Earth which is represented in War of the Ring (Di Meglio et al., 2011). The game represents a geographical world where players can move by activating game mechanisms. There are many different ways in which this world can be represented. Dividing it into spatial units is the most common way (hexagons, zones, points). These units can have characteristics like resources, events, or size. They can be defined to allow additive elements in an easy and mechanical/mathematical way (hexagons) or divided to represent geographical entities, assuming different shapes. These mountains, rivers, oceans and other entities can delimit these zones. Some games use maps and establish a network/relational system between the zones (areas or points with individual information) in which they divide the territory. Barriers and easier connections allow asymmetric relationships and interconnections that better simulate territories. For example, the river crossings and the natural constraints that make transport hard, like mountains, deserts or others. Popular games like Pandemic Legacy (Daviau & Leacock, 2015) use this extensively (Figure 4).

Figure 4. Network/relationship map (points and arcs) in Pandemic Legacy: Season 1. Source: Dicebreaker (https://www.dicebreaker.com/games/pandemic-legacy-season-1).

Depending on the complexity, the spatial units, either geographically adapted to be regular forms like hexagons or just points and zones connected in a network of arcs, can include extensive information. This information can be printed in elements like hexagon cardboard tiles or coded in side tables/tracks and maps, which allow quantifying the system's dynamics as a playable model (Figure 5). In a way, players are transported to this analogue world if they are immersed in the game. This effect has been described as the magic circle, where time and space change when players are engaged (Huizinga, 2014; Salen & Zimmerman, 2004). In this sense, we argue that modern board games with spatial units and systems are geogames, allowing players to interact with worlds similarly to those games created with real-world data. We are not suggesting that these experiences are the same as going into an actual location. However, it offers a more effortless and cost-effective way to explore geographical content using readily accessible materials, making the potential of geogames easily available to schools and low-income communities.

Figure 5. Spatial hexagon representation of a territory and the track of temperature in Terraforming Mars. Source: Fryxgames (https://fryxgames.se/product/terraforming-mars).

4.3. From Location-Based and Geospatial-Based Games to Imaginative Spaces in Geogames and Modern Board Games

Revisiting the book *Geogames and Geoplay* and exploring beyond the bibliometric analysis sample, various chapters discuss the expansion of the concept of real spaces within games. In chapter 2, Ahlqvist et al.

(2018, p. 26) present the concept of GIS-MOG and distinguish space between the real world and the game world, where game elements and items can "only exist in the game world and do not correspond to real world features." In the meantime, they refer to the combination of real-world and game-world elements as a "hybrid space" game pattern. This involves mixing physical and virtual interactions, where cyberspace is extended to geographic places and objects, and vice-versa. This blending creates a mediated space that exists beyond the strictly physical (Scheider & Kiefer, 2018).

The idea of simulations and abstracted realities in geogames is viewed as "instantiations of real-world systems, abstracted to some thematic focus," capable of providing insights into that system's behaviour (Ahlqvist & Schlieder, 2018, p. 14). Games can provide a "safe space" in which players can experiment with "different realities, interventions, and changes in the represented space" (Poplin & Vemuri, 2018, p. 86). This highlights the use of games to create simulated environments or alternate scenarios based on real geography while still allowing for imaginative manipulation.

Urban planning games, for example, occur in a "virtual space" where different solutions can be simulated. When dealing with LBGs, these are described as having different conceptual layers, including the "ludic" (game rules, mechanics) and "narrative" (scripts, story) layers, which deploy or implement concepts of the underlying "environmental" layer (Scheider & Kiefer, 2018). A building in the environment (environmental layer) can "play the role of a castle on the narrative layer" and be a place for resources (ludic layer; Scheider & Kiefer, 2018, p. 135). Game localization involves the design of a "spatial narrative," where roles or story points are fixed to locations, objects, or activities in environmental space.

Geogames can "defamiliarize" players with places, breaking routines and encouraging them to "look at the world anew" (Mathews & Holden, 2018, p. 168). Narrative and role-based play help players "experience and see familiar places in new ways" and "re-inhabit the world, often in a playful manner" (Mathews & Holden, 2018, p. 168). Taking on roles (e.g., environmental historian or wildlife ecologist) allows players to view a real place from different perspectives, supported by virtual characters and data.

The idea of Places of Gameplay is presented by Schlieder et al. (2018) to describe how some LBGs, like certain live-action role-playing games, create imaginative spaces such as a "magic forest, which may have little resemblance with features of the geographic environment" (p. 113). This is contrasted with serious games that link players to existing places; here, the concept of creating game spaces with imaginative characteristics is present.

As we have seen, modern board games are delivering geo-spatial experiences through low-tech and simplified materials. The limitations of using boards, cards, tokens, and physical pieces rely on the players to fill in the gaps and build imaginary spaces (Rogerson & Gibbs, 2018). However, this is not a pure sandbox experience. Even the most minimalist narrative games propose a game framework to support the narrative development and achieve coherence. Traditional tabletop narrative games tend to depend on a game master to set the narrative, while modern board games rely more on the mechanical system. In either case, supported by the game master or the game system itself, players enter these imaginary spaces, making decisions that change the game world. To use these design characteristics to build geogames, serious games, or other game-based approaches beyond pure entertainment, it is necessary to master these game design elements.

Through our sample retrieved from BGG, it is possible to identify some patterns. More than a ludemic approach, we identified a process. One of the first steps is to represent the world, usually with a map. The most common approach is to divide it into spatial units. Hexagons are the best solution to model multidirectional distances, since the centres between adjacent units are all equidistant. These hexagonal grids are used to model adjacency effects and travel distances in all directions. However, non-scale maps are standard, representing points, arcs, and regions when asymmetric spatial relationships are a better fit.

After representing space, there is a need to track the characteristics of the spatial units, usually by staking pieces over the spatial units or using track bars. Each location can have special characteristics to complement the previous elements that might require text. The overall world characteristics can be represented on side boards, not directly on the spatial units' material and graphical representation. Some of the games introduce the travel system. In these cases, there is a need to define a mechanism that controls the movement cost and directions, considering the narrative of what entities are moving, by what means, and considering the territory's characteristics, even when arcs and other logical connections between regions abstract them.

Figure 6 presents a three-step simplified version of this process of defining a world in an analogue territory, following modern board game design trends to support the imaginary spaces and narratives. Since geogames tend to propose traveling through the virtual world, we specifically define the player interactions aiming for movement. In step 1, we can specify if we are using hexagons or any other geometrical shape grid, or a more realistic and scale-relatable map with regions, points, and arcs. Besides the shape, we need to define the relationships between the spatial units, like adjacency and connections. In step 2, we need to define how to track the information of the spatial units as isolated units or groups, according to their characteristics. This might require modelling the logic connections between the spatial units or the overall world characteristics. A common technique is to use progress tracks or the placement of different tokens and objects that represent various things over the spatial units and their relationships. Step 3 is concerned with how players interact with the game world and each other, in the case of a multiplayer game. Movement mechanisms tend to be combined with resource management and time effects. All these mechanisms can be consulted in the latest work by Engelstein and Shalev (2019), *Building Blocks of Tabletop Game Design: An Encyclopedia of Mechanisms*.

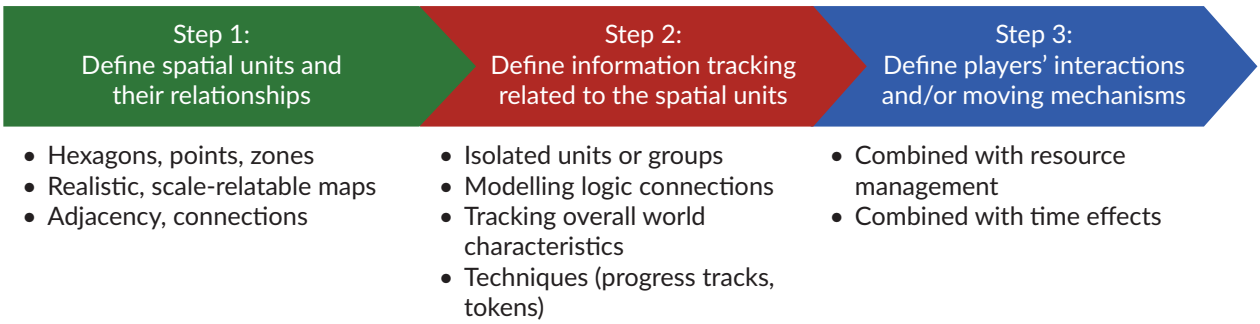

Figure 6. Summarized process of defining a world based on territorial and spatial representation in modern board games.

To illustrate the process outlined in Figure 6, we apply the guidelines from Sousa (2025) for spatial and urban planning analogue games. This framework details game mechanisms and their interpretations, which align with our proposal. Figure 7 offers a complementary visual scheme for future research. We use Suburbia, Scythe, and Terraforming Mars as examples. All three use hexagons to represent territory, but with varying

scales. The functional representation in Suburbia contrasts with the scaled, planetary representation in Terraforming Mars, exemplifying step 1 of Figure 6. All three games also use icons to supplement the hexagons, establishing adjacency and connection effects (step 2). The hexagons act as spatial units that set the framework for movement, area control, and occupation. Additionally, all games use integrated tracks to monitor urban, spatial, and environmental indicators, while game components simulate economic development and player interactions (step 3).

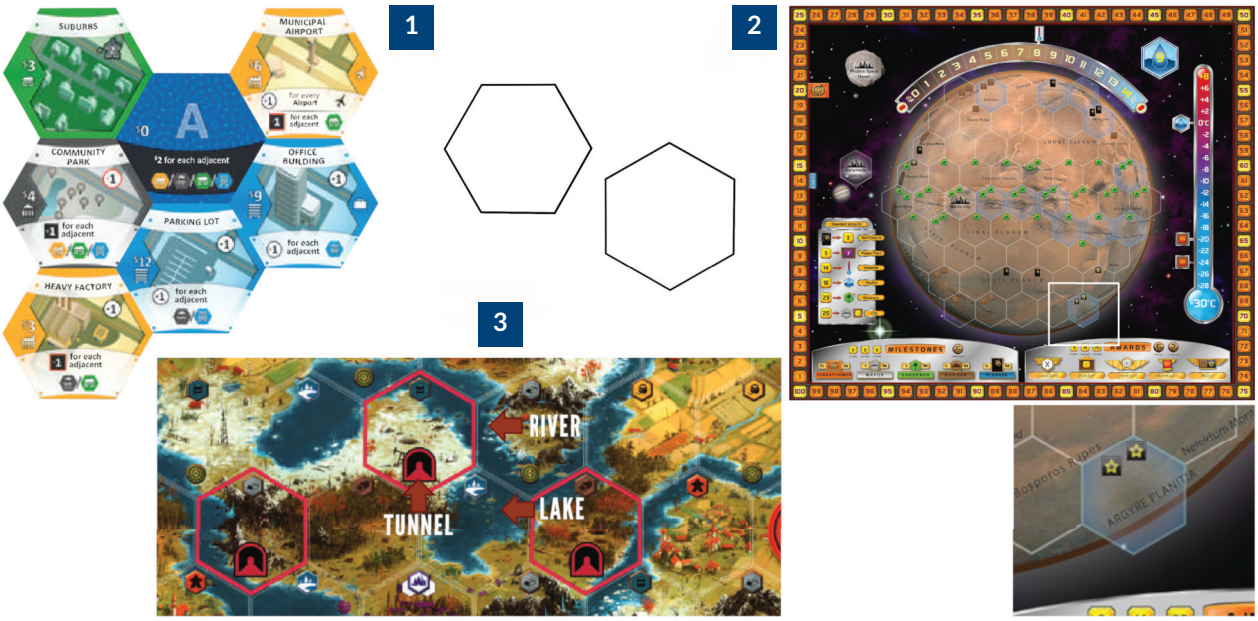

Figure 7. Screenshots from the board game rulebooks (available at the publishers' website): (1) Suburbia, (2) Scythe, (3) Terraforming Mars.

5. Closing Remarks

Our quest to explore geogames from an analogue perspective led us to explore the trend of modern board gaming and how they have changed how spatial models are represented. Besides the physical models, the ability to enter an imaginary world, even without a graphical representation, is a powerful experience. Tabletop narrative games have been delivering these experiences since the 1970s. Modern board games in the last two decades have mixed the graphical representations with narrative development in new ways. Having examined some of these games and their characteristics, it is clear that many incorporate geographic and spatial elements. We acknowledge that a vast body of literature exists on serious games and simulations that are highly relevant to geogames, including foundational work from the 1970s and extensive research published in journals like *Simulation & Gaming*. This study's primary focus on commercial entertainment board games with geospatial elements, while a deliberate choice to narrow our scope, represents a limitation that future research could address by including this broader body of literature. Yet, despite acknowledging the limitations of our analysed sample—including the subjectivity in keyword selection and the potential for indexing inaccuracies—the field of geogame research continues to neglect modern board games.

We argue that modern board games are geogames in the sense that they create a virtual spatial world where players can travel, combining their imagination with a solid game mechanical system that helps track and

build a spatial context that supports interaction. These games simulate complex geographical phenomena and represent spatial relationships using abstract systems like hexagonal grids, networks, or zones, which players navigate through meaningful decisions. Central to this experience is the player's imagination, which works in concert with the game's physical components to build an immersive "magic circle"—a safe space for experimentation and learning. This process not only facilitates a deeper understanding of spatial dynamics but also leverages the inherent social nature of board games to foster collaborative problem-solving and offer novel perspectives on geographical issues. Consequently, their accessibility and cost-effectiveness make modern board games a potent and inclusive tool for geographical education and engagement in diverse settings. We systematized these findings in a summarized process (Figure 6). However, we recognized that applying these approaches might not be as simple as it seems. Despite the low-tech ease of building these games from a material perspective, modern board games require considerable game design knowledge to be effective.

The inherent accessibility, low-tech requirements, and cost-effectiveness of modern board games present compelling advantages for educational and community-based applications, particularly in contexts with limited technological resources. Their ability to transport players into "magic circles" of imagined spaces, guided by tangible components and clear rules, offers a powerful and engaging medium for exploring geographical concepts. This study strongly advocates for the inclusion of modern board games within the broader scope of geogame research and design. Recognizing the "design revolution" within the board gaming world and the increasing sophistication of their spatial representation and mechanical systems opens new avenues for understanding spatial reasoning, simulating complex environments, and fostering engagement with geographical content in a tangible and imaginative way. However, we also acknowledge that effectively leveraging the potential of modern board games for serious applications requires a deep understanding of their intricate design principles. Mastering this design knowledge is crucial for harnessing the power of analogue geogames in education, community engagement, and other game-based interventions, ultimately enriching the field of geogames with a wealth of under-explored possibilities.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

Due to the nature of the research, data sharing is not applicable to this article.

LLMs Disclosure

The authors used Google NotebookLM to assist with grammar checking and the processing of literature metadata for the bibliometric analysis conducted with VOSviewer.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

References

Abt, C. C. (1987). *Serious games*. University Press of America.

Adanalı, R. (2021). How geogames can support geographical education? *Review of International Geographical Education (RIGEO)*, *11*(1), 215–235. https://doi.org/10.33403/rigeo.855550

Ahlqvist, O., Loffing, T., Ramanathan, J., & Kocher, A. (2012). Geospatial human-environment simulation through integration of massive multiplayer online games and geographic information systems. *Transactions in GIS*, *16*(3), 331–350.

Ahlqvist, O., & Schlieder, C. (Eds.). (2018). *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (1st ed.). Springer. https://doi.org/10.1007/978-3-319-22774-0

Archambault, E., Campbell, D., Gingras, Y., & Larivière, V. (2009). Comparing bibliometric statistics obtained from the Web of Science and Scopus. *Journal of the American Society for Information Science and Technology*, *60*(7), 1320–1326.

Arnaudo, M. (2018). *Storytelling in the modern board game: Narrative trends from the late 1960s to today*. McFarland.

Arnaudo, M. (2023). *The tabletop revolution: Gaming reimagined in the 21st century*. McFarland.

Bartoschek, T., Schwering, A., Li, R., Münzer, S., & Carlos, V. (2018). OriGami: A mobile geogame for spatial literacy. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 37–62). Springer. https://doi.org/10.1007/978-3-319-22774-0_3

BoardGameGeek. (n.d.). *BoardGameGeek*. https://boardgamegeek.com/wiki/page/BoardGameGeek

Booth, P. (2021). *Board games as media*. Bloomsbury Publishing.

Charlie, K., Launius, R., Petersen, S., & Willis, L. (1987). *Arkham horror* [Board game]. Chaosium.

Cramer, F. (2015). What is 'post-digital'? In D. M. Berry & M. Dieter (Ed.), *Postdigital aesthetics: Art, computation and design* (pp. 12–26). Palgrave Macmillan. https://doi.org/10.1057/9781137437204_2

Daviau, R., & Leacock, M. (2015). *Pandemic legacy: Season 1* [Board game]. Z-Man Games.

Di Meglio, R., Maggi, M., & Nepitello, F. (2011). *War of the Ring: Second edition* [Board game]. Ares Games.

Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*, 523–538.

Elwen, & Mín. (2020). *Lost ruins of Arnak* [Board game]. Czech Games Edition.

Engelstein, G., & Shalev, I. (2019). *Building blocks of tabletop game design: An encyclopedia of mechanisms* (2nd ed.). CRC Press. https://doi.org/10.1201/9780429430701

Fryxelius, J. (2016). *Terraforming Mars* [Board game]. FryxGames.

Ham, E. (2015). *Tabletop game design for video game designers*. CRC Press.

Hocking, C. (2009). Ludonarrative dissonance in Bioshock: The problem of what the game is about. In D. Davidson (Ed.), *Well played 1.0: Video games, value and meaning* (pp. 114–117). ETC Press.

Huizinga, J. (2014). *Homo ludens*. Routledge.

Lhowe, C. (2018). The revenge of analog: Real things and why they matter. *Design and Culture*, *10*(2), 231–232. https://doi.org/10.1080/17547075.2018.1468716

Mathews, J., & Holden, C. (2018). The design and play of geogames as place-based education. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 161–176). Springer. https://doi.org/10.1007/978-3-319-22774-0_8

Matyas, S., Matyas, C., Schlieder, C., & Kiefer, P. (2008). CityExplorer—A geogame extending the magic

circle. In H.-G. Hegering (Ed.), *Informatik 2008: Beherrschbare Systeme—dank Informatik* (pp. 503–504). Gesellschaft für Informatik.

Mizer, N. J. (2019). *Tabletop role-playing games and the experience of imagined worlds* (Vol. 3). Palgrave Macmillan.

Mota, G. S., Carrasco, T. S., dos Santos, J. J., & Rodrigues, C. (2025). Bibliometric overview of the systems approach in geomorphology production: Journals Q1 and Q2, Earth-Surface Processes (SJR). *Revista Brasileira de Geomorfologia*, *26*(1), 1–20.

Nand, A. (2021). *110,000 games in a chart*. BoardGameGeek. https://boardgamegeek.com/blogpost/116720/110000-games-chart

Nguyen, D., Kritz, J., Gaina, R. D., & Perez-Liebana, D. (2024). Unveiling modern board games: An ML-based approach to BoardGameGeek data analysis. In *2024 IEEE Conference on Games (CoG)* (pp. 1–4). IEEE.

Nikolaidou, D. (2018). The evolution of fantastical storyworlds: A study of tabletop role-playing settings. *Ex-centric Narratives: Journal of Anglophone Literature, Culture and Media*, *1*(2), 218–229.

Oppermann, L., Schaal, S., Eisenhardt, M., Brosda, C., Müller, H., & Bartsch, S. (2017). Move, interact, learn, eat: A toolbox for educational location-based games. In *International Conference on Advances in Computer Entertainment* (pp. 774–794). Springer.

Poplin, A., & Vemuri, K. (2018). Spatial game for negotiations and consensus building in urban planning: YouPlaceIt! In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 63–90). Springer. https://doi.org/10.1007/978-3-319-22774-0_4

Rogerson, M. J., & Gibbs, M. (2018). Finding time for tabletop: Board game play and parenting. *Games and Culture*, *13*(3), 280–300.

Rogerson, M. J., Gibbs, M., & Smith, W. (2016). "I love all the bits": The materiality of boardgames. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 3956–3969). ACM. https://doi.org/10.1145/2858036.2858433

Rogerson, M. J., Gibbs, M., & Smith, W. (2020). More than the sum of their bits: Understanding the gameboard and components. In D. Brown & E. MacCallum-Stewart (Eds.), *Rerolling boardgames: Essays on themes, systems, experiences and ideologies* (pp. 106–135). McFarland.

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. MIT Press. https://books.google.pt/books?id=UM-xyczrZuQC

Samarasinghe, D., Barlow, M., Lakshika, E., Lynar, T., Moustafa, N., Townsend, T., & Turnbull, B. (2021). A data driven review of board game design and interactions of their mechanics. *IEEE Access*, *9*, 114051—114069. https://doi.org/10.1109/ACCESS.2021.3103198

Scheider, S., & Kiefer, P. (2018). (Re-)localization of location-based games. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 131–159). Springer. https://doi.org/10.1007/978-3-319-22774-0_7

Schlieder, C., Kiefer, P., & Matyas, S. (2006). Geogames: Designing location-based games from classic board games. *IEEE Intelligent Systems*, *21*(5), 40–46.

Schlieder, C., Kremer, D., & Heinz, T. (2018). Teaching geogame design: Game relocation as a spatial analysis task. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 111–130). Springer. https://doi.org/10.1007/978-3-319-22774-0_6

Shipp, S. (2024). *Thematic integration in board game design*. CRC Press.

Sousa, M. (2023a). Finding ludemes in modern board games: Analyzing the top number one games of Board Game Geek. *Board Game Studies Journal*, *17*(1), 205–229.

Sousa, M. (2023b). Modeling urban spaces with cubes: Building analogue serious games for collaborative planning. *International Journal of Film and Media Arts*, *8*(1), 8–35.

Sousa, M. (2024). Moving pieces and allocating budget together: A framework for using analog serious games in sustainable collaborative planning. *Sustainability*, *16*(19). https://doi.org/10.3390/su16198348

Sousa, M. (2025). Finding mechanisms to build analog games for spatial planning and city building. In *2025 IEEE Conference on Games (CoG)* (pp. 1–8). IEEE.

Sousa, M., Antunes, A. P., Pinto, N., & Zagalo, N. (2022a). Fast serious analogue games in planning: The role of non-player participants. *Simulation & Gaming*, *53*(2), 175–193. https://doi.org/10.1177/10468781211073645

Sousa, M., Antunes, A. P., Pinto, N., & Zagalo, N. (2022b). Serious games in spatial planning: Strengths, limitations and support frameworks. *International Journal of Serious Games*, *9*(2), 115–133. https://doi.org/10.17083/ijsg.v9i2.510

Sousa, M., & Bernardo, E. (2019). Back in the game: Modern board games. In N. Zagalo, A. I. Veloso, L. Costa, & Ó. Mealha (Eds.), *Videogame sciences and arts* (pp. 72–85). Springer. https://doi.org/10.1007/978-3-030-37983-4_6

Sousa, M., Oliveira, A. P., Cardoso, P., Zagalo, N., & Vairinhos, M. (2021). Defining the mechanisms for engagement design protocol towards the development of analogue and hybrid serious games: Learning from FlavourGame. In *Joint International Conference on Serious Games* (pp. 31–46). Springer.

Sousa, M., Oliveira, P., & Zagalo, N. (2021). Mechanics or mechanisms: Defining differences in analog games to support game design. In *IEEE Conference on Games 2021* (pp. 1–8). IEEE.

technavio. (2022). *Board games market to grow by USD 2.56 bn from 2020 to 2025: Rapid improvements in content & gameplay to boost market growth* [Press release]. PR Newswire. https://www.prnewswire.com/news-releases/board-games-market-to-grow-by-usd-2-56-bn-from-2020-to-2025-rapid-improvements-in-content--gameplay-to-boost-market-growth--17000-technavio-reports-301456304.html

Trammell, A. (2023). *The privilege of play: A history of hobby games, race, and geek culture*. New York University Press.

Woods, S. (2012). *Eurogames: The design, culture and play of modern European board games*. McFarland.

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429–472.

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Geogames' Environments as Hosts for the Collective Expression of Emotions in Urban Space

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Abstract

Urban space is perceived by users on many different dimensions. One important aspect of spatial perception is the emotions that users associate with it. Mapping the emotions associated with specific spaces can make an important contribution to urban design processes. The conclusions drawn from their graphic representation can form the basis for specific spatial actions, leading to the creation of places that users can and want to become attached to. Geogames, which combine high usability with a pleasant and engaging form of interaction, are an effective tool for supporting processes related to the expression of spatial needs and opinions of inhabitants. There is a noticeable lack of easily accessible and engaging tools for mapping people's emotions in urban space. This article describes a case study in which the game Minecraft was used as a tool for aggregating data on emotions associated with a given space. Based on GIS data, a digital model of a university campus was created in the game, where the study participants placed graphic representations of their emotions. An important issue addressed in this work was whether and how multiplayer and single-player modes can influence the expression of different emotions. The map of participants' emotions in multiplayer mode was a spatial sequence, while in single-player mode, it was a series of scattered points. Multiplayer mode was characterised by a greater number of negative emotions, but this could have been caused by the mutual influence of the other participants. The information collected provides important insights into the subjective perception of space, which can be used for further planning activities. A tool was created, the availability of which facilitates the repeatability of the experiment and thus enables further research.

Keywords

emotion mapping; geogames; place attachment; spatial planning; urban space

1. Introduction

The perception of urban space is a multifaceted phenomenon, involving diverse dimensions and levels. In addition to the most basic conjunctural dimension, which allows for an immediate evaluation of the attractiveness of space (Brielmann et al., 2022), other sensory-based channels for reading spatial information can be distinguished (de Wit, 2023). The psychological layer is also extremely important, which, although strongly connected with the visual dimension, reaches much deeper, shaping a sense of security and well-being (Dai et al., 2021). Also significant in the psychological dimension are the emotions that a space evokes in users. Methods based on heart rate variability (HRV) readings make it possible to measure emotional responses to given spatial conditions (Paül i Agustí et al., 2019). Whether and how we respond to space and the emotions it evokes in us can provide important informational input for further planning efforts involving the search for patterns and regularities that underpin specific spatial interventions.

Mapping emotions in urban spaces involves a variety of different approaches and methods spanning from subjective surveys through objective wearable-based metrics up to crowd sourcing based on social media platforms. Subjective methods focus on the user's impression of the space. There is a number of different tools, such as surveys and interviews (Grazuleviciute-Vileniske et al., 2025) or feeling maps (Weinreb & Rofè, 2013) that allow for estimating how users feel about a given place. Objective methods work partially beyond consciousness and focus on biochemical microreactions of the human body. There are methods involving biosensors delivering information about physiological reactions connected with GPS data (Resch et al., 2015) as well as affective systems for researching emotions in public spaces for urban planning, providing data about emotional impressions of space in time (Kaklauskas et al., 2021). Going further, social media and georeferencing and geotagging functionalities (Grazuleviciute-Vileniske et al., 2025) and a sentiment layer stitched into posts, comments, and reactions, allow us to draw significant conclusions on how different places are perceived by users.

Currently, management, development, and education related to cities and urban areas involve the use of various digital tools and systems. Among the tools used are video games or elements of video games that support these processes. These are known as serious games. Their purpose is not only entertainment but also to illustrate and simulate real-life problems and situations occurring in built environments (Beattie et al., 2020).

A very specific kind of serious game used in urban processes is geogames. Their definition has significantly expanded over the years. First mentioned in 2005 as games involving real-life locations (Schlieder et al., 2005), geogames moved towards integrating GIS that started providing a basis for playful representations, which were considered to have GIS-specific high realism of depiction (Henry, 2018). As geogames refer to real places (Adanalı, 2021), they focus on Earth and its parts (Poplin et al., 2022). Along with the development of open repositories such as OpenStreetMap, GIS data were utilised in geogames more and more widely, resulting in numerous productions (Antoniou & Schlieder, 2018). Nowadays, geogames take various forms, ranging from modified desktop products to mobile location-based game apps.

Geogames, such as a modified version of the Minecraft game, can be a valuable medium that makes the urban planning process engaging and inspiring for children and youth. As digital collaboration platforms enhance co-creation and raise awareness of the spatial context of everyday life, they generate agency in

shaping the future of urban space (Poplin et al., 2022). Combined with analogue games, Minecraft also provides potential in SDG-related green education that, through a scoring system, allows the role of green structures in urban design to be explored (Egusa et al., 2025). What is more, thanks to projects such as LillyPad, various states of environmental danger can be simulated in order to train spatial skills and raise natural disaster resilience (Tomaszewski et al., 2020). Besides educational gains, digital geogames are a significant element enhancing civic engagement in urban planning. By facilitating local community involvement, geogames may be tools used to improve quality of life and knowledge-building (Romano & Rogora, 2023). As a creative medium, these games are both created from scratch, such as B3 – Design your Marketplace!, or, a ready-made, adapted product like the aforementioned Minecraft delivers the potential of turning regular citizens into designers. Therefore, people can express their needs using the digital space of the game as a canvas for acts of creation (Delaney, 2022; Poplin, 2014). Geogames are also recognised as platforms supporting decision-making processes by delivering simulated scenarios that help improve understanding of the complexity of city structure (Adrienne & Nora, 2024). What is more, digital games that involve GIS data can serve as platforms for building spatial consensus among various stakeholders involved in the decision-making process (Poplin & Vemuri, 2018).

Even though both topics—emotional mapping and the use of geogames in urban-related processes—are important and dynamically developing research and practice fields, there is a significant lack of examples exploring how geogames can contribute to the process of investigating the emotions of people in urban space. Utilising GIS data in a game environment and then converting game output back into usable GIS data provides an interesting area of exploration and research. Games like Minecraft have proven flexibility in working with GIS data as well as being an attractive medium, especially for younger users. What is more, it provides single-player and multiplayer modes. Single players interact with the game world alone, encountering only prescripted in-game characters. In multiplayer mode, the user plays with other human gamers in the same environment and time, observing, affecting, and interacting with their actions.

The main goal of this study is to explore the potential of the Minecraft game as a tool for aggregating data about users' emotions in urban space, including the possibilities of converting game output into utilisable GIS data to be used by stakeholders such as local authorities and planners in the decision-making process. As the Minecraft game provides both single-player and multiplayer modes that allow individual and collective interactions with the game world, we consider the question of whether and how the game outcome may differ. Is there any bias for specific types of emotions? What emotions are more likely to be expressed when a game is played alone or with other players? Answering these questions may be helpful in determining which mode is preferable in implementing the presented method in practice. The article has the following structure: Firstly, a literature study is presented that outlines the current state of knowledge in the fields of geogames and emotions in urban space. The study method is shown with the process overview, data collection, and characteristics of participants. Results are then presented and discussed, including the context of other research. The article ends with a summary outlining the conclusions of the study and potential implementation in urban practice.

2. Literature Study

2.1. Geogames

Geogames are interactive applications that can be used for both educational and participatory purposes. They are location-based games with clearly defined temporal and spatial boundaries, whose activities are set in a specific geographic space (Heinz & Schlieder, 2019). Initially, games of this type were designed primarily for intense outdoor physical activity (Hall, 2010). Their advantage over traditional consoles was the player's ability to move freely in real space (Schlieder et al., 2005). In the beginning, they were based on board game mechanics, as exemplified by the GeoTicTacToe game (Schlieder et al., 2005). This feature—the ability to play outdoors, based on real-world locations—opened new perspectives, especially in an educational context.

Today's widespread use of smartphones as a platform for geolocation gaming creates unique opportunities, both in terms of in-game task design and location-based learning (Schaal et al., 2018). This allows us to augment reality with digital elements, which is the case in popular games such as Pokémon Go and Ingress. The point systems used in them can be an additional motivator for players to travel greater distances and extend gameplay time (Westerholt et al., 2020). Allowing the player to make choices during gameplay increases learning satisfaction (Kremer et al., 2013). However, it is important to be careful about using too much multimedia, which can contribute to cognitive load (Brosda et al., 2016).

Geogames are most often based on seek-and-find mechanics, while they rarely utilise simulation. Its use can enhance the enjoyment of gameplay, as well as make the issues raised within the game appear more real, thereby supporting learning in the environmental field. Simulation elements must not last too long, as this can reduce player engagement, with even a very simplified simulation still having a positive impact on gameplay (Schneider et al., 2017, 2020).

The use of novel technologies in educational contexts can be highly motivating and engaging for youth (Poplin et al., 2022). Incorporating familiar mechanics and environments from popular games, such as Minecraft, can further enhance youth interest by encouraging them to play, engage, and participate in the urban planning process (Andrade et al., 2020; Poplin et al., 2022). This type of activity can also contribute to the development of spatial thinking skills and geographic inquiry (Adanalı, 2021). Furthermore, the presence of educational elements in the games in no way diminishes the enjoyment of the game (Kiefer et al., 2006). The enjoyment and immersion described here resonate with the concept of flow—a state of optimal experience that arises when players feel both challenged and in control, particularly relevant in spatially oriented, participatory game environments (Aarseth & Günzel, 2019). Minecraft stands out as a unique platform for geogames due to its popularity and its ability to enable the process of co-creating space in an inclusive and cooperative manner, especially when numerous online users are involved. Its use can significantly improve the efficiency and quality of decision-making in urban planning and design (Delaney, 2022). At the primary school level, there is still a lack of practical tools for teaching spatial skills to children and young people. This problem is recognised by Bartoschek et al. (2018), while pointing out that there are technologies that can be effectively applied to educational outdoor games, an example of which is the OriGami game.

To fully reach the educational potential of games, their use should go beyond traditional didactic approaches. Meanwhile, teachers and designers often treat geolocation games merely as a tool for transferring knowledge, rather than creating a space for inquisitive, place-based learning (Mathews & Holden, 2018).

This problem also occurs at the university level, where most courses on GIS are rigid and straightforward in character. In this case, the use of gamification elements can improve the way the course is structured, even if there are no entertainment elements involved (DeMers, 2018). Using digital tools based on GIS and agent-based modelling (ABM) to engage young people in local spatial planning enables them to combine their personal experiences with systems thinking. This can lead to more accurate decision-making at both the neighbourhood and city-wide scale (Poplin et al., 2017).

Geogames use simplified models of real systems, focusing on selected issues or topics. Despite this simplification—or perhaps because of it—they allow a better understanding of the behaviour of complex systems in the specific context of the game (Ahlqvist & Schlieder, 2018). Although they do not fully capture the realities of the world, they can contribute to a deeper understanding of the interdependence between human and natural systems (Ahlqvist et al., 2018). An example of this approach is the Lily Pad project by Tomaszewski et al. (2020), in which a combination of serious games, GIS, spatial thinking, and disaster resilience knowledge can lead to increased adaptive capacity in communities. As a result, it can even contribute to saving lives when an actual disaster occurs.

Another example is The Game of Peat by Aditya and Laksono (2018), which aims to raise environmental awareness among peatland residents. At the same time, this game can be used to collect field data that will allow decision-makers to more effectively protect and manage these valuable ecosystems.

2.2. Emotions in Urban Space

Emotions are a key part of geogame users' experience, influencing their engagement, immersion, and the educational value of these applications. As Mauss et al. (2005) point out, emotions are multi-component responses, involving coordinated changes in subjective feeling, motor expression, and physiology. In the context of geographic games, which by definition combine physical and virtual space, it is crucial to understand the hierarchical organisation of affect, encompassing affective traits, moods, and emotions, where higher levels organizationally influence lower levels through threshold modulation. The distinction between emotions—brief, intense responses to specific environmental situations—and moods, which last significantly longer and may occur without apparent reason, is important for interpreting participants' affective reactions in games, as moods can modulate emotion elicitation thresholds, influencing their interpretation (Rosenberg, 1998). Emotional reactions in games are largely the result of subjective cognitive appraisal processes, in which players evaluate the personal relevance and adaptive implications of in-game events, which can lead to paradoxical emotions where seemingly negative actions evoke positive feelings. These reactions encompass a broad spectrum of experiences—from basic states such as fear, joy, or disgust, through higher-order forms like nostalgia or guilt, to complex mixed states in which different valences are simultaneously activated (Hemenover & Bowman, 2018). The emotions experienced by the player can influence their behaviour. The player's choices leading to immoral behaviour in the virtual world, if associated with feelings of guilt, can lead to an increase in sensitivity to moral violations (Grizzard et al., 2014).

Emotions significantly influence cognitive functions, including attention, memory storage and retrieval, as well as decision-making processes (Wilkinson, 2013). As such, they play an important role in shaping interactive experiences. These emotional states initiate motivational processes that can translate into action

depending on the characteristics of the emotional state and level of arousal (de Byl, 2015). In the context of educational games, both frustration and boredom can considerably weaken learning motivation. Simultaneously, increased emotional activation may enhance motivation and concentration during the learning process, regardless of whether this activation stems from enjoyment of the activity or concern about potential failure (Wilkinson, 2013).

While the use of real-time emotion detection in gaming can contribute to controlling the player's experience (Granato et al., 2020), similar technologies for recognising emotional patterns can be applied in a broader urban context, where residents' emotions can be mapped and used in spatial planning processes. As Li et al. (2016) point out, finding an objective and accurate method for assessing people's emotional responses to urban spaces is of fundamental importance for urban design practices and related policies. If the composition between space and user is not successfully achieved, a sense of unease may arise, which can escalate into anger or fear (Ansaloni & Tedeschi, 2016).

One method of mapping emotions is to use social media with geolocation. The data collected in this way can be used to support urban planning processes. An example of this approach is the study by Kovacs-Gyori et al. (2018), which analysed emotion mapping during the 2012 Olympic Games in London by utilising geotagged tweets, demonstrating the broad applicability of Twitter data analysis for urban planning in the context of large-scale planned events. Similarly, Kong et al. (2022) used an analysis of opinions published on social media concerning 99 parks in Beijing to support the assessment of the attractiveness and quality of various types of large-scale green areas. These strategies are complemented by the use of data collected by dedicated smartphone applications, which allow for the collection of subjective emotional declarations synchronised with the user's location (Neuner et al., 2025). Kołakowska et al. (2020) showed that smartphone sensors are a valuable source of information about users' emotions. Through the appropriate selection of sensors, the development of labelling protocols, and the design of features, it is possible to create practical applications for real-time emotion detection. Paül i Agustí et al. (2022) used HRV measurements for this purpose and then compared them with the participants' subjective assessments. A comprehensive integration of these approaches was proposed by Resch et al. (2015) by combining data from physiological sensors, mobile applications, and social media content analysis for multi-level mapping of emotions in urban environments, supporting the evaluation of urban projects and decision-making based on diverse sources of information about residents' well-being.

2.3. Playful Approaches in Urban Planning Besides Games

Several alternative approaches have been proposed to enhance the efficiency of spatial-planning processes. One method is the use of VR and AR technologies (Kavouras et al., 2025; Ng et al., 2024; Paraschivoiu et al., 2025). Game mechanics transferred to a non-gaming context, known as gamification (Deterding et al., 2011), have the potential to increase learning effectiveness (Dicheva et al., 2015). Badges and leaderboards increase motivation, while point collection encourages players to engage in more challenging tasks (Huang & Hew, 2015). However, it is essential to adjust the level of difficulty appropriately and to preserve the autonomy of participants in choosing their goals, as otherwise these elements may become demotivating (Abramovich et al., 2013; Sanmugam & Mohamed, 2020). Gamification can also serve as an effective communication tool in urban design. For example, Muehlhaus et al. (2023) showed that a mobile application incorporating game elements increased participants' motivation in a real-world planning project.

Incorporating playful elements into urban design can effectively engage and empower people without expert knowledge to actively co-create space. The use of a simple card game during workshops conducted by Huyghe et al. (2014) showed that a friendly and playful atmosphere encourages activity, promotes open exchange of ideas, and stimulates creativity, which ultimately translates into proposals for real solutions. Harriss (2010) found that using board games, narrative scenarios, and play-based prototypes within participatory sessions deepened engagement and led to more innovative, context-sensitive solutions. Applying card games in design can also be an effective tool in educating students, supporting a user-centred approach to urban space design (Mavros et al., 2022).

Location-based urban games and similar playful interventions foster more inclusive city design. Transforming existing infrastructure into a playground that encourages passers-by to interact, by utilising its natural potential, is the starting point for better design (Altarriba Bertran et al., 2022). An example of this approach is the workshop in Barcelona led by Hjorth and Lammes (2024), where field games were co-designed to sensitise participants to inequalities in the accessibility of urban space. Elements of play with the surrounding space can also be incorporated into the daily activities of both children and adults, which can inspire real architectural changes in residential spaces (Çetin Er & Özcan, 2024). Using playful elements in urban design, both to get the local community involved and to educate future and current designers, can really improve its effectiveness.

3. Materials and Methods

3.1. Process Overview

To achieve the stated research goal, a workshop was organised in which a group of participants navigated through a fragment of urban space recreated in the game Minecraft, based on GIS data. While Minecraft game mechanics are primarily based on placing box-like voxels, called blocks, of different types and materials (for example, grass, rock, wood, or glass), we have assigned specific types of blocks to certain emotions. Every block type in the game has an assigned ID number. The main aim of the participants was to place blocks with specific emotions assigned in places where these emotions are felt. The study took into account only outdoor areas. Participants were allowed to freely explore the environment. It aimed to provoke the natural course of movement that an individual could have in real space. There was no limit on the number of Minecraft blocks that could be placed.

For the study, Plutchik's wheel of emotions was used. Although it may raise some criticism due to its generality and superficiality, it was adequate for our study, which aims to create a method that may be commonly adapted for any type of user. At the same time, it remains more up-to-date than, e.g., Paul Ekman's basic emotion taxonomy. Figure 1 shows the Minecraft block types selected to represent specific emotions.

Figure 1. Emotions and Minecraft block types that represent them.

The process of the study consisted of the following steps:

1. Area selection: For this study, the area of Poznan University of Technology's Warta Campus was selected.
2. Generation and post-production of the Minecraft world: Using GIS data from various sources, the campus space was generated and then manually curated in the Minecraft game.
3. Recruitment of participants: Using local communication channels, participants were recruited among Poznan University of Technology students.
4. Kick-off meeting with participants: During the single kick-off meeting, participants were informed about the goal of the study, all tasks, and process elements were listed and explained.
5. Survey walks: Participants were asked to perform individual survey walks to gather impressions and reflections on the subject space.
6. Grouping the participants: Participants were divided into two groups. Members of the first group were playing single-player mode, while members of the second group were playing multiplayer mode.
7. Distribution of Minecraft world copies: Files containing a prepared world were distributed among single-player group members, and a multiplayer session was arranged.
8. Gameplay: All participants conducted a 1-hour gameplay session to fulfil the task related to placing blocks assigned to specific emotions.
9. Gathering modified worlds: Modified world files were gathered from participants.
10. Data extraction and mapping: Using the FME Workbench (Safe Software) software, coordinates of blocks representing specific emotions were extracted, converted into operable GIS data, and subsequently mapped.

3.2. Participants

Participants of the study were recruited from the main users of the Poznan University of Technology's Warta Campus: students and academic staff. Using local communication channels, recruitment for the workshops was announced. During a kick-off meeting organised after the recruitment step, the study overview and main tasks were presented. Exact steps were presented along with study elements, including:

- Preparation for the workshop involving the survey walk;
- Method of dividing users into groups;
- Channels for distributing Minecraft world files;
- Main rules and guidelines for interacting with the Minecraft world;
- Emotion taxonomy used in the research;
- Submission due and channel for sending modified world files for single-player group members.

No data about participants were collected to provide anonymity for the study. After individual survey walks, participants were randomly divided into two groups, one of which had simultaneous and multiplayer gameplay while members of the other group conducted the gameplay individually on independent copies of the prepared game map. During the multiplayer session, participants had an audio connection with each other so they were able to see avatars and hear other players. After gameplay, all single-player world files were gathered from participants.

3.3. Study Area

The study covered the area of the Warta Campus of Poznan University of Technology, located in the central part of the city bounded by Kórnicka Street to the south, the Warta River to the west, Jana Pawła II Street to the east, and the Cybina River to the north. The main axis of the campus is Piotrowo Street, running in a north–south direction. The campus includes buildings of individual departments, a Lecture Center, and a Sports Center, as well as student dormitories. The exact location of all facilities is shown in Figure 2.

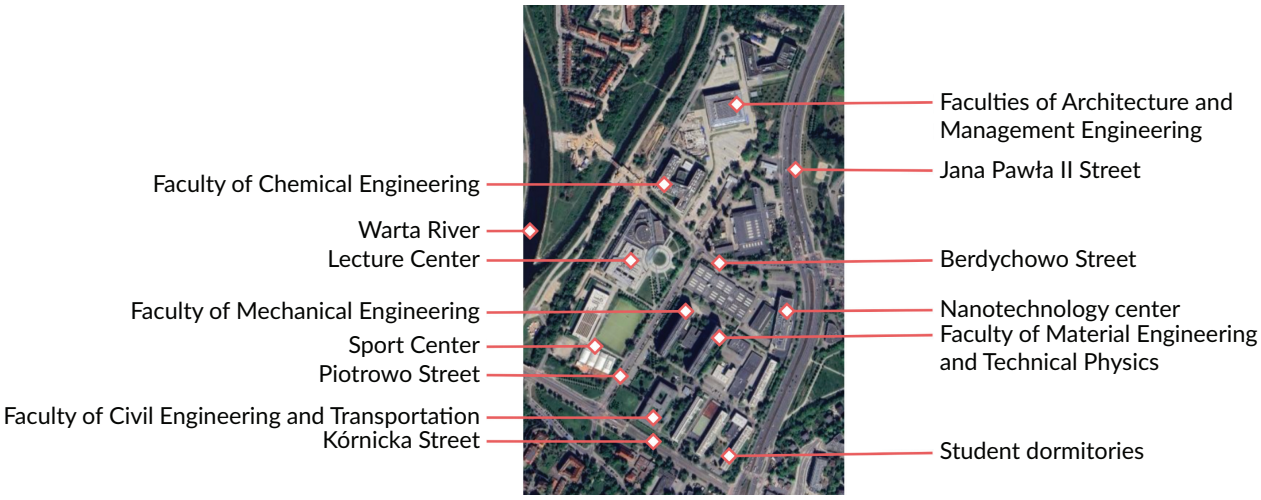

Figure 2. Map of Warta Campus with its main elements.

3.4. Data Preparation and Processing

The input data for generating the model of the campus was firstly prepared in the QGIS software based on geoinformatic data derived from sources such as OpenStreetMap (land use), the General Office of Geodesy and Cartography (numerical terrain model), the Spatial Information System of the City of Poznań (buildings), and the Geoportal service (tree stand). With the use of FME Workbench software, a Minecraft game level was generated. Next came the process of manual refinement and cleaning of the model, involving enrichment

of buildings with architectural elements and small architecture in the World Edit environment. Accurate and precise GIS data allowed the creation of an approximately 1:1 scaled digital copy of the campus within the game environment (Figure 3).

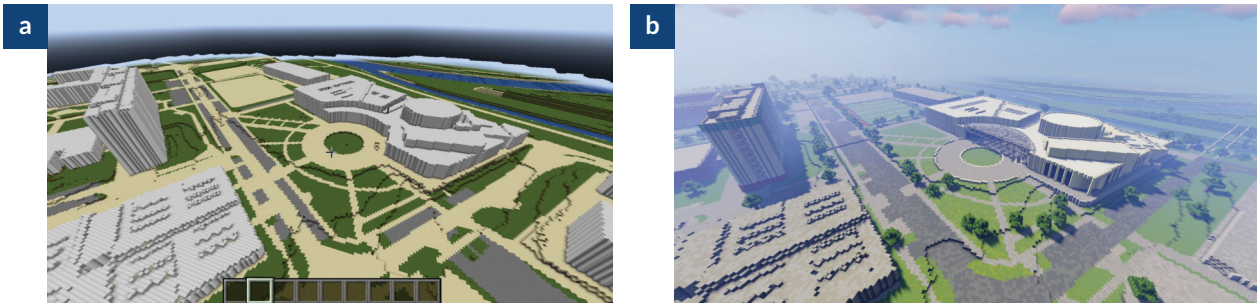

Figure 3. Campus site in Minecraft: (a) raw, GIS-based world; (b) world after postproduction.

The game environment was set up in the following way: Firstly, players were located in a closed room containing expositors with blocks and emotions connected to them (Figure 4), then, through a portal, they were transported to the campus (at the point shown in Figure 5).

Figure 4. Initial in-game view: blocks and emotions assigned to them.

Figure 5. Starting point for each player on the campus.

After the workshop, the worlds collected from the participants, enriched with blocks representing the listed emotions, were re-read in the FME Workbench software environment and filtered based on block identifiers determining their types. This allowed us to separate segments consisting of blocks of a given type and then transform them into points described by coordinates from the local datum, and finally export the resulting data in CSV format to the QGIS software.

The research involved 10 participants representing both students and academic staff. The study took place in March and April 2025. For multiplayer mode, there was a single world accessible instantly after the workshop. Single-player participants sent back modified worlds. One of the single-player participants did not send her world.

4. Results

4.1. Single-Player Results

The total number of distributed markers was 2,654. Most markers were associated with Joy/Ecstasy (1,113 markers) and Vigilance/Anticipation (607 markers). The fewest markers were associated with Fear/Terror (39 markers) and Rage/Anger (48 markers). Markers covered the whole area of the campus, with a stronger presence in the centre, southeast, and northern parts (Figure 6).

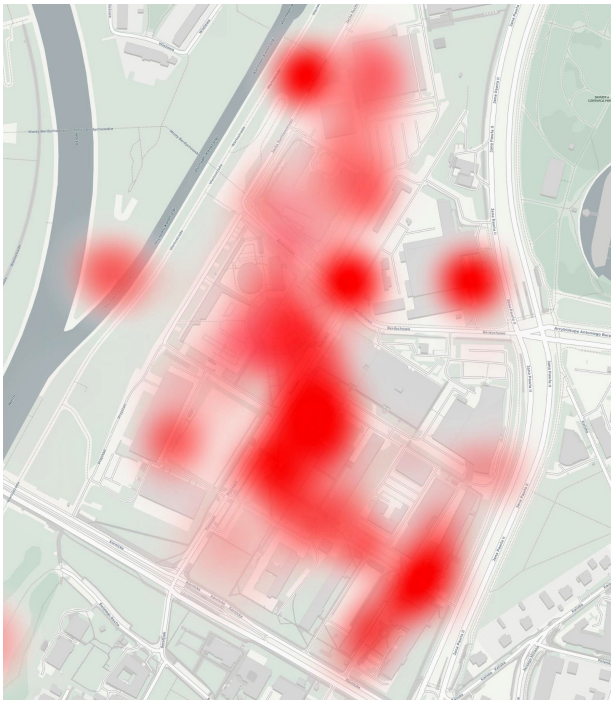

Figure 6. Heatmap for the distribution of all single-player markers.

In the case of nearest neighbor distance (NND), there is a significant bias between positive and negative emotions. While in the first group the NND value spans from 2.04 to 3.90, for negative emotions values range from 4.41 to 9.56. The considerably greater dispersion of the negative emotion values shows that single-player participants do not spend much time in places considered unpleasant, even when it is just a

virtual representation. The highest cohesion was observed for Admiration/Trust (NND = 2.04), while the highest dispersion was observed for the distribution of Fear/Terror markers (NND = 9.56). The average NND value is 4.82.

In most cases, the distribution of emotion markers was a combination of linear and clustering. There are two exceptions in the cases of Fear/Terror and Rage/Anger, with, respectively, dispersed and clustered distribution.

When it comes to placing markers for positive emotions, the most popular location was the Lecture Center, located in the centre of the campus. The space in front of the building can be considered to facilitate fostering relations between users. The other characteristic place for positive emotions was the riverside, showing a strong connection between the campus and the river. Table 1 contains detailed data about all emotions.

Table 1. Characteristics of marker distribution for single-player mode.

Emotion	# of markers (% of all markers in single-player mode) $n = 2{,}654$	NND	Distribution	Main locations
Amazement/Surprise	167 (6.3%)	3.90	Linear/Clustering	Lecture Center, Faculty of Mechanical Engineering, Faculty of Material Engineering and Technical Physics
Joy/Ecstasy	1,113 (41.9%)	2.11	Linear/Clustering	Central north–south core of the campus, riverside
Admiration/Trust	267 (10.1%)	2.04	Linear/Dispersed	Lecture Center, Faculty of Mechanical Engineering, Faculty of Material Engineering and Technical Physics, north part of the campus
Vigilance/Anticipation	602 (22.7%)	3.75	Linear/Clustering	Lecture Center, Faculty of Chemical Engineering
Fear/Terror	39 (1.5%)	9.56	Dispersed	None specific
Loathing/Disgust	336 (12.7%)	4.41	Linear/Dispersed	Student dormitories, Faculty of Chemical Engineering
Rage/Anger	48 (1.8%)	7.04	Clustering	Berdychowo/Piotrowo street crossing
Grief/Sadness	82 (3.1%)	5.75	Linear/Clustering	Sports Center, Faculty of Chemical Engineering

Single-player results show that participants from this group were more focused on positive impressions of the campus. This may be connected with the consistent order of presenting emotions, as the positive ones are always presented first, which may lead to the conclusion that players started with positive emotions and, towards the end of the session, they were accelerating the play and paying less attention to negative emotions. The lack of linear reduction of placed markers, however, speaks against this hypothesis.

4.2. Multiplayer Mode Results

A total of 3,904 markers were placed in multiplayer mode. Again, most were related to Joy/Ecstasy (1,410 markers), followed by Loathing/Disgust (608 markers). The fewest were recorded for Grief/Sadness (157 markers) and Fear/Terror (195 markers). Markers covered the whole campus area with a very strong presence in the north (Figure 7).

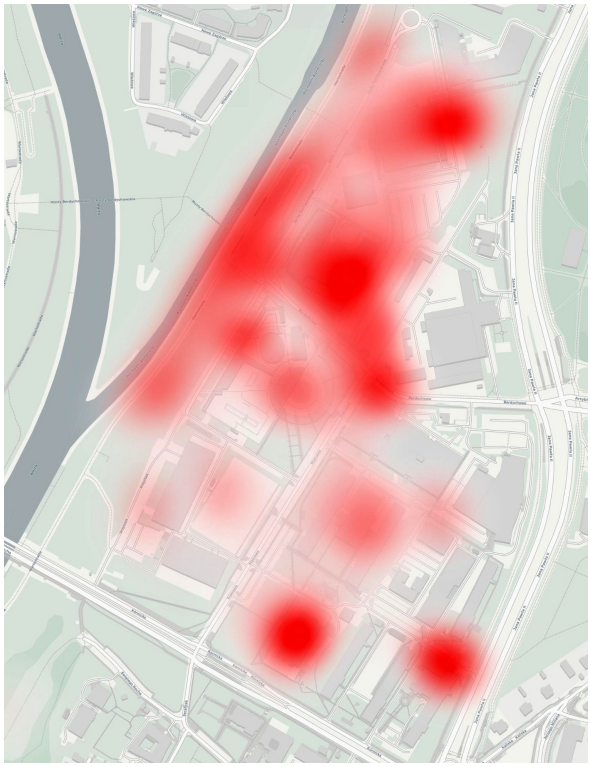

Figure 7. Heatmap for the distribution of all multiplayer markers.

When it comes to dispersion, there is no observable pattern, and all NND values are comparable spanning 1.64 to 4.02, with an average of 2.54. This indicates collective exploration and low player dispersion in the game environment. The lowest NND value was observed for Rage/Anger.

Multiplayer mode can be characterised by a more diversified distribution of types among different emotions markers. Amazement/Surprise and Joy/Ecstasy had linear distribution with a tendency to surround buildings in the case of the Amazement/Surprise. Linear and clustering can be observed for Admiration/Trust, Vigilance/Anticipation, Fear/Terror, and Loathing/Disgust. Clustering distribution was characteristic for Range/Anger and Grief/Sadness. Positive emotion tends to have a linear distribution, while negative emotion tends to cluster. It may indicate that in a group, users are more eager to stop at spots that can be considered problematic.

For positive emotions, the Lecture Center seems to be most emblematic due to its open and relations-oriented form. The Sports Center and the riverside also can be outlined as places gaining positive perception. Negative emotions are specific to the Berdychowo/Piotrowo street crossing, and for the northern part of the campus. Negative emotions are also occurring around pedestrian crossings on Priotrowo Street.

For multiplayer mode, less bias for dispersion can be observed. Along with a clustering tendency for negative emotions, we can say that collectively, players are more confident in facing and reflecting on negatively perceived areas. Table 2 contains detailed data about multiplayer mode.

Table 2. Characteristics of marker distribution for multiplayer mode.

Emotion	# of markers (% of all markers in multiplayer mode) $n = 3{,}904$	NND	Distribution	Main locations
Amazement/Surprise	406 (10.4%)	2.53	Linear	Lecture Center, Faculties of Architecture and Management Engineering, Faculty of Chemical Engineering
Joy/Ecstasy	1,410 (36.1%)	1.90	Linear	Riverside, Sports Center, Piotrowo Street, walkway to the Faculties of Architecture and Management Engineering
Admiration/Trust	231 (5.9%)	4.02	Linear/Clustering	Riverside, Faculties of Architecture and Management Engineering, Sports Center
Vigilance/Anticipation	598 (15.3%)	2.33	Linear/Clustering	Northern part of the campus, Lecture Center
Fear/Terror	195 (5.0%)	3.42	Linear/Clustering	Sports Center, Faculty of Material Engineering and Technical Physics
Loathing/Disgust	608 (15.6%)	1.93	Linear/Clustering	Walkway to the Faculties of Architecture and Management Engineering, Faculty of Mechanical Engineering, Sports Center
Rage/Anger	299 (7.7%)	1.64	Clustering	Northern part of the campus, pedestrian crossings, Berdychowo/Piotrowo street crossing
Grief/Sadness	157 (4.0%)	2.56	Clustering	Front of Faculty of Civil Engineering and Transportation, Berdychowo/Piotrowo street crossing

4.3. Mode Comparison

As data from one of the participants were not obtained, there is no point in comparing the exact values of markers for both modes, so the percentage values were juxtaposed. Table 3 shows differences in percentage values for each emotion in both single-payer and multiplayer modes. There is no significant difference between modes; variance does not exceed 7%.

There is an important distinction in the average and distribution of NND values. Single-player mode is characterised by a much larger average and range of NND values. This observation leads to the conclusion that the collective experience of the game environment, when players can see and hear each other, may

Table 3. Percentage differences between marker amounts in single-player and multiplayer modes.

Emotion	Single-player	Multiplayer	Single-player/multiplayer difference
Amazement/Surprise	6.3%	10.4%	−4%
Joy/Ecstasy	41.9%	36.1%	+6%
Admiration/Trust	10.1%	5.9%	+4%
Vigilance/Anticipation	22.7%	15.3%	+7%
Fear/Terror	1.5%	5.0%	−4%
Loathing/Disgust	12.7%	15.6%	−3%
Rage/Anger	1.8%	7.7%	−6%
Grief/Sadness	3.1%	4.0%	−1%

cause organised and group-attracted actions, while individual experience seems to be more chaotic and unorganised. This can be observed especially in the case of a multiplayer-specific phenomenon of surrounding buildings with markers. What is more, the multiplayer mode tends to be more problem-oriented, which can be observed in clusters of negative emotion markers.

4.4. The Image of Warta Campus

This research allowed us to draw an emotional picture of the Warta campus of Poznan University of Technology.

In the case of positive emotions, one can primarily see an accumulation of Joy/Ecstasy points in the central part of the campus and also along the shoreline. Significant in this regard are the entrance areas in front of the Lecture Center, the Faculties of Architecture and Management Engineering, and by the building of the Faculty of Mechanical Engineering. Curiosity is aroused by the pending construction of the university's new rectorate building during the survey. Above all, the entrance area in front of the Lecture Center is admired, while a mixture of emotions are evoked around the buildings of the Faculty of Chemical Technology and the Faculties of Architecture and Management Engineering. The representation of positive emotion markers for both single-player and multiplayer modes is shown in Figure 7.

Negative emotions are mainly aroused by the intersection of Piotrowo and Berdychowo streets, and the area running north of this point constitutes the exit zone from the student parking lot. There is also a clear path associated with Fear/Terror in the southwest corner of the Sports Center indicating that this place is highly unpleasant. Similar, path shaped pattern may be observed among Student dormitories for Loathing/Disgust markers (Figure 9).

It should be noted that there is no uniform division of locations into those experienced unequivocally negatively and positively. Many locations, such as the intersection of Piotrowo and Berdychowo streets and the road to the building of the Faculties of Architecture and Management Engineering, arouse both positive and negative emotions in users. The only exceptions are the entrance area in front of the Lecture Center and the shoreline along the western part of the campus.

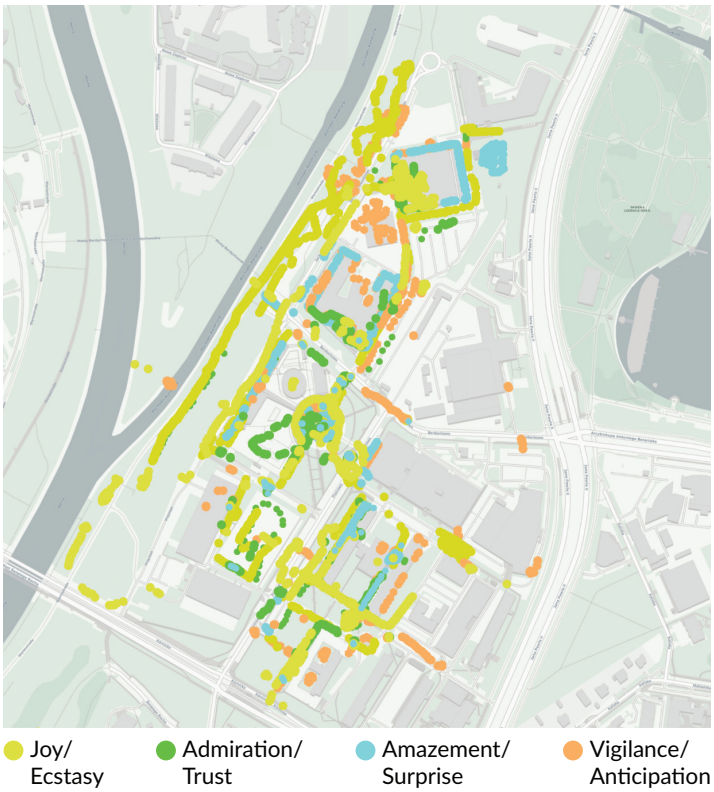

Figure 8. Positive emotion markers for both single-player and multiplayer modes.

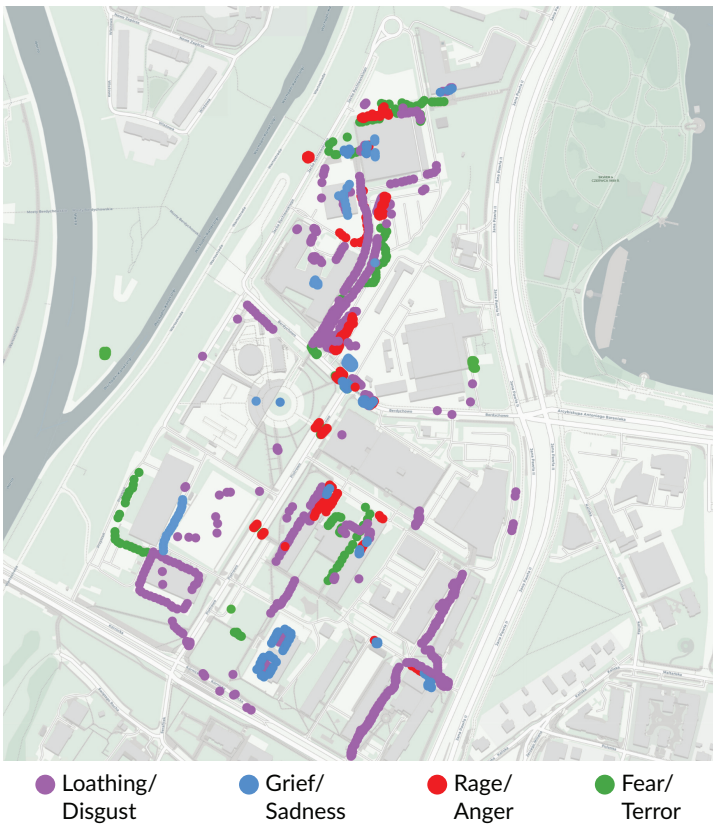

Figure 9. Negative emotion markers for both single-player and multiplayer modes.

5. Discussion

The study undertook to verify the applicability of geogames as a tool for collective emotion mapping using the Minecraft game as an example. An additional research goal was to determine if and how single-player and multiplayer modes affect the externalisation of emotions in the game. Plutchnik's emotion taxonomy was used here, which may contain some limitations, though. The essence of this study, however, was to create an accessible environment for all, devoid of complex nuances that can hinder or even block the experimentation of users.

In the context of geogames research, this article explores an as-yet-unaddressed issue related to the emotional value of space perception. Existing research undertakes to show geogames as tools utilised in urban-oriented processes such as education (Egusa et al., 2025; Poplin et al., 2022), civic engagement (Delaney, 2022; Poplin, 2014; Romano & Rogora, 2023), decision-making support (Adrienne & Nora, 2024; Poplin & Vemuri, 2018), as well as the issue of emotional mapping (Kaklauskas et al., 2021; Resch et al., 2015; Weinreb & Rofè, 2013). In these cases, voxel Minecraft elements are used to present physical elements of the built environment. There are no attempts to explore game environments to facilitate discrete aspects of the space, such as the emotions connected with the space. Mapping them and making it more engaging and potentially oriented to young users is also a research gap that needs attention. This work starts to fill it, creating a field for further studies. Firstly, this research does not take into account the interiors of the buildings, which, in many cases, are strongly connected with outdoor areas, especially in terms of people's movement. The research assumes participation of regular users who have more in-depth insight into the research area. It would be interesting to investigate the impression of new users, which could be useful for assessing the touristic attractiveness of given spaces. What is more, there is a significant aspect of narrativity that would provide more dispersion control and could make results more meaningful if the study is oriented to specific areas. Another issue that should be highlighted is the level of detail of the modelled space, which at first glance may be crucial in perceiving the space. Introducing a moderator of virtual experience appears to be especially interesting. Furthermore, it would facilitate the channelling of research results.

It has to be underlined that the in-game step is preceded by survey walks in real space, which is considered a stage that should always be present in such a process. This is important especially considering the simplicity of Minecraft game graphics. Another approach to this topic is to involve the use of mobile devices equipped with the Minecraft application. Shortening the time gap between spatial impression and its registration appears to offer the premise of greater data accuracy. Another question can be asked about how generic a model can be to successfully serve in the process. How does it relate to the size and complexity of the area? Nonetheless, the real space should always be the main reference, despite the game engine's attractive way of aggregating data that are easy to work with.

The above discussion is concluded in the following SWOT analysis, underlining the strengths, weaknesses, opportunities, and threats associated with the presented methodology and its results (Figure 10).

One of the main strengths of this method is its ability to efficiently identify problematic areas within the studied territory. In this case, the intersection of Piotrowo and Berdychowo streets should be mentioned. In addition, the data obtained in GIS format are ready for inclusion in spatial information systems. An additional

advantage often mentioned in the case of digital games is that they operate in a safe virtual environment free from physical barriers and threats. It is also worth noting that this is another step towards involving young people in city-building processes. The main weakness is the bias in the results caused by the distortion of spatial impressions by the influence of other group members. Another problem seems to be the lack of clear standardisation of the method, which would facilitate its wider implementation. The opportunities offered by using Minecraft to map emotions in urban space are related to the possibility of finding patterns and relationships between the characteristics of a given space and the emotions it evokes. In addition, the attractive formula can be a catalyst for engagement and building spatial awareness among young people and children. Among the risks that can be identified is the risk of digital exclusion if the issue of moderation and tutoring of participants is neglected. Additional risks are posed by the overinterpretation of collected data, which are considered in isolation from other spatial data. The final element that needs to be addressed is the simplification of real space in the game environment. It is important that this process is closely linked to the actual impression and appropriate representation of space in the game environment.

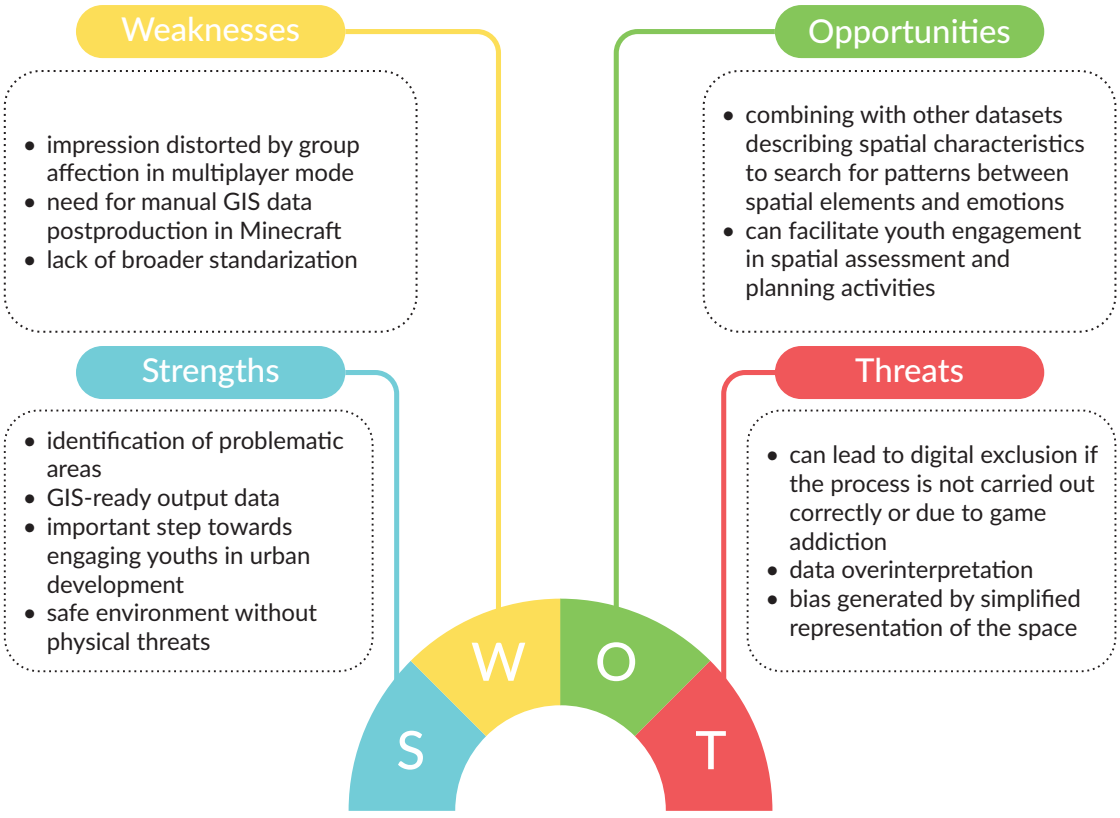

Figure 10. SWOT summary for the presented methodology.

6. Conclusions

This article demonstrates that games such as Minecraft, with the support of GIS data, can provide a useful environment for collecting spatial data—in this case, data on the emotions that users experience in urban spaces. This allowed us to provide valuable information on the emotional image of the Warta Campus of Poznan University of Technology. Concerning the differences between the impact of single-player and multiplayer modes on the results, the following conclusions can be pointed out:

- Multiplayer mode favours the expression of negative emotions, especially in the case of fear and anger. However, it is not known where in the range between the results of the two game modes lies the actual perception of the space.
- The data obtained from the multiplayer mode more often have the character of spatial sequences, while in the case of the single-player mode they have the character of scattered points. Regardless of the mode, positive emotions prevailed, testifying to the favourable character of the campus space for users.
- Results show that multiplayer may be more appropriate for further implementation due to more consistent results. What is more, this method is also easier to handle due to the fact that a single world file is produced during the process.
- The proposed methodology could be implemented during the formation of urban space development plans and interventions at the preliminary steps of such a process. Furthermore, it may provide interesting results for researching and evaluating the perception of modern real estate developments that are usually metrics-oriented.

Data provided by the presented method, connected with spatial characteristics of the space, seem to be valuable input for investigating more complex patterns of why certain spaces generate positive and negative emotions. These patterns can be useful for urban space diagnosis and implementation plans aiming to obtain certain impressions of a given place. This kind of emotionally oriented tailoring is a step toward creating city spaces that are more deeply connected with their users.

The study opens a space for further inquiries that are an extension of the subject matter dealt with here. This includes both the deepening of issues related to emotions and the application of the presented methodology of aggregation and transformation of spatial data to other layers of perception of urban space, such as a sense of safety and attachment, or the transitional character of the space.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

Data created during this study are available here: https://github.com/jzszot/URBAN-PLANNING

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

References

Aarseth, E., & Günzel, S. (Eds.). (2019). *Ludotopia: Spaces, places and territories in computer games*. transcript Verlag.

Abramovich, S., Schunn, C., & Higashi, R. M. (2013). Are badges useful in education?: It depends upon the type of badge and expertise of learner. *Educational Technology Research and Development*, *61*(2), 217–232. https://doi.org/10.1007/s11423-013-9289-2

Adanalı, R. (2021). How geogames can support geographical education. *Review of International Geographical Education Online*, *11*(1), 215–235. https://doi.org/10.33403/rigeo.855550

Aditya, T., & Laksono, D. (2018). Geogame on the peat: Designing effective gameplay in geogames app for haze mitigation. *ISPRS—International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 5–10. https://doi.org/10.5194/isprs-archives-xlii-4-5-2018

Adrienne, G.-R., & Nora, F. (2024). Key factors to enhance efficacy of 3D digital environments for transformative landscape and urban planning. *Landscape and Urban Planning*, *244*, Article 104978. https://doi.org/10.1016/j.landurbplan.2023.104978

Ahlqvist, O., Khodke, N., & Ramnath, R. (2018). GeoGame analytics—A cyber-enabled petri dish for geographic modeling and simulation. *Computers, Environment and Urban Systems*, *67*, 1–8. https://doi.org/10.1016/j.compenvurbsys.2017.08.013

Ahlqvist, O., & Schlieder, C. (2018). Introducing geogames and geoplay: Characterizing an emerging research field. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 1–18). Springer. https://doi.org/10.1007/978-3-319-22774-0_1

Altarriba Bertran, F., Bisbe Armengol, L., Cooke, C., Chen, I., Dong, V., Dastoor, B., Tadano, K., Dean, F., Wang, J., Altarriba Bertran, A., Duval, J., & Isbister, K. (2022). Co-imagining the future of playable cities: A bottom-up, multi-stakeholder speculative inquiry into the playful potential of urban technology. In *CHI Conference on Human Factors in Computing Systems* (pp. 1–19). ACM. https://doi.org/10.1145/3491102.3501860

Andrade, B. A. d., Poplin, A., & Sena, Í. S. d. (2020). Minecraft as a tool for engaging children in urban planning: A case study in Tirol Town, Brazil. *ISPRS International Journal of Geo-Information*, *9*(3), Article 170. https://doi.org/10.3390/ijgi9030170

Ansaloni, F., & Tedeschi, M. (2016). Understanding space ethically through affect and emotion: From uneasiness to fear and rage in the city. *Emotion, Space and Society*, *21*, 15–22. https://doi.org/10.1016/j.emospa.2016.09.006

Antoniou, V., & Schlieder, C. (2018). Addressing uneven participation patterns in VGI through gamification mechanisms. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 91–110). Springer. https://doi.org/10.1007/978-3-319-22774-0_5

Bartoschek, T., Schwering, A., Li, R., Münzer, S., & Carlos, V. (2018). OriGami: A mobile geogame for spatial literacy. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 37–62). Springer. https://doi.org/10.1007/978-3-319-22774-0_3

Beattie, H., Brown, D., & Kindon, S. (2020). Solidarity through difference: Speculative participatory serious urban gaming (SPS-UG). *International Journal of Architectural Computing*, *18*(2), 141–154. https://doi.org/10.1177/1478077120924337

Brielmann, A. A., Buras, N. H., Salingaros, N. A., & Taylor, R. P. (2022). What happens in your brain when you walk down the street? Implications of architectural proportions, biophilia, and fractal geometry for urban science. *Urban Science*, *6*(1), Article 3. https://doi.org/10.3390/urbansci6010003

Brosda, C., Bartsch, S., Oppermann, L., & Schaal, S. (2016). On the use of audio in the educational location based game platform MILE. In *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct* (pp. 1049–1054). ACM. https://doi.org/10.1145/2957265.2964198

Çetin Er, C., & Özcan, O. (2024). Learning from users: Everyday playful interactions to support architectural spatial changes. *Proceedings of the ACM on Human-Computer Interaction*, *8*, 1–25. https://doi.org/10.1145/3677085

Dai, L., Zheng, C., Dong, Z., Yao, Y., Wang, R., Zhang, X., Ren, S., Zhang, J., Song, X., & Guan, Q. (2021). Analyzing the correlation between visual space and residents' psychology in Wuhan, China using street-view images and deep-learning technique. *City and Environment Interactions*, *11*, Article 100069. https://doi.org/10.1016/j.cacint.2021.100069

de Byl, P. (2015). A conceptual affective design framework for the use of emotions in computer game design. *Cyberpsychology*, *9*(3), Article 4. https://doi.org/10.5817/CP2015-3-4

de Wit, S. I. (2023). Perception in motion – Alternative research techniques for exploring the urban landscape. In L. Pauwels (Ed.), *Research in urban sociology* (pp. 39–61). Emerald Publishing Limited. https://doi.org/10.1108/S1047-004220230000018B002

Delaney, J. (2022). Minecraft and playful public participation in urban design. *Urban Planning*, *7*(2), 330–342. https://doi.org/10.17645/up.v7i2.5229

DeMers, M. N. (2018). Structural gamification of a university GIS course. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 195–208). Springer. https://doi.org/10.1007/978-3-319-22774-0_10

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9–15). ACM. https://doi.org/10.1145/2181037.2181040

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. *Journal of Educational Technology & Society*, *18*(3), 75–88.

Egusa, R., Kimura, Y., & Tsuji, H. (2025). Integrating analog games and Minecraft for urban greening education: A serious game approach for elementary students. In *Proceedings of the 17th International Conference on Computer Supported Education - Volume 1: CSEDU* (pp. 598–603). SciTePress. https://doi.org/10.5220/0013441400003932

Granato, M., Gadia, D., Maggiorini, D., & Ripamonti, L. A. (2020). An empirical study of players' emotions in VR racing games based on a dataset of physiological data. *Multimedia Tools and Applications*, *79*(45/46), 33657–33686. https://doi.org/10.1007/s11042-019-08585-y

Grazuleviciute-Vileniske, I., Ivaskevicius, M., Mlinkauskiene, A., Zaleckis, K., & Povilaitiene, I. (2025). Exploring the emotional geography of Kaunas city center: A mixed-method approach to understanding place identity. *Land*, *14*(4), Article 783. https://doi.org/10.3390/land14040783

Grizzard, M., Tamborini, R., Lewis, R. J., Wang, L., & Prabhu, S. (2014). Being bad in a video game can make us morally sensitive. *Cyberpsychology, Behavior, and Social Networking*, *17*(8), 499–504. https://doi.org/10.1089/cyber.2013.0658

Hall, R. J. (2010). Cheating attacks and resistance techniques in geogame design. In *Futureplay '10: Proceedings of the International Academic Conference on the Future of Game Design and Technology* (pp. 82–89). ACM. https://doi.org/10.1145/1920778.1920790

Harriss, H. (2010). Ludic architecture: Playful tools for participation in spatial design. *Design Principles and Practices*, *4*(5), 174–185.

Heinz, T., & Schlieder, C. (2019). Addressing spatio-temporal geogame relocation issues using design evaluation heuristics and agent-based simulation. In *11th International Conference on Virtual Worlds and Games for Serious Applications* (VS-Games) (pp. 1–4). IEEE. https://doi.org/10.1109/VS-Games.2019.8864532

Hemenover, S. H., & Bowman, N. D. (2018). Video games, emotion, and emotion regulation: Expanding the scope. *Annals of the International Communication Association*, *42*(2), 125–143. https://doi.org/10.1080/23808985.2018.1442239

Henry, N. J. (2018). A cost-effective workflow for depicting landscapes in immersive virtual environments. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 177–194). Springer. https://doi.org/10.1007/978-3-319-22774-0_9

Hjorth, L., & Lammes, S. (2024). Sensing playgrounding: Playful design workshops to reimagine the city as playground. *Space and Culture*, *27*(2), 172–186. https://doi.org/10.1177/12063312231213254

Huang, B., & Hew, K. (2015). Do points, badges and leaderboard increase learning and activity: A quasi-experiment on the effects of gamification. In *ICCE 2015: The 23rd International Conference on Computers in Education* (pp. 275–280). APSCE. https://library.apsce.net/index.php/ICCE/article/view/3213

Huyghe, J., Wouters, N., Geerts, D., & Vande Moere, A. (2014). LocaLudo: Card-based workshop for interactive architecture. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems* (pp. 1975–1980). ACM. https://doi.org/10.1145/2559206.2581348

Kaklauskas, A., Bardauskiene, D., Cerkauskiene, R., Ubarte, I., Raslanas, S., Radvile, E., Kaklauskaite, U., & Kaklauskiene, L. (2021). Emotions analysis in public spaces for urban planning. *Land Use Policy*, *107*, Article 105458. https://doi.org/10.1016/j.landusepol.2021.105458

Kavouras, I., Rallis, I., Sardis, E., Protopapadakis, E., Doulamis, A., & Doulamis, N. (2025). Empowering communities through gamified urban design solutions. *Smart Cities*, *8*(2), Article 44. https://doi.org/10.3390/smartcities8020044

Kiefer, P., Matyas, S., & Schlieder, C. (2006). Learning about cultural heritage by playing geogames. In R. Harper, M. Rauterberg, & M. Combetto (Eds.), *Entertainment Computing—ICEC 2006* (Vol. 4161, pp. 217–228). Springer. https://doi.org/10.1007/11872320_26

Kołakowska, A., Szwoch, W., & Szwoch, M. (2020). A review of emotion recognition methods based on data acquired via smartphone sensors. *Sensors*, *20*(21), Article 6367. https://doi.org/10.3390/s20216367

Kong, L., Liu, Z., Pan, X., Wang, Y., Guo, X., & Wu, J. (2022). How do different types and landscape attributes of urban parks affect visitors' positive emotions? *Landscape and Urban Planning*, *226*, Article 104482. https://doi.org/10.1016/j.landurbplan.2022.104482

Kovacs-Gyori, A., Ristea, A., Havas, C., Resch, B., & Cabrera-Barona, P. (2018). #London2012: Towards citizen-contributed urban planning through sentiment analysis of twitter data. *Urban Planning*, *3*(1), 75–99. https://doi.org/10.17645/up.v3i1.1287

Kremer, D., Schlieder, C., Feulner, B., & Ohl, U. (2013). Spatial choices in an educational geogame. In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications* (VS-GAMES) (pp. 1–4). IEEE. https://doi.org/10.1109/VS-GAMES.2013.6624243

Li, X., Hijazi, I., Koenig, R., Lv, Z., Zhong, C., & Schmitt, G. (2016). Assessing essential qualities of urban space with emotional and visual data based on GIS technique. *ISPRS International Journal of Geo-Information*, *5*(11), Article 218. https://doi.org/10.3390/ijgi5110218

Mathews, J., & Holden, C. (2018). The design and play of geogames as place-based education. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 161–176). Springer. https://doi.org/10.1007/978-3-319-22774-0_8

Mauss, I. B., McCarter, L., Levenson, R. W., Wilhelm, F. H., & Gross, J. J. (2005). The tie that binds? Coherence among emotion experience, behavior, and physiology. *Emotion*, *5*(2), 175–190. https://doi.org/10.1037/1528-3542.5.2.175

Mavros, P., Conroy Dalton, R., Kuliga, S., Gath Morad, M., Robson, S., & Hölscher, C. (2022). Architectural cognition cards: A card-based method for introducing spatial cognition research and user-centred thinking into the design process. *Architectural Science Review*, *65*(2), 120–137. https://doi.org/10.1080/00038628.2021.2008299

Muehlhaus, S. L., Eghtebas, C., Seifert, N., Schubert, G., Petzold, F., & Klinker, G. (2023). Game.UP: Gamified urban planning participation enhancing exploration, motivation, and interactions. *International Journal of Human–Computer Interaction*, *39*(2), 331–347. https://doi.org/10.1080/10447318.2021.2012379

Neuner, A., Kremer, D., & Walker, B. (2025). Urban green spaces and mental wellbeing: A methodology for

measuring structural characteristics of individual-level green space exposure and its associations with wellbeing. *Geomatica*, *77*(1), Article 100051. https://doi.org/10.1016/j.geomat.2025.100051

Ng, P., Zhu, S., Li, Y., & van Ameijde, J. (2024). Digitally gamified co-creation: Enhancing community engagement in urban design through a participant-centric framework. *Design Science*, *10*, Article e17. https://doi.org/10.1017/dsj.2024.17

Paraschivoiu, I., Steiner, R., Wieser, J., & Meschtscherjakov, A. (2025). Crafting cities together: Co-located collaboration with augmented reality for urban design. *Computer Supported Cooperative Work (CSCW)*, *34*(1), 249–291. https://doi.org/10.1007/s10606-025-09510-8

Paül i Agustí, D., Guilera, T., & Guerrero Lladós, M. (2022). Gender differences between the emotions experienced and those identified in an urban space, based on heart rate variability. *Cities*, *131*, Article 104000. https://doi.org/10.1016/j.cities.2022.104000

Paül i Agustí, D., Rutllant, J., & Lasala Fortea, J. (2019). Differences in the perception of urban space via mental maps and heart rate variation (HRV). *Applied Geography*, *112*, Article 102084. https://doi.org/10.1016/j.apgeog.2019.102084

Poplin, A. (2014). Digital serious game for urban planning: "B3—Design Your Marketplace!" *Environment and Planning B: Planning and Design*, *41*(3), 493–511. https://doi.org/10.1068/b39032

Poplin, A., Andrade, B. d., & Sena, Í. d. (2022). Let's discuss our city! Engaging youth in the co-creation of living environments with digital serious geogames and gamified storytelling. *Environment and Planning B: Urban Analytics and City Science*, *50*(4), 1087–1103. https://doi.org/10.1177/23998083221133828

Poplin, A., Shenk, L., Krejci, C., & Passe, U. (2017). Engaging youth through spatial socio-technical storytelling, participatory gis, agent-based modeling, online geogames and action projects. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *4*, 55–62. https://doi.org/10.5194/isprs-annals-IV-4-W3-55-2017

Poplin, A., & Vemuri, K. (2018). Spatial game for negotiations and consensus building in urban planning: YouPlaceIt! In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 63–90). Springer. https://doi.org/10.1007/978-3-319-22774-0_4

Resch, B., Summa, A., Sagl, G., Zeile, P., & Exner, J.-P. (2015). Urban emotions—Geo-semantic emotion extraction from technical sensors, human sensors and crowdsourced data. In G. Gartner & H. Huang (Eds.), *Progress in Location-Based Services 2014* (pp. 199–212). Springer. https://doi.org/10.1007/978-3-319-11879-6_14

Romano, M., & Rogora, A. (2023). A serious game proposal for exploring and designing urban sustainability. In E. Arbizzani, E. Cangelli, C. Clemente, F. Cumo, F. Giofrè, A. M. Giovenale, M. Palme, & S. Paris (Eds.), *Technological imagination in the green and digital transition* (pp. 811–820). Springer.

Rosenberg, E. L. (1998). Levels of analysis and the organization of affect. *Review of General Psychology*, *2*(3), 247–270. https://doi.org/10.1037/1089-2680.2.3.247

Sanmugam, M., & Mohamed, H. (2020). Leaderboard: Analysis review behind the usage in gamification. *ASM Science Journal*, *13*(Special Issue 3), 89–93.

Schaal, S., Otto, S., Schaal, S., & Lude, A. (2018). Game-related enjoyment or personal pre-requisites—Which is the crucial factor when using geogames to encourage adolescents to value local biodiversity? *International Journal of Science Education, Part B*, *8*(3), 213–226. https://doi.org/10.1080/21548455.2018.1441571

Schlieder, C., Kiefer, P., & Matyas, S. (2005). Geogames: A conceptual framework and tool for the design of location-based games from classic board games. In M. Maybury, O. Stock, & W. Wahlster (Eds.), *Intelligent technologies for interactive entertainment* (Vol. 3814, pp. 164–173). Springer. https://doi.org/10.1007/11590323_17

Schneider, J., Schaal, S., & Schlieder, C. (2017). Geogames in education for sustainable development: Transferring a simulation game in outdoor settings. In *2017 9th International Conference on Virtual Worlds and Games for Serious Applications* (VS-Games) (pp. 79–86). IEEE. https://doi.org/10.1109/VS-GAMES.2017.8056574

Schneider, J., Schaal, S., & Schlieder, C. (2020). Integrating simulation tasks into an outdoor location-based game flow. *Multimedia Tools and Applications*, 79(5/6), 3359–3385. https://doi.org/10.1007/s11042-019-07931-4

Tomaszewski, B., Walker, A., Gawlik, E., Lane, C., Williams, S., Orieta, D., McDaniel, C., Plummer, M., Nair, A., San Jose, N., Terrell, N., Pecsok, K., Thomley, E., Mahoney, E., Haberlack, E., & Schwartz, D. (2020). Supporting disaster resilience spatial thinking with serious geogames: Project Lily Pad. *ISPRS International Journal of Geo-Information*, *9*(6), 405. https://doi.org/10.3390/ijgi9060405

Weinreb, A. R., & Rofè, Y. (2013). Mapping feeling: An approach to the study of emotional response to the built environment and landscape. *Journal of Architectural and Planning Research*, *30*(2), 127–145.

Westerholt, R., Lorei, H., & Höfle, B. (2020). Behavioural effects of spatially structured scoring systems in location-based serious games—A case study in the context of OpenStreetMap. *ISPRS International Journal of Geo-Information*, *9*(2), Article 129. https://doi.org/10.3390/ijgi9020129

Wilkinson, P. (2013). Affective educational games: Utilizing emotions in game-based learning. In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications* (VS-GAMES) (pp. 1–8). IEEE. https://doi.org/10.1109/VS-GAMES.2013.6624219

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ARTICLE

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Geogame-Based Simulation for Active Mobility Planning in Socially Sustainable Cities

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Abstract

The tendency to simplify urban complexity in planning, without considering diverse social and geographical contexts, can exacerbate the urban mobility crisis. Within this paradigm, geogames offer geospatial, collaborative, playful, and inclusive means of evaluating sustainable urban design projects. To achieve the main objective of this study—namely, integrating game-based simulation into an interconnected dual-geogame framework—Cities: Skylines (C:S) was employed to model the city of Concepción. An initial calibration geogame, Scenario A, facilitated an expert-led diagnostic process through visualisation and exploration. Based on these findings, a participatory neighbourhood scenario (B) was designed to support active mobility planning, incorporating alternatives proposed by citizens during the Covid-19 pandemic. This model assessed quantitative changes in agents' modal shift preferences. Technically, C:S integrates agent-based modelling to evaluate mobility impacts within a simulated urban environment. The results informed a second geogame, where the scenario (B) was presented and refined through collaborative co-creation with undergraduate students. Through this process, alternative interventions were negotiated, adjusted for post-pandemic relevance, and enriched through consensus. Students successfully co-designed an improved version of the neighbourhood—Scenario C—focused on enhancing active mobility. These findings suggest that geogame-based simulation can reduce uncertainties associated with agent preference shifts within C:S and facilitate consensus-building for socially sustainable urban projects. The geogame framework contributes to developing a systemic, geospatial, playful, and inclusive approach to real-world urban planning, providing valuable insights for the planning and design of future socially sustainable cities.

Keywords

active mobility; game-based simulation; geogames; participatory urban design; sustainable urban planning

1. Introduction

1.1. Planning Urban Systems and Active Mobility

The rational understanding of cities has evolved towards open, self-organising, and complex systems (Portugali, 2000). Urban planning based on functional simplification has led to critical issues such as excessive land consumption, car dependency, the loss of public spaces, and urban fragmentation (Jirón & Mansilla, 2014). Furthermore, there remains a lack of specific measures to mitigate the negative effects of conventional mobility planning in addressing complex urban challenges (Jirón & Rivas, 2020), as well as a limited adoption of proximity-based strategies that foster more inclusive and socially resilient cities (Guzmán et al., 2024; Ramírez-Saiz et al., 2022). From a systems perspective, sustainable urban mobility (SUM) can be structured to promote healthy, walkable environments, integrating proximity-based solutions and accessible transport options for longer journeys. During the Covid-19 pandemic, mobility restrictions revealed higher satisfaction with sustainable short-distance travel (Núñez Cerda et al., 2024), reinforcing the importance of strategies that encourage active mobility (AM; Haufe et al., 2016; Markvica et al., 2020). This highlights the need for compact urban environments that enhance accessibility to everyday activities, countering fragmented urbanisation models that perpetuate unsustainable travel habits (Núñez, Albornoz, Gutiérrez, & Zumelzu, 2022). Against this backdrop, urban accessibility is a key factor in connecting people with activities. Its sustainable management in urban planning requires removing barriers that limit access—not only related to transport but also to urban and socio-cultural factors. In this regard, considering citizens' perceptions is essential to promoting AM (Guzmán et al., 2024). Within the framework of sustainable urban planning (SUP), public participation is a fundamental component in the development of sustainable strategies. Citizen consultations enable the identification of perceived alternatives and the promotion of satisfactory travel experiences that prioritise AM over motorised transport (Núñez, Albornoz, Gutiérrez, & Zumelzu, 2022; Núñez Cerda et al., 2024). This opens new opportunities for the implementation of collaborative methodologies that facilitate solutions within the complex political systems in which cities evolve (Mayer et al., 2005). In this participatory context, urban design approaches must become more communicative and inclusive, particularly in response to the digital transformation accelerated by the Covid-19 pandemic (Wang & Vu, 2023).

1.2. Geogame-Based Simulation for SUP

Academic urban simulation is a key digital tool in urban planning (Ruiz-Tagle, 2007; Ruiz-Tagle et al., 2009; Waddell, 2002), which has recently been integrated into video games as an innovative approach to analysis, representation, experimental decision-making, and negotiation (Mayer et al., 2004, 2005; Poplin, 2011). Game-based simulations offer significant advantages, particularly through the use of agent-based modelling (ABM; Bilal et al., 2025; González-Méndez et al., 2021; Juraschek et al., 2017; Piños & Burian, 2022; Piños et al., 2020; Prajapati et al., 2023), which enables the testing of urban design strategies and the assessment of their impact on a simulated society (Cartes-Siade et al., 2024, p. 122). However, their main limitation lies in the weak integration of scientific datasets, which prevents game-based simulations from achieving the analytical depth of digital twins or GIScience-based ABM. Digital twins and GIScience-based ABM, by contrast, systematically incorporate real-world data, albeit with methodological and operational constraints that must be addressed (Ribeiro-Rodrigues & Bortoleto, 2024; Weil et al., 2023). Mitigating these shortcomings requires tackling challenges that ensure effective communication among stakeholders, which

represents a medium- to long-term process with implementation and funding difficulties, particularly in the Global South. An innovative strategy to bridge this gap is the integration of game-based methodologies that foster participatory urban planning (Hudson-Smith & Shakeri, 2022; Poplin, 2011). In this context, geogames emerge as a key tool for communication and stakeholder engagement due to their inclusive and playful nature (Poplin et al., 2020), with simulation being one of their most distinctive features (Ahlqvist & Schlieder, 2018). Geogames, defined as digital tools that combine geospatial elements with game mechanics, facilitate public participation in urban decision-making processes. Their potential lies in their ability to integrate interactive dynamics with real-time spatial data, allowing participants to explore, evaluate, and modify urban scenarios intuitively. These methodologies promote a collective understanding of urban space by actively involving different stakeholders in its construction and analysis (de Andrade et al., 2020; Poplin et al., 2020, 2022; Poplin & Vemuri, 2018; Vieira & Coutinho, 2016).

1.3. Research Gap in Participatory Geogames

However, there is currently no evidence of integrating game-based simulation strategies with systemic quantitative data within the framework of participatory geogames, specifically aimed at strengthening AM. This gap presents a pioneering opportunity at the global level for the development of geogame methodologies that combine game-based simulation with the geospatial, playful, and inclusive characteristics of geogames. Such an approach could extend its applicability across different phases of SUP (Poplin et al., 2020; UN-Habitat, 2007). In this context, we hypothesise that it is feasible to incorporate urban data into geogames through game-based simulation approaches, thereby establishing a direct link between playful urban design and the promotion of AM. Accordingly, our main research question was: How can various geogames created with quantitative game-based simulations be interconnected across different phases of SUP? To address this question, the objective of this study is to design and evaluate a dual-geogame methodology that integrates playful, game-based urban simulation into participatory planning processes, thereby contributing to socially sustainable AM and informed urban decision-making. The implementation of interconnected geogames via game-based simulation in Cities: Skylines (C:S) may thus facilitate the quantitative interpretation and systemic, geospatial, playful, and inclusive co-creation of sustainable urban futures.

Following this introduction, the article is structured in five sections. Sections 2 and 3 introduce the theoretical framework, which situates the study within complex urban systems and sustainable planning approaches to address AM based on user preferences, while also reviewing emerging tools for SUP, with a particular focus on general game-based methods, game-based simulations, and geogames as participatory instruments for city-making. Section 4 describes the methodological design, which implements dual geogames integrating C:S into the SUP process, first with experts and subsequently with students, to evaluate perceptions and strategies for AM. Section 5 presents the results and discussion, which highlight the potential of dual geogames to visualise, negotiate, and redesign SUM scenarios, thereby bridging quantitative data with participatory governance. Finally, Section 6 presents the conclusions, which suggest that geogame-based simulation represents an emerging approach for advancing SUP and SUM policies for AM, while also enhancing public engagement in urban transformation.

2. Systemic Urban Planning

Urban planning is based on the interaction between urbanisation and development, adopting a systemic perspective in which multiple urban subsystems are articulated through everyday mobility practices and social dynamics (Jirón & Mansilla, 2014). However, contemporary planning has tended to simplify urban complexity, promoting fragmented and highly specialised models characterised by multiple functional centres that are spatially disconnected. This extreme specialisation, rather than fostering territorial cohesion, has exacerbated spatial inequalities and restricted equitable access to urban opportunities, all within a framework of political and social complexity (Mayer et al., 2005). This territorial organisation has prioritised economic accumulation over urban transformation, displacing citizens from the construction of their environment and limiting their participation in decision-making processes (Jirón & Rivas, 2020). In response to this issue, a bottom-up approach to urban planning has been proposed as an alternative to the traditional top-down model (Semeraro et al., 2020). A model incorporating this perspective is SUP, which integrates communication mechanisms, and playful, inclusive citizen participation (UN-Habitat, 2007). This approach becomes even more relevant in contexts of high urban mobility uncertainty, where factors such as health crises and climate change impact urban sustainability and decision-making (Chondrogianni & Karatzas, 2023; Le Gouais et al., 2023).

2.1. The "Unsustainability" of Mobility

The fragmented urbanisation model has led to a crisis of urban unsustainability, driven by the dominance of modernity in shaping contemporary metropolises (Escudero, 2017; Jirón & Rivas, 2020; Nijkamp & Kourtit, 2013). This process has reinforced the proliferation of the automobile as the dominant mode of transport, with negative social, economic, and environmental impacts, including the functional simplification of urban space, energy depletion, the reduction of public spaces, noise pollution, and air pollution (Becker et al., 2020; Ruiz, 2002; Tromaras et al., 2019). In the short term, the unsustainability of urban accessibility is exacerbated by factors such as rapid population growth, uncontrolled urban land expansion, and the development of environments that exceed walkable distances (Huang et al., 2010; Rahman, 2016). Additionally, dissatisfaction with urban landscape quality discourages AM, affecting quality of life and social well-being by generating stress, segregation, and a heightened perception of urban insecurity (Nijkamp & Kourtit, 2013; Núñez Cerda et al., 2024; Zumelzu & Herrmann-Lunecke, 2021). The Covid-19 pandemic further exacerbated this scenario by paralysing urban mobility and restricting access to essential activities, disrupting travel habits and revealing the lack of viable alternatives in many cities (Arias-Molinares et al., 2022; López-Soler et al., 2023; Vega-Gonzalo et al., 2023). However, in consolidated neighbourhoods with access to essential services, urban proximity enhanced satisfaction with pedestrian mobility, reinforcing the need to advance towards proximity-based urban models (Núñez, Albornoz, Gutiérrez, & Zumelzu, 2022). Designing cities for SUM requires not only environmental considerations but also economic and social dimensions aimed at ensuring equitable and efficient accessibility within the urban system (León et al., 2019; Núñez, Albornoz, León, & Zumelzu, 2022). In this regard, tools such as social geomarketing can contribute to identifying demand patterns and designing accessibility strategies aligned with the real needs of the population, thereby promoting AM and fostering a more inclusive, sustainable, and healthy urban planning approach (Haufe et al., 2016; Kong et al., 2024; Markvica et al., 2020; Papageorgiou et al., 2024).

2.2. Social Geomarketing and AM

Social geomarketing emerges as a key tool for analysing citizens' stated needs (Albornoz et al., 2020) and their level of (dis)satisfaction with urban mobility (Núñez, Albornoz, Gutiérrez, & Zumelzu, 2022; Núñez Cerda et al., 2024). In this regard, urban accessibility, understood as a service, can present differentiated barriers depending on sociodemographic segments, highlighting the importance of studying accessibility perception and its impact on everyday mobility (Evans, 2015; Jirón & Mansilla, 2013; Núñez, Albornoz, León, & Zumelzu, 2022). Analysing citizens' perceptions of accessibility and sustainable travel enables the identification of conditions that encourage the retention of walking as a primary mode of urban mobility (Herrmann-Lunecke et al., 2020; Zumelzu et al., 2022). In this context, citizen consultations facilitate the identification of barriers and sustainable alternatives, promoting strategies to mitigate dissatisfaction and consolidate sustainable AM travel habits in line with individuals' modal intentions (Rejeb et al., 2023). Satisfaction with perceived accessibility is crucial for evaluating urban design and guiding its revitalisation, strengthening the relationship between urban well-being and minimum socially acceptable conditions of walkable neighbourhoods (Yuen et al., 2024). Additionally, this approach could help address the democratic deficit within complex systems theory, enabling the evolution of urban systems through participatory processes (Rodríguez, 2018). Within this framework, integrating playful and inclusive methodologies, such as game-based methods and geogames, represents an innovative opportunity to incorporate citizen-driven alternatives into the design of sustainable neighbourhoods. This approach could foster AM and SUP within the broader concept of healthy cities that promote mental well-being (Herrmann-Lunecke et al., 2021; Zumelzu et al., 2022, 2024).

3. Game-Based Methods

For citizen consultations to serve as an effective input in urban design and contribute to residents' satisfaction, urban planners require innovative tools that strengthen participatory processes, enhance communication, and foster collaboration (Devisch, 2008). Three categories of immersion have been identified in technological approaches to public participation: challenge-based, sensory, and imaginative. Methods such as GIS, computer-aided design, planning support systems, virtual environments, and digital games can facilitate immersion in one or more of these categories (Gordon et al., 2011; Sousa, 2023). The use of game mechanics to encourage public participation and urban decision-making has been consolidated under the concept of gamification, where video games and playful approaches are applied in non-recreational contexts (Krath et al., 2021; Muehlhaus et al., 2023; Tan, 2022). However, debate persists regarding the psychological and learning mechanisms underpinning gamification, particularly in its actual effectiveness for participation and urban decision-making. In this regard, game-based approaches have advanced the integration of playful strategies with urban planning and sustainable design methodologies, offering new opportunities to support public participation and decision-making (Hammady & Arnab, 2022; Krath et al., 2021; UN-Habitat, 2007).

3.1. Game-Based Urban Simulation

Game-based strategies integrate playful approaches into urban planning, bridging digital simulation and participatory decision-making (Poplin, 2011). Digital technologies should enhance urban analysis rather than serve as ends in themselves (Hudson-Smith & Shakeri, 2022). Urban simulation is vital for understanding complex systems and reducing planning uncertainties. Cartes-Siade et al. (2024, p. 122) suggest that

game-based simulation can be used to analyse the city as a set of interconnected subsystems and may be directly integrated into analyses of SUM and accessibility (Núñez, Albornoz, Gutiérrez, & Zumelzu, 2022; Núñez Cerda et al., 2024). Within these, artificial societies explore with ABM micro-spatial mechanisms shaping macro-scale urban dynamics (Bersini, 2012; Vélez, 2019). ABM, as an analytical tool for smaller administrations (Mueller et al., 2018), deepens understanding of mobility challenges rather than predicting exact urban dynamics. It also enables empirical and participatory validation of urban scenarios via bottom-up simulation. This supports refining SUP strategies, integrating citizen participation and urban resilience. In this context, game-based simulation offers an innovative approach to training urban planners, enabling the visualisation and analysis of complex territorial dynamics (Andhika & Anggita, 2022; Roy, 2019). While widely used in geographic and urban education (Arnold et al., 2019; Khan & Zhao, 2021; Minnery & Searle, 2014; Robinson et al., 2021; Ruiz-Tagle & Gurovich, 2007; Senior et al., 2023), their integration into participatory planning remains limited. Hudson-Smith and Shakeri (2022) argue that the low adoption of these approaches is not primarily due to technical limitations but rather to how these tools have been interpreted within the dominant narratives of urban planning, which has hindered their integration into decision-making processes. Nevertheless, exploratory experiences have emerged, demonstrating the potential of urban active game-based simulation in territorial planning, with applications in urban design, policy evaluation, and mobility analysis (Bello-Maldonado, 2019; Jolly & Budke, 2023; Juraschek et al., 2017; Kavouras et al., 2023; Koens et al., 2020; Liu et al., 2021; Olszewski et al., 2020; Piňos & Burian, 2022; Piňos et al., 2020; Raghothama et al., 2022; Roumpani, 2022; Tan, 2022).

3.2. Limitations of Urban Simulation Video Games

Despite their potential in urban planning, game-based simulations have been criticised for their limitations in scientific, participatory, and inclusive contexts. Comparisons between SimCity 4 and CityLife with urban modelling tools reveal that, although these games share principles with scientific approaches, their principal limitation is the lack of flexibility to adjust simulation parameters after observation and learning (Rufat & Ter Minassian, 2012). Another issue is the absence of mixed land use in early versions of SimCity—a deficiency that persists in more recent editions (Bereitschaft, 2015). Moreover, most commercial city-building games adopt a top-down, governance perspective that privileges a single decision-maker, thereby oversimplifying the multi-actor nature of real-world planning (Bereitschaft, 2015; Raghothama et al., 2022). Intellectual property constraints also present a challenge, as proprietary code often turns simulation logic into a "black box," where rules must be inferred through gameplay rather than explicitly understood (D'Artista & Hellweger, 2007; Devisch, 2008). Nevertheless, such restrictions can be mitigated through modding—a process that modifies game behaviour using custom scripts (Scacchi, 2010; Sotamaa, 2010). C:S exemplifies this potential, as its active modding community has created tools ranging from cosmetic enhancements to advanced extensions in geographic and agent-based simulation, enabling forms of virtual geoplay through highly realistic urban recreations (Olszewski et al., 2020; Piňos et al., 2020). While C:S is not a serious game by design, it can be employed within a game-based simulation framework consistent with the paradigm of serious applications of games in participatory urban planning (Poplin, 2011).

3.3. C:S

C:S utilises an ABM framework to simulate citizen and vehicle behaviour in dynamic urban environments, representing cities as self-organising systems where agent interactions generate emergent urban

phenomena (Juraschek et al., 2017; Portugali, 2000). From an ABM perspective, each resident in C:S functions as an autonomous agent, meaning that their movements, activities, and decisions influence the configuration of the virtual urban system. These interactions can be affected both by the actions of other agents and by the geographical conditions of the environment (Bersini, 2012; Bilal et al., 2025; González-Méndez et al., 2021; Piños et al., 2020; Prajapati et al., 2023). The ability to experiment with these models enables the simulation of complex urban dynamics and the evaluation of environmental, economic, and social sustainability scenarios (Jolly & Budke, 2023; Juraschek et al., 2017). These immersive and participatory strategies have been applied in urban planning with the support of residents, authorities, and academics, as well as in educational settings (Andhika & Anggita, 2022; Olszewski et al., 2020; Shi et al., 2025). From a methodological perspective, geoplay emerges as a key approach within serious geogames, allowing users to experiment with urban scenarios, modify environmental elements, and co-create urban solutions based on real data (Ahlqvist & Schlieder, 2018; Poplin et al., 2022). While C:S is a valuable tool for game-based simulations within the context of geoplay, it has limitations in acquiring real-time data and spatially representing scientific indicators, restricting its applicability in participatory processes compared to GIS-based ABM models and urban digital twins (Crooks et al., 2019; Heppenstall et al., 2012; Mohammadi & Taylor, 2017). However, various scholars highlight that these tools also face challenges, such as cost, accessibility, and the scalability of their models in diverse urban contexts (Ribeiro-Rodrigues & Bortoleto, 2024; Weil et al., 2023). Overcoming these limitations requires addressing scientific and technical challenges while ensuring collaboration between citizens, academia, and local stakeholders. In the Global South, where resources for technological development may be limited, geogames offer an accessible and innovative alternative to fostering participation in SUP.

3.4. Geogames

In a digital context, geogames are games that integrate real geospatial information and GIS-based technologies to mediate the gaming experience. According to Ahlqvist and Schlieder (2018), they combine geographic data with spatial principles in their mechanics and dynamics, establishing a direct link with urban simulation. Both approaches share the representation of spatial systems, incorporating key concepts such as location, distance, networks, and granularity, which are essential for modelling interactions between actors and urban elements. Unlike purely quantitative theoretical urban simulations (Ruiz-Tagle et al., 2009; Waddell, 2002), geogames enable direct experimentation with the urban environment, facilitating participatory planning and real-time analysis of urban dynamics. Additionally, they can be used for urban scenario modelling, allowing players to explore development alternatives, test urban policies, and simulate infrastructure before its real-world implementation. From a participatory perspective, Poplin et al. (2020, 2022) highlight that geogames not only integrate geospatial information but also promote the co-creation of urban environments, particularly among younger populations. In this context, the novelty of geogames within the gaming sphere, through various forms of interaction (de Andrade et al., 2020), suggests a strengthening of their connection with playful urban simulation. This is achieved through the exploration of digital environments, experimentation with urban models, and the gamification of decision-making processes, positioning geogames as innovative tools for education, citizen participation, and urban planning (Shakeri, 2022).

From the theoretical review, we identify a key gap in the integration of systemic quantitative data from game-based simulations within participatory geogames, particularly in their application to the design of

urban scenarios that promote AM. Currently, no methodology links game-based urban simulation with the geospatial and playful interaction of geogames while simultaneously incorporating parameters derived from citizens' everyday experiences and validated by local stakeholders in planning and design. This absence represents a pioneering opportunity to explore how dual geogames integrating systemic quantitative data from game-based simulations can serve as tools for SUP. In this regard, we propose the use of C:S as an immersive and participatory platform for new geogames, integrating citizen consultation data to evaluate impacts on urban system sustainability. The central challenge is to consolidate an interconnected dual-geogame strategy applicable to SUP, enabling stakeholders to geoplay with urban scenarios, test AM policies, and analyse their effects in a quantifiable manner. Such an approach may contribute to reducing uncertainties in urban decision-making. In the short term, this methodology suggests the potential to provide innovative tools for planning proximity-based cities, healthier urban environments, and AI-enabled smart cities in the Global South, positioning geogame-based simulation as a promising component of sustainable, systemic, playful, and inclusive urban planning.

4. Methodology

The methodology is based on a proof of concept that examines the integration of game-based urban simulation as a tool for developing an interconnected dual-geogame framework (Figure 1). The method follows a sequential approach, beginning with the initial game-based simulation, its calibration and validation through the first geogame, and its iterative refinement throughout the study. Initially, urban game-based simulation data are analysed to assess their geospatial and urban accuracy by comparing them with real-world conditions. These data are then adjusted through the first geogame iteration. Subsequently, intermediate results emerge from the initial negotiation and consensus-building phase, serving as inputs for the second geogame. In this stage, participants explore and negotiate modifications to the urban design, ultimately reaching a final consensus that informs the development of an urban project aimed to promote AM as an input for SUP. The planning of both geogames is provided in the Supplementary File.

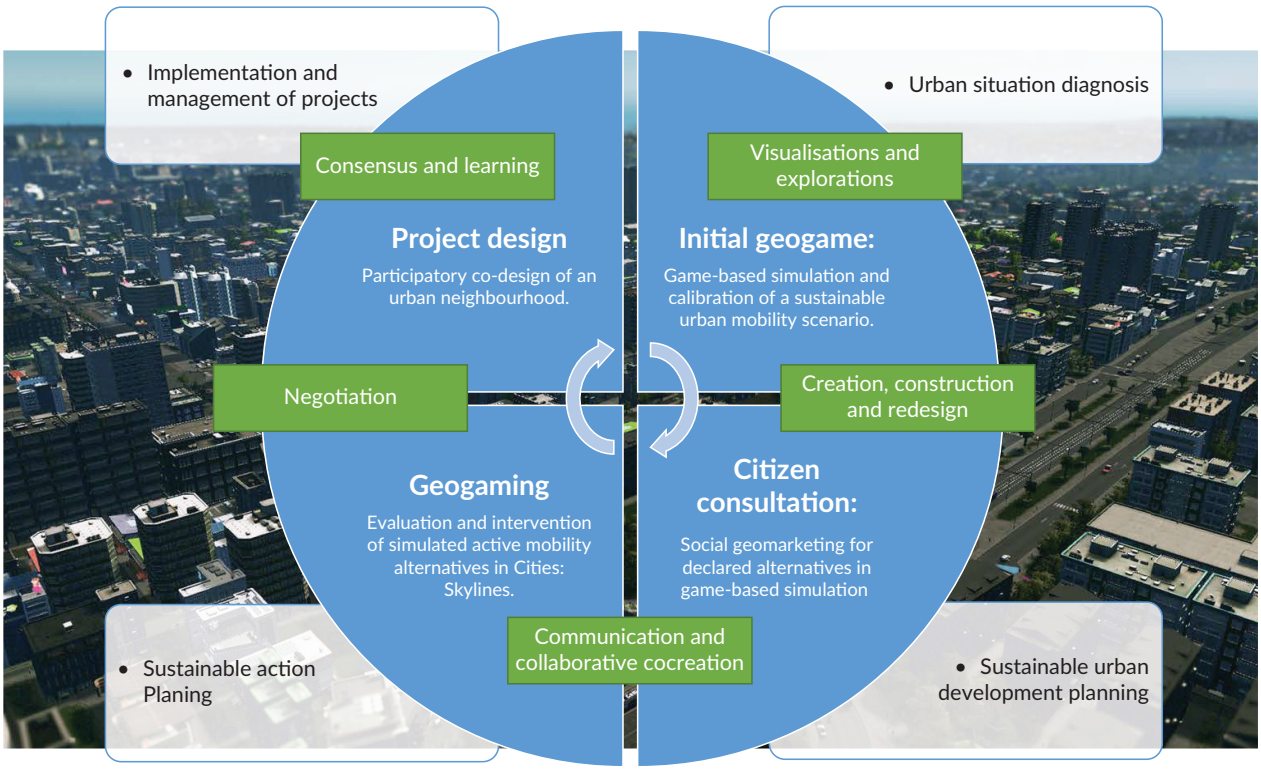
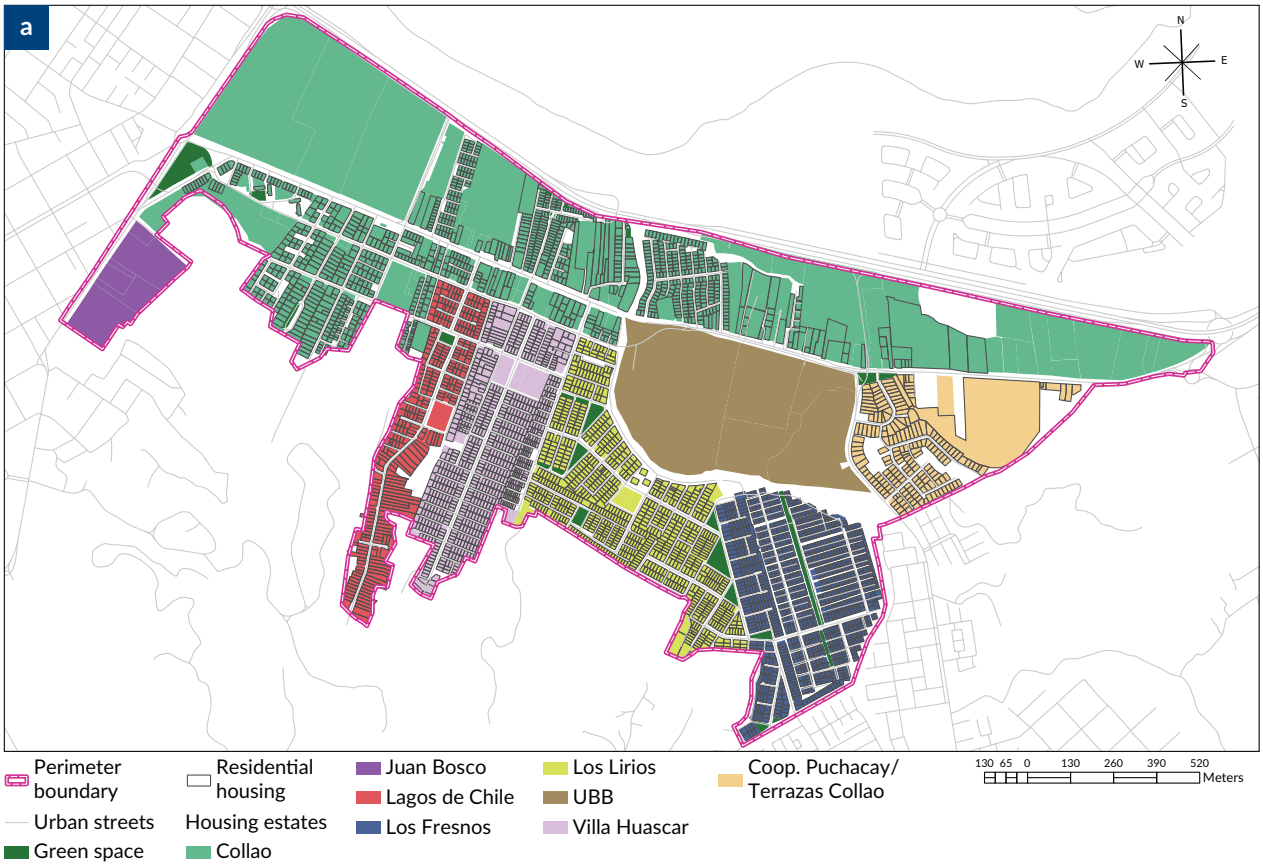


Figure 1. SUP phases: Geogame-based methodology. Note: Dual-geogame interconnected components (blue), according to the main stages of the geogame (green), supporting the different phases of SUP (white).

4.1. Case Study: The Collao Neighbourhood

Collao is a neighbourhood in Concepción, one of the municipalities of the Metropolitan Area of Concepción. It is located approximately 2 km northeast of the city centre and comprises seven housing estates, as well as the University of Bío-Bío. Núñez Cerda et al. (2024) characterise Collao as a homogeneous residential neighbourhood, defined by predominantly detached housing interspersed with medium-rise isolated buildings, front gardens, and open green spaces (Figure 2a). Its geographic condition makes this territorial unit particularly relevant for this study. The area is characterised by a degree of geographic isolation caused by the remnants of the coastal mountain range, and is bounded to the east by the Nonguén stream. As a result, its connectivity relies solely on the Collao–Novoa road system. This contrasts with other sectors of the Metropolitan Area of Concepción, whose connectivity is shaped by a geometrically organised street network based on the gridiron plan (Figure 2b). Building on this contextual overview of Collao, the next step was to operationalise these urban characteristics through an initial game-based simulation in C:S.



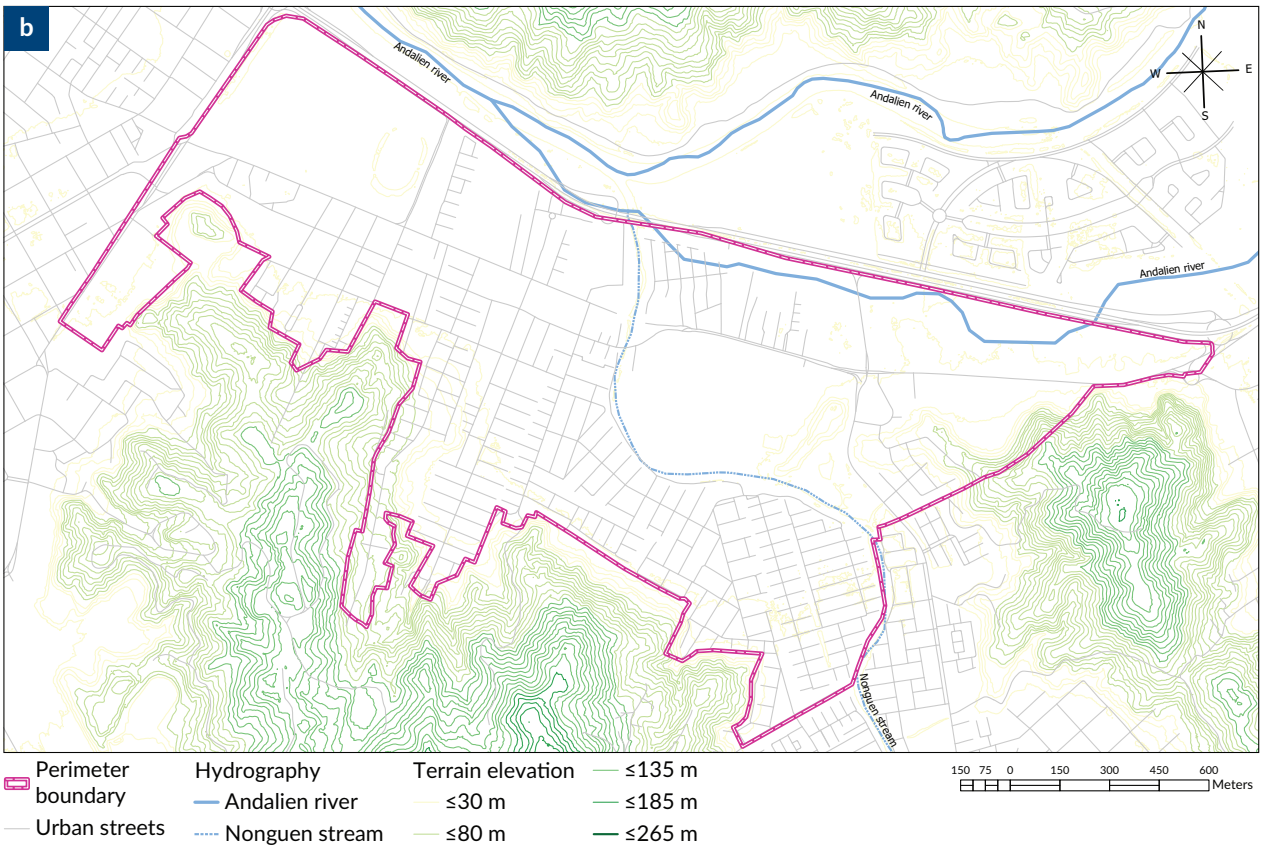


Figure 2. Collao neighbourhood: (a) urban profile; (b) geographic profile.

4.2. Initial Game-Based Simulation of Concepción With C:S

To integrate game-based simulation as a methodological tool within geogames, the city of Concepción was modelled in C:S with mods (Table 1). C:S was selected as the game-based simulation engine due to its modding capacity, which enabled the integration of real geographical elements (topography, scale, and extent), urban components (form, fabric, and functions), and demographic data with mobility patterns, offering a flexibility not achievable with conventional ABM tools. To achieve structural validation of the model before its use in geogames, geodata automatic processing was employed, optimising C:S for academic and urban-modelling purposes (Andhika & Anggita, 2022; Juraschek et al., 2017; Olszewski et al., 2020; Piños et al., 2020). The simulated urban system was calibrated by adjusting population, distances, and urban flows so that the dynamics of the virtual urban fabric mirrored real-world conditions. This process was validated through a comparison with existing urban data, ensuring that the game-based simulation maintained spatial and functional coherence for geoplay before its application in geogames.

Table 1. C:S mods used in the study and their primary functions.

Mod	Functionalities
OpenStreetMap Import	Integrates real-world topography and networks
Ploppable RICO 2.5.6	Enables the placement of specific buildings
Improved Public Transport 2	Manages public transport lines and vehicle assignments
Real Time 2.6	Simulates more realistic citizen schedules and routines
CSL Map View	Exports map imagery and cartographic views
Traffic Volume	Statistics on modal share and traffic routes
More City Statistics	Expands available urban metrics and temporal data
Realistic Population 2	Adjusts demographic probabilities and mobility patterns
TM:PE 11.9.1.0	Provides detailed junction, lane, and traffic controls

4.3. Interconnected Geogames Using the Game-Based Simulation of Concepción

To refine the methodological strategy, we organised it into five interconnected phases that ensure coherence between game-based simulation approaches, their implementation in geogames, and their capacity to support citizen participation and sustainable decision-making in urban planning. This methodological synthesis is presented in Figure 3.

4.3.1. Phase 1: Exploratory Geogame and Game-Based Simulation Validation

Once the C:S scenario was completed, an initial geogame—Which Mode Is Better?—was designed with a purely exploratory focus, aimed at calibrating the game-based simulation and validating its functionality within the SUP framework. Participant selection reflected the study's exploratory scope: Six experts were invited based on their disciplinary backgrounds in architecture, urban sociology, geography, urban mobility, and sustainable planning. This ensured a diverse range of perspectives relevant to AM and participatory urban design. Their expertise provided the basis for calibrating the model of Concepción and framing the initial scenario in relation to local contingencies (Carrasco, 2023).

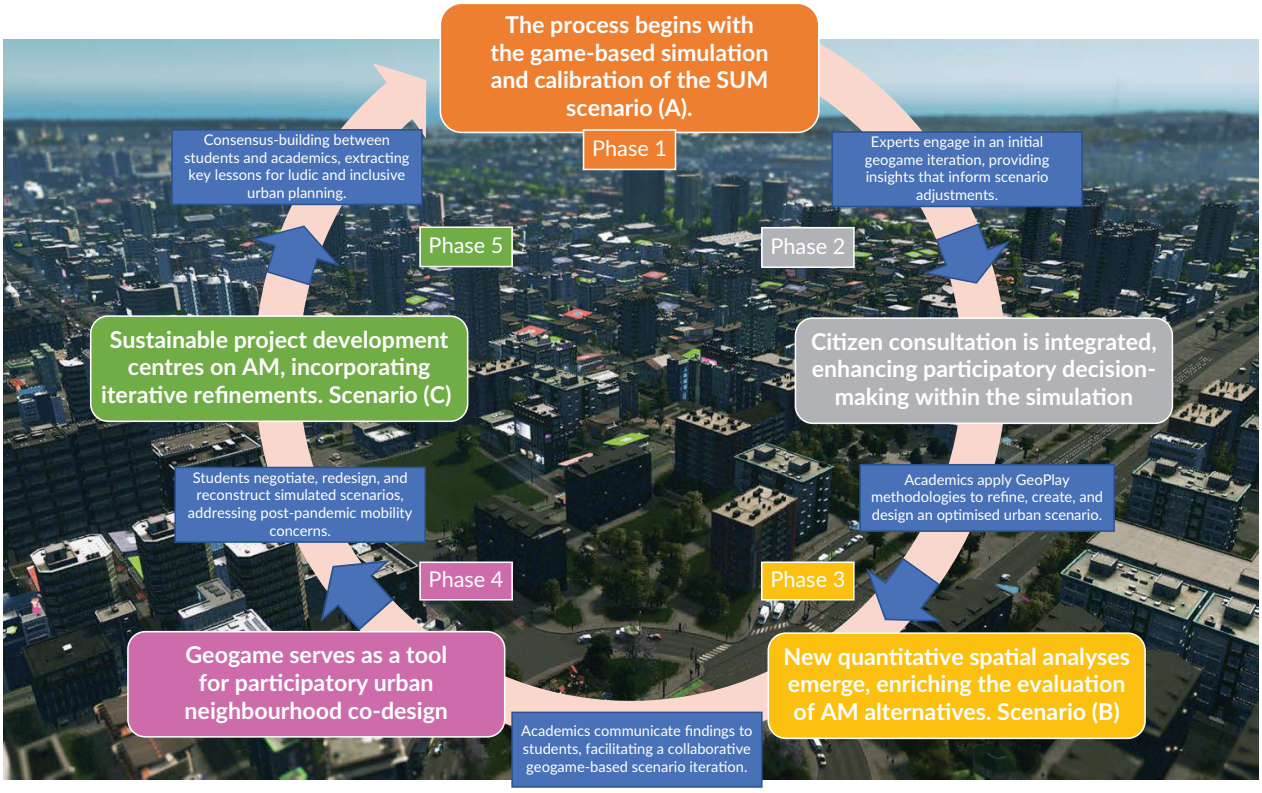


Figure 3. Dual geogame interconnected methodology. The main objective of each phase is highlighted in the blue box.

4.3.2. Phase 2: Incorporating Citizen Perception and Evaluating Impacts

Building on the insights gained from the initial geogame, citizen perception was incorporated by integrating sustainable alternatives proposed to improve AM during the Covid-19 pandemic. These alternatives, collected using social geomarketing techniques in Núñez, Albornoz, Gutiérrez, and Zumelzu (2022) and Núñez Cerda et al. (2024), quantified travel preferences, accessibility perceptions, resident-identified barriers, and satisfaction levels through a stated preference survey. Using these data, the impact of sustainable alternatives on urban agents' AM behaviour was simulated, generating a sustainable scenario in which the neighbourhood subsystem of Collao within the urban model of Concepción was modified through geoplay.

4.3.3. Comparative Strategy Between Two Game-Based Simulated Scenarios

To assess these modal shifts, geoplay was used to create a duplicate of the virtual urban system, iterating a modified version (B) with the declared alternatives alongside the original unmodified version (A). This allowed for a comparative analysis of AM dynamics by measuring differences in urban agents' interactions within each scenario.

4.3.4. Phase 4: Which Scenario Works Best?

A second geogame with partial game-based simulation results was designed to enable the visualisation, exploration, communication, redesign, reconstruction, and negotiation of post-pandemic alternatives. Undergraduate architecture students enrolled in the Urbanism II course (average age 20 years) were selected, as they represent both "informed citizens" and a demographic group typically targeted by participatory geogames (Poplin et al., 2020, 2022). Their involvement was particularly suitable for testing the pedagogical and collaborative potential of the methodology. This sampling choice aligns with exploratory practices in urban living labs, where student-based prototyping is commonly employed to refine participatory tools in controlled environments (Martínez-Bello et al., 2021; Morales et al., 2023). Their familiarity with urban concepts and their age—representative of a key demographic for AM—facilitated a critical yet accessible engagement with the game-based simulation. While not fully generalisable, this sample offered valuable insights into the methodological performance of the geogame framework, serving as a pilot stage before broader application with more diverse stakeholders (Almeida & Deutsch, 2025). Students assessed spatial variations in modal travel preferences and neighbourhood design, ultimately engaging in all phases of the geogame and co-creating a new post-pandemic scenario (C), derived from Scenario B.

4.3.5. Phase 5: Consolidating a Dual and Interconnected Geogame Strategy

The second geogame refined previous insights and consolidated a dual strategy interconnected across different stages of SUP, in line with Poplin et al. (2020). This process led to the co-creation of a sustainable urban design project aimed at improving conditions for satisfactory AM within the study group. To systematically evaluate participants' experiences, a structured survey was implemented, covering seven thematic areas: (a) game-based simulation experience; (b) role and decision-making; (c) learning and critical thinking; (d) collaboration and participation; (e) perceived change and transformative experience; (f) scenario comparison; and (g) overall evaluation. Each thematic block was explicitly linked to one or more phases of the geogame, including the embedded game-based simulation, thereby ensuring that the survey captured the full range of participant interactions across the process.

Responses were collected using a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*), which enabled the quantification of general perception trends across the group. To complement this, open-ended questions were integrated into each thematic area, inviting participants to elaborate on their perceptions, reflect on specific aspects of the game-based simulation, and propose improvements. The combination of quantitative and qualitative items provided both breadth and depth: Descriptive statistics (frequencies and percentages) offered an overview of patterns in student responses, while thematic coding of open-ended answers added contextual richness and highlighted recurrent illustrative reflections or concerns. This descriptive–interpretive strategy was deemed appropriate for an exploratory pilot, as it allowed findings to inform the assessment of methodological performance without overstating generalisability. The full survey instrument is openly available for consultation: https://forms.gle/yxSBZ9GLVoZ9kCg9A

All phases were conducted in accordance with the ethical guidelines of the University of Bío-Bío. The protocol was formally approved by the University's Research Ethics Committee. Participation was entirely voluntary, informed consent was obtained through an official form, and no personal identifiers or sensitive data were collected, ensuring confidentiality and strict adherence to institutional standards. For reference, all participant

quotes used illustratively in the next section of results and discussion are anonymised and identified with sequential codes (e.g., Expert-UM-00 = Urban Mobility experts; Expert-UP-00 = Urban Planning experts; Student-00 = student participants).

5. Results and Discussion

The results are presented sequentially, following the methodological phases. They are structured around the dual and interconnected geogame configuration, emphasising its role within the SUP framework and its potential impact on urban decision-making. This integrated presentation enables an immediate discussion of the findings in relation to the theoretical framework and methodological strategy, thereby reinforcing the contribution of geogames incorporating a game-based simulation as a tool for SUP.

5.1. Game-Based Simulation of Concepción

The initial game-based simulation, serving as the foundation for the dual-geogame framework, was calibrated with real urban flows following Piños et al. (2020); see Figures 4a and 4b in the current article. To enhance accuracy, we incorporated a rigorous process of spatial, demographic, and subsystem-level validation. Spatially, the CSL Map View mod exported raster maps from C:S to ArcGIS Pro, enabling validation of geographic extent, network lengths, and urban morphology against official cartographic data of Concepción (Figure 4c), as in Olszewski et al. (2020). For example, the Collao neighbourhood has

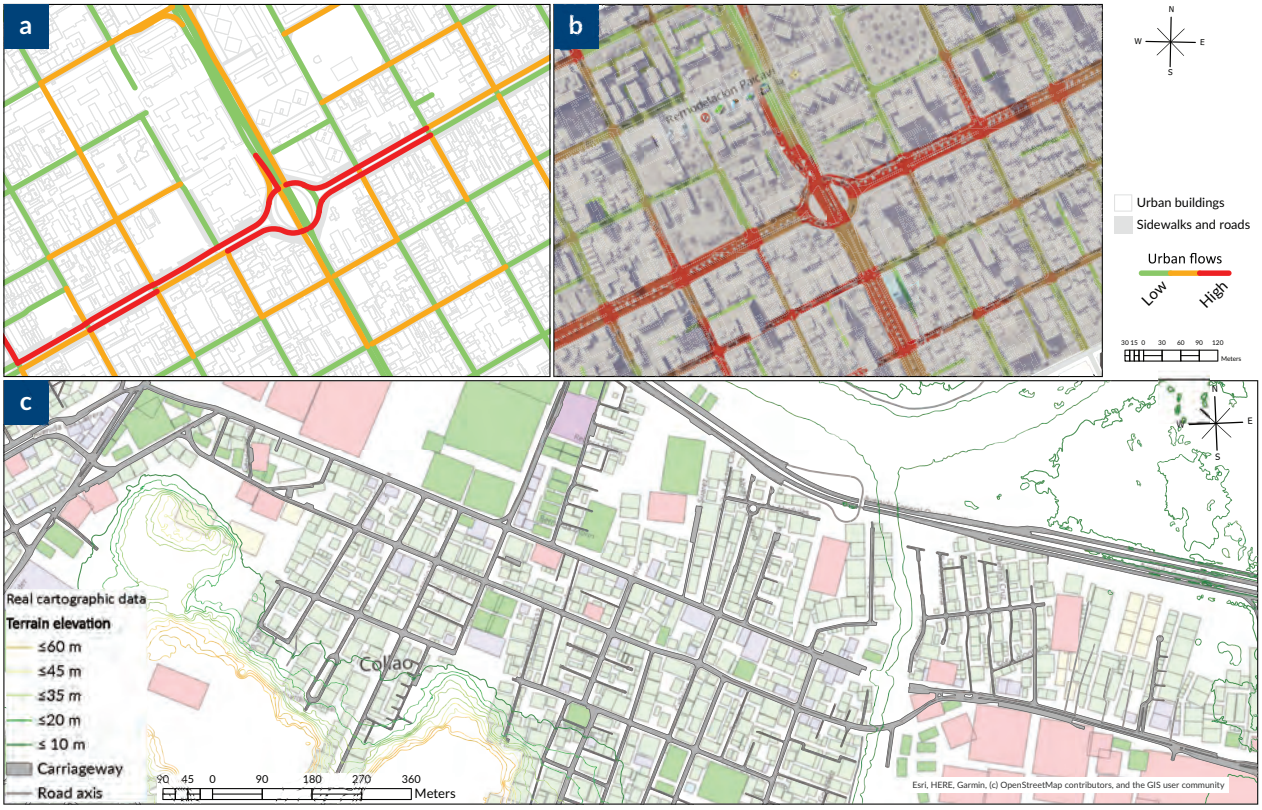


Figure 4. Calibration of Concepción in C:S: (a) observed real-world traffic flows; (b) simulated traffic flows in C:S; (c) real cartography overlaid on a raster base exported from C:S.

approximately 20,412 residents, while the simulated population in C:S was 20,186, indicating close alignment between observed and modelled demographic patterns. This refinement reinforces the value of geoplay, as it enables the adjustment of environmental elements and the co-creation of urban solutions with quantitative data. Overall, the approach strengthens the theoretical foundations of geogames as participatory tools, consistent with the geographical principles of Ahlqvist and Schlieder (2018) and the participatory frameworks discussed by Poplin et al. (2020). Thus, geogames emerge as a bridge between game-based simulations and real urban dynamics, underscoring their applicability in SUP.

5.2. First Calibration Geogame: Which Mode Is Better?

To assess the applicability of Concepción's game-based simulation in C:S within a geogame, we conducted an exploratory phase to validate the urban model and examine its potential as a decision-support tool. Experts in urban planning and mobility explored the city to evaluate geospatial accuracy and functional reliability, consistent with studies that highlight expert validation as essential for digital simulations (Mayer et al., 2005). The main objective was to analyse changes in traffic flow under different transport scenarios, geoplaying within a structured debate on infrastructure (Carrasco, 2023). Game-based simulation has been shown to support scenario-based decision-making in spatial planning (Ahlqvist & Schlieder, 2018; de Andrade et al., 2020). Two scenarios were tested: (a) Base Scenario—no public transport intervention; and (b) Tram Scenario—introduction of a tram network. Using cartographic data and statistical outputs exported from C:S, the tram-based scenario improves overall traffic flow by more than 60% (Figure 5). Experts highlighted the tool's ability to visualise real-time impacts of SUM strategies, reinforcing prior findings on the value of geogames for urban experimentation and participatory planning (Poplin et al., 2020, 2022; Poplin & Vemuri, 2018; Vieira & Coutinho, 2016).

5.2.1. Preliminary Results: Perceptions and Experience

During the calibration geogame, experts emphasised the novelty of the approach and its potential as a realistic geo-urban game-based simulation. They valued the model's capacity to visualise, explore, and analyse urban dynamics through active simulations, consistent with studies distinguishing interactive methods from static modelling tools (Roumpani, 2022; Shi et al., 2025):

> Beyond aesthetics and 3D modelling, this is about playing with consequences through ABM when introducing changes to a system. It's about seeing in real time, "What would happen if…?" (Expert-UP-01, 2024)

Unlike traditional GIS models reliant on static datasets (Heppenstall et al., 2012; Mohammadi & Taylor, 2017), C:S enabled participants to test interventions dynamically, reducing both the cost and risk of real-world experimentation (Shakeri, 2022). This aligns with the theoretical grounding of ABM, where cities are framed as complex self-organising systems, and interactions among agents produce emergent patterns (Bersini, 2012; Vélez, 2019). Experts also acknowledged the value of ABM for participatory planning, as it allows game-based simulation of mobility and accessibility dynamics in bottom-up contexts (Semeraro et al., 2020):

> I've always wanted to know what would happen if we removed private cars from a city or its centre. How would people organise their mobility? (Expert-UM-01, 2024)

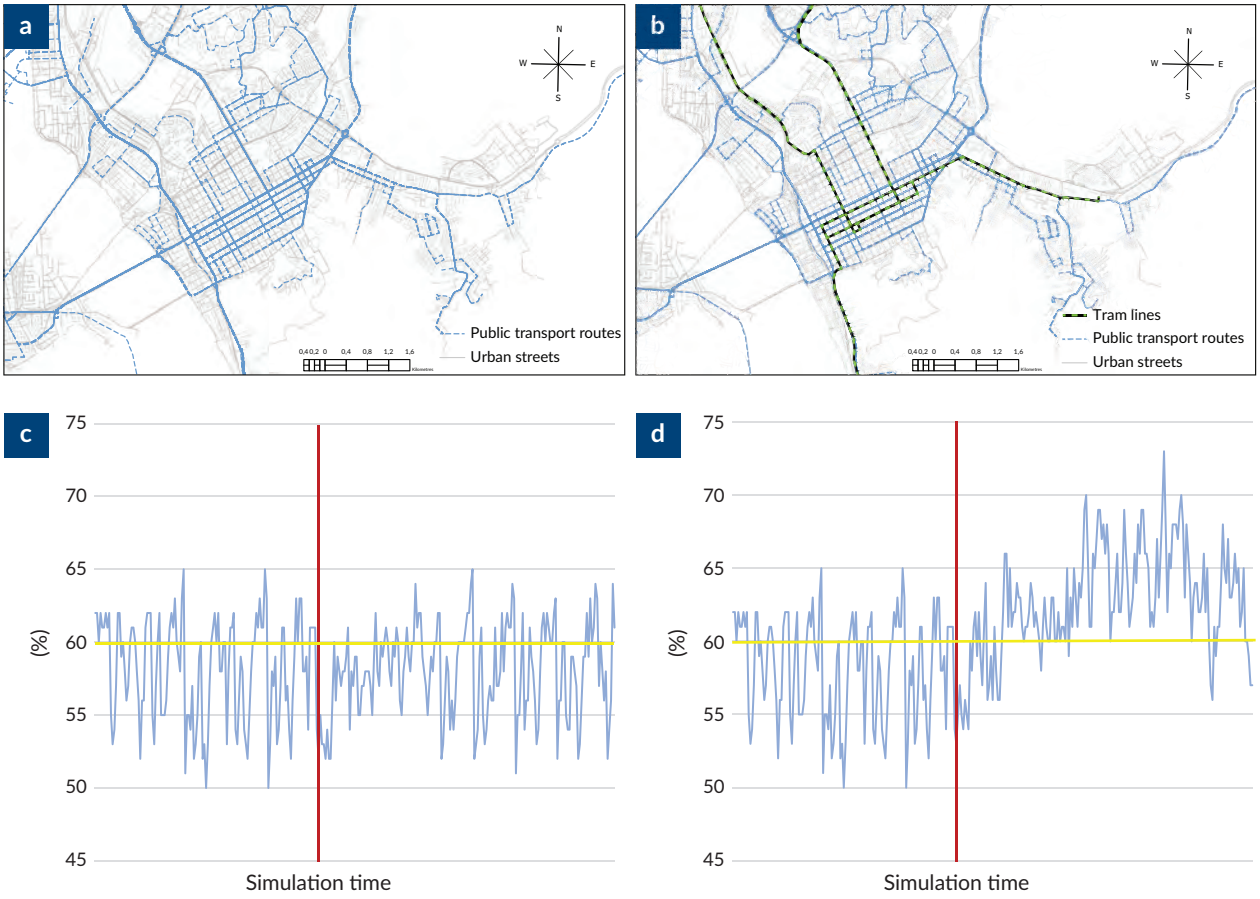


Figure 5. Summary of scenarios and traffic dynamics variations: (a) base scenario; (b) tram scenario; (c) traffic flow efficiency in the base scenario; (d) traffic flow efficiency in the tram scenario. The implemented modifications (red x-axis) improve overall traffic flow by over 60% (yellow y-axis).

This concern aligns with SUP and AM approaches, where game-based simulation in the geogame acts as an experimental laboratory for testing alternative scenarios under expert review (Juraschek et al., 2017; Olszewski et al., 2020; Piños & Burian, 2022). In this case, the model was used to evaluate the reconfiguration of public space for promoting AM (Haufe et al., 2016; Markvica et al., 2020; Núñez Cerda et al., 2024). Experts highlighted the value of geogames for participatory planning, as they enable both citizens and professionals to experiment with sustainable mobility strategies before real-world implementation. By reducing quantitative uncertainties and exploring systemic traffic impacts, participants proposed the co-creation of an integrated and sustainable transport system (Figure 5):

> The tram used to follow the old cart path along here….Look, let's connect that route to the city centre, maybe by reallocating street space from private vehicles. (Expert-UM-01, 2024)

> Based on its realistic simulations, we could reach decision-making stages with data—not exact, but approximate: from 55% to 65% traffic flow. That would allow us to sit down and discuss changes in real time. (Expert-UP-01, 2024)

Building on these reflections, participants stressed the importance of prioritising citizen perceptions and mobility alternatives as the basis for testing new scenarios. This shift reinforced the bottom-up approach

emphasised by Semeraro et al. (2020), where decision-making emerges from citizens towards governance. Within this framework, ABM remains essential for modelling emergent interactions in urban systems (Bersini, 2012; Vélez, 2019):

> Do you have any information on participatory initiatives or citizen consultations regarding perceptions and everyday mobility preferences? (Expert-UM-02, 2024)

Rather than focusing exclusively on mass transit, participants suggested strategies to improve individual travel within the 15-minute city framework (Guzmán et al., 2024). They also highlighted the need to enhance urban elements that support AM and healthy cities, echoing findings on accessibility, well-being, and social sustainability (Herrmann-Lunecke et al., 2020; Núñez, Albornoz, Gutiérrez, & Zumelzu, 2022; Núñez Cerda et al., 2024; Zumelzu et al., 2022, 2024):

> Is it possible to test not only changes in design and infrastructure? Does C:S allow for modifications in public policy and other phenomena? (Expert-UP-02, 2024)

These insights underline the value of expanding decision-making processes to include citizens, ensuring that urban design projects genuinely contribute to SUP. By incorporating perceptions into quantitative game-based simulations, geogames can help reduce uncertainty and evaluate not only spatial interventions but also broader policy measures. This question and these discussions underscore the potential of geogames as playful strategies to capture citizen perceptions and integrate them into game-based urban modelling with policy simulation, thereby fostering more equitable and sustainable solutions aligned with SUP (Poplin et al., 2020). Participants highlighted the importance of expanding scenarios beyond infrastructure to include management and regulatory strategies, bridging theoretical modelling with real urban dynamics (Ruiz-Tagle et al., 2009; Waddell, 2002). In response, a second geogame was designed to incorporate the negotiated outcomes into the Concepción game-based simulation in C:S. Unlike the expert phase, this instance engaged university students from the Collao area—everyday users of AM and urban accessibility— whose feedback offered valuable insights into local perceptions. This new dual-geogame framework thus operates at two levels: (a) structured geoplay with experts to validate urban strategies within the SUM framework, contributing to the observations of Jolly and Budke (2023); and (b) interconnected game-based simulation with citizens-in-training to test participatory redesign processes and support more inclusive governance.

5.3. Second Geogame: Which Scenario Works Best?

The second geogame was implemented with 21 undergraduate architecture students, who engaged both individually and in teams (Figure 6). The activity began with an introduction to the conceptual foundations of geogames and their framework, following the phases outlined by Poplin et al. (2020, 2022). To contextualise the exercise, students reviewed interim results from the first geogame, including the iterative game-based simulation of Scenario B that had been negotiated and proposed by experts. Preliminary results for the Collao scenario indicate an average daytime increase of 44.3% in walking, a 178.7% increase in bicycle use, and a 2.4% positive variation in perceived satisfaction compared with the same scenario without modifications. Finally, at the urban system level, traffic flow efficiency increased by 1.23% (Figure 7). A demonstration video of the simulated city in C:S was then presented, illustrating how such tools can support AM and stimulate students' interest in the application of game-based simulations. After this initial

stage, students participated in scheduled geogame sessions with C:S, where they explored the simulated environment and contributed to developing a new sustainable urban scenario (Scenario C) by incorporating their proposals into Scenario B. Upon completion, a survey designed for this study was administered to evaluate their perceptions and the methodological outcomes.

Figure 6. Students interacting with C:S.

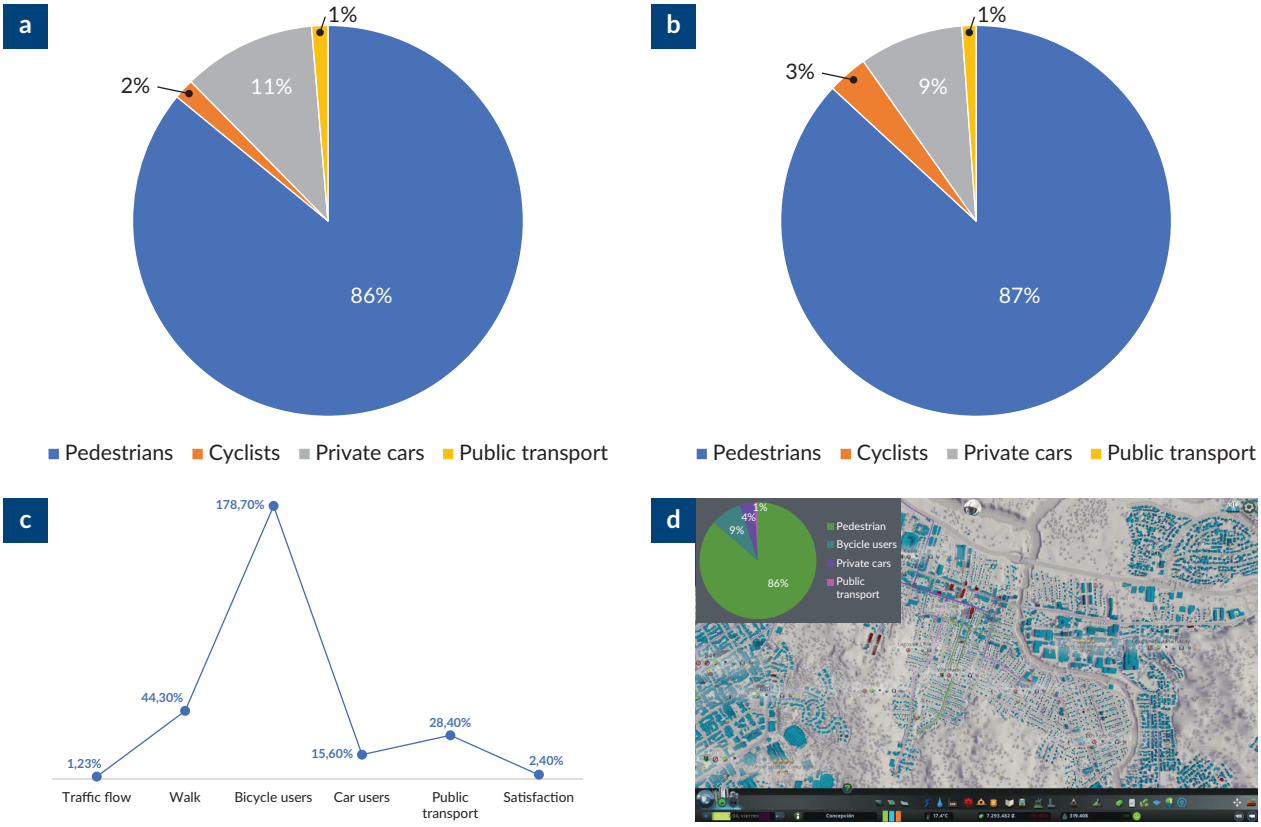


Figure 7. Comparison of Collao scenarios communicated to students: (a) urban system baseline modal split; (b) urban system modal split after expert-proposed modifications; (c) percentage variations for Concepción; (d) Collao in C:S with applied modifications.

5.3.1. Visualisation and Exploration

Students reported that comparing alternative scenarios through the game-based simulation in C:S was both immersive and realistic, with 100% agreeing (28.6%) or strongly agreeing (71.4%) that it effectively reflected real-world urban challenges (Figure 8). All participants also stated that the gameplay dynamic motivated their active involvement and facilitated their understanding of SUP. These findings support Ahlqvist and Schlieder's (2018) argument on the intersection of geographic concepts with play, where realistic game-based simulations play a central role, and align with Crooks et al. (2019) on the potential of ABM-based GIScience. In this sense, geogames and geoplay provide dynamic means of modelling urban systems that interrelate objects, agents, and rules within a playful environment, while remaining grounded in quantitative spatial data. These results validate theoretical propositions and highlight how geogames can communicate participant roles and support decision-making in SUP.

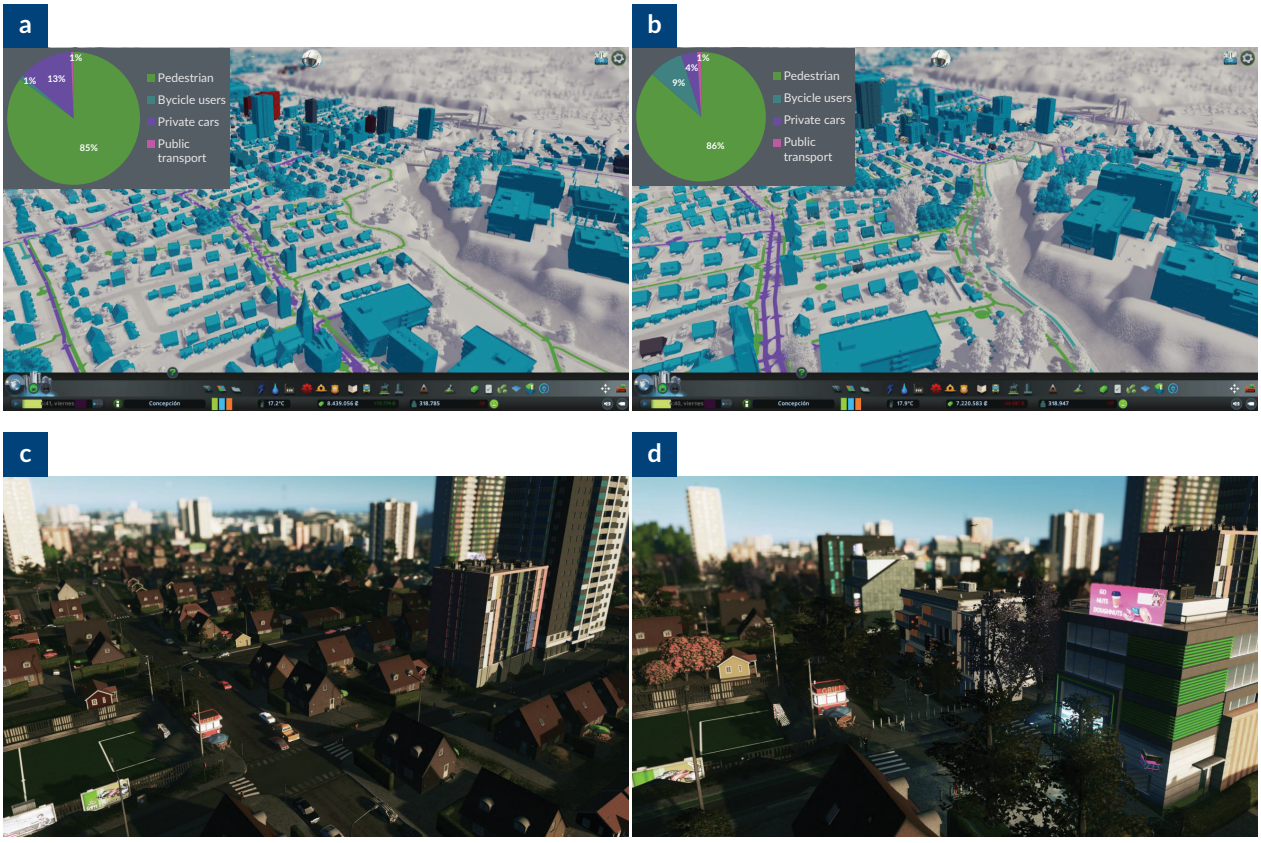


Figure 8. Comparison of game-based simulated scenarios in C:S: (a) base routes and modal split; (b) resulting routes and modal split after simulated variations; (c) geospatial view of the base scenario; (d) geospatial view of the modified scenario with an updated built environment.

5.3.2. Communication and Evaluation

At this stage, students assumed the role of "omnipotent planners," a common feature in academic and game-based simulations, allowing them to freely explore and make decisions in a top-down urban planning context. Most participants (85.7%) reported feeling in full control and demonstrated a clear understanding of the role, while 14.3% expressed doubts, highlighting ethical–moral concerns about the implications of urban

decisions—for example, rezoning or expropriating residential areas to create public spaces. These reflections were reinforced in the evaluation phase, where 85.7% agreed that the geogame helped them critically assess the impacts of planning choices and understand their consequences within the game-based simulation. Such findings resonate with Bereitschaft's (2015) critique of urban video game simulations, highlighting progress in fostering participatory engagement. However, a minority remained unconvinced of these benefits. This underscores the need to refine playful strategies that broaden inclusion, in line with Raghothama et al.'s work (2022) on openness and complexity in planning environments. Building on this stage, students were then assigned collaborative roles that incorporated other stakeholders' perspectives, leading them to redesign the Collao neighbourhood with a focus on AM, aligned with bottom-up approaches (Semeraro et al., 2020).

5.3.3. Redesign and Collaborative Negotiation

Students compared the original scenario—lacking community-informed alternatives—with the pandemic-era scenario (B) that incorporated proposals from Collao residents. While 28.6% considered the latter effective, 71.4% argued for a redesign, emphasising the dynamic and evolving nature of cities. Their reflections motivated the creation of a post-pandemic scenario (C), aimed at strengthening AM through new interventions. This process supports the use of perception-based methods for modal shift interventions (Haufe et al., 2016; Markvica et al., 2020) and aligns with walkability improvements suggested by Herrmann-Lunecke et al. (2020) and Zumelzu et al. (2022, 2024), which have been linked to greater satisfaction with urban environments (Núñez Cerda et al., 2024):

> Collaboration enabled us to develop a better scenario by combining both perspectives. (Student-01, 2025)

> Our city is constantly changing, so it wouldn't be feasible to rely solely on a pandemic-based scenario. (Student-03, 2025)

The collaborative dimension of the geogame was also evident: 85.7% of students agreed that the dynamic encouraged teamwork, while 71.4% highlighted the value of incorporating others' perspectives. Even participants working individually benefited from facilitator guidance, confirming the importance of structured support in participatory simulations (de Andrade et al., 2020; Poplin et al., 2020, 2022). Across all groups, the geogame fostered a sense of belonging to a learning community, reinforcing findings from earlier implementations. These results contribute to the debate on the role of playful elements in gamified processes, especially in decision-making and role-playing (Hammady & Arnab, 2022; Krath et al., 2021; Robinson et al., 2021; Senior et al., 2023). Ultimately, Scenario C illustrates how a playful quantitative game-based simulation—embedded within an interconnected geogame framework grounded in real geographic elements—can facilitate consensus-building and spontaneous learning through the development of an urban design project (Figure 9).

5.3.4. Consensus and Learning

The second geogame revealed strong consensus-building dynamics and meaningful learning outcomes. A total of 71.4% of participants agreed that the ludic game-based simulation enhanced their understanding of urban sustainability concepts, supporting Senior et al.'s (2023) findings on playful learning. All students

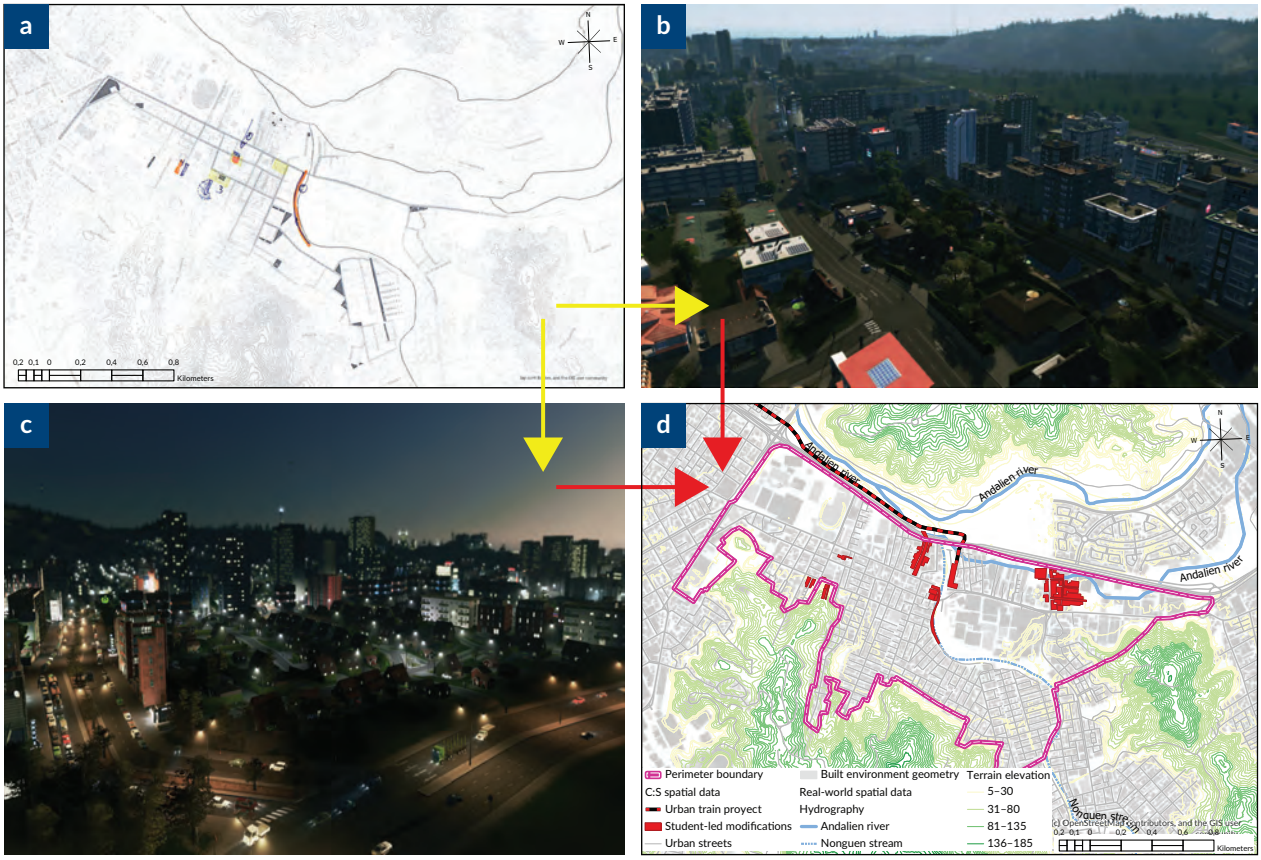


Figure 9. Sustainable urban design project process of Scenario C: (a) student sketch of proposed interventions; (b–c) game-based simulation of these interventions in C:S; (d) final cartographic outputs exported to ArcGIS Pro. Yellow arrows indicate the transfer of design alternatives into C:S; red arrows indicate their georeferenced mapping in the Collao neighbourhood.

also recognised that the quantitative dimension of C:S facilitated critical reflection on competing urban interests and the complexity of planning processes, thus contributing to the development of a civic perspective on urban problems. Students proposed diverse interventions that moved beyond vehicle-centred planning (Núñez Cerda et al., 2024; Zumelzu et al., 2024), including multimodal transport, public space improvements, and proximity-based housing:

> My teammate and I proposed implementing a Biotren line to reduce congestion, along with enhancements to cycle lanes in Collao–Novoa, better lighting, and improved pedestrian walkways. (Student-02, 2025)

> I decided to design residential buildings near key destinations—such as the university—to encourage mobility through proximity, particularly for students. (Student-04, 2025)

Through these exchanges, students reached consensus both among peers and with facilitators, reflecting the iterative negotiation processes of SUP. The immediacy of testing proposals within the simulation fostered what we term a "metaconsensus," emerging from the recurring question: "What would happen if we implemented this?". Participants also highlighted the intuitive and realistic nature of C:S, underscoring its role in facilitating agreement and future-oriented planning:

> Intuitive, and a very useful tool for learning all the things that need to be considered before making any changes within a city. (Student-10, 2025)

> I learnt that it is important to share my point of view and personal experiences to contribute to urban improvement. (Student-05, 2025)

These reflections reinforce Ahlqvist and Schlieder's (2018) notion of "georealistic" simulations, illustrating how game-based simulations embedded in geogames can enhance both individual learning and collective decision-making in urban contexts. Building on this idea, geogames emphasise playful interaction, negotiation, and co-creation, articulated here through a novel geogame-based simulation approach. Unlike other digital participatory tools such as digital twins or VR games, which focus mainly on representation, geogames add a playful and collaborative layer that strengthens inclusive and participatory decision-making, fully aligning with the principles of SUP (Poplin et al., 2020). These insights provide the foundation for the key contributions of the dual and interconnected geogame framework.

5.4. Key Contributions of the Dual Interconnected Geogame

Responding to the research question and objective, our results suggest that the dual and interconnected geogame—built on distinct game-based simulation strategies—provides a feasible and innovative method within SUP for fostering socially sustainable active mobility. By incorporating a game-based simulation tool, this approach reinforces the role of geogames as instruments for co-creating urban strategies through quantitative urban data modelling. By enabling participatory decision-making in complex urban systems, it allows diverse actors to negotiate shared interests and generate context-sensitive solutions. Overall, the findings point to progress towards the democratisation of complex urban planning processes, consistent with Rodríguez (2018). The key contributions of each iteration are summarised in Table 2.

Table 2. Contributions of each interconnected geogame iteration.

Aspect	Scenario A	Scenario B	Scenario C
Participants	Planning and mobility experts	Facilitators	Architecture students
Objective	Validate game-based simulation	Test citizen-informed AM alternatives	Co-create post-pandemic design improvements
Method	SUM scenario testing	Geoplay with social geomarketing data	Immersive game-based simulation and scenario redesign
Role Assumed	Initial omniscient planner (top-down urban planning)	Scenario B tester	Collaborative designer (bottom-up urban planning)
Outcome	Game-based simulation validated for bottom-up planning	Improved modal shift and spatial accessibility	Scenario C achieved metaconsensus through participatory co-creation
SUP Contribution	Introduced C:S for expert-based analysis	Integration of bottom-up data	Reinforced geogames for systemic, playful, and inclusive urban design

6. Final conclusions

This study suggests the feasibility of integrating quantitative urban data into participatory geogames through game-based simulation, in line with our initial hypothesis and objective. The dual and interconnected geogame methodology appears to enable both experts and students to interact with real spatial data in C:S; experts contributed to the calibration and validation of a sustainable scenario (B), while students co-designed an enhanced version (C) informed by citizen preferences. The findings point to the potential of geogames as decision-support tools that may foster metaconsensus, strengthen civic engagement, and promote systemic and inclusive urban co-creation through the guiding question "What if?" By linking playful design with AM promotion, geogames may be positioned as methodological innovations for advancing SUP and contributing to socially sustainable active mobility. The second geogame, in particular, illustrates how game-based simulation might empower citizens as critical agents in addressing urban challenges while supporting learning and collaboration. Overall, the research indicates that geogames may act as a bridge between quantitative game-based simulation and bottom-up planning, as suggested by Cartes-Siade et al. (2024, p. 122), and provides additional evidence of their potential to generate metaconsensus and democratise decision-making in complex urban systems, especially in resource-constrained Global South contexts. As such, this study should be read as a proof of concept, suggesting a transferable methodological pathway for medium-sized cities in similar contexts.

Nonetheless, the scalability of the dual-geogame methodology may remain constrained by the need for tailored facilitation, technical configurations, and participant training, which could limit its broader application in low-capacity institutional settings. Although the game-based simulations integrated real demographic and spatial data, they did not yet incorporate live or time-sensitive datasets that might improve responsiveness and decision-making accuracy. Participant involvement—while rich in qualitative feedback—was limited to small-scale pilots with experts and undergraduate architecture students. The latter offered valuable insights into the methodological performance of the framework, but represent a relatively homogeneous group in terms of age, background, and exposure to urban concepts, which may introduce biases and limit generalisability. Their dual role as both "informed citizens" and future professionals could further influence perceptions and negotiation processes. Still, positioning students as an exploratory sample aligns with living lab practices and student-based prototyping, where early testing in controlled environments is used to refine participatory tools before engaging broader and more diverse stakeholders, in line with the quintuple helix model proposed by Almeida and Deutsch (2025), for example. Ethical safeguards—including institutional approval, informed consent, and data confidentiality—were followed, yet gamified participation also raises questions of inclusion, as factors such as age, digital literacy, or gaming experience may shape engagement. Future research should therefore broaden stakeholder diversity and explore additional safeguards to enhance inclusivity, strengthening the robustness and representativeness of participatory planning outcomes.

In this light, geogames may emerge as disruptive methodologies that challenge conventional planning approaches (Hudson-Smith & Shakeri, 2022; Poplin et al., 2022), opening new avenues for more democratic, playful, and data-informed urban governance. Future research could explore the integration of real-time data, adaptive AI systems, and the involvement of more diverse stakeholder groups across all phases of SUP, and further consolidate the role of interconnected geogame-based simulation as agile and participatory tools. Future research could also contrast geogame-based simulations with other digital participatory

approaches to evaluate their relative effectiveness in fostering socially sustainable active mobility and other urban transformations—ultimately positioning geogames as part of The Future's Language of Urban and Regional Planning.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The full survey instrument is openly available for consultation: https://forms.gle/yxSBZ9GLVoZ9kCg9A

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

References

Ahlqvist, O., & Schlieder, C. (2018). Introducing geogames and geoplay: Characterizing an emerging research field. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay* (pp. 1–18). Springer. https://doi.org/10.1007/978-3-319-22774-0_1

Albornoz, E., Núñez, F., & Mena, C. (2020). Geomarketing: Desde una visión comercial a una aplicación social, en contextos metropolitanos. *Revista de Geografía Norte Grande*, *76*, 143–167. https://doi.org/10.4067/S0718-34022020000200143

Almeida, F., & Deutsch, N. (2025). Urban living labs as catalysts for innovation: Advancing urban ecosystems within the quintuple helix model. *Urban Governance*, *5*(2), 133–141. https://doi.org/10.1016/j.ugj.2025.05.005

Andhika, G., & Anggita, M. (2022). Model into playable simulation in games cities. In W. Striełkowski, J. M. Black, S. A. Butterfield, C.-C. Chang, J. Cheng, F. P. Dumanig, R. Al-Mabuk, M. Urban, & S. Webb (Eds.), *Proceedings of the International Webinar on Digital Architecture 2021 (IWDA 2021)* (pp. 302–306). Atlantis Press. https://doi.org/10.2991/assehr.k.220703.054

Arias-Molinares, D., García-Palomares, J. C., & Gutiérrez, J. (2022). Micromobility services before and after a global pandemic: impact on spatio-temporal travel patterns. *International Journal of Sustainable Transportation*, *17*(9), 1058–1073. https://doi.org/10.1080/15568318.2022.2147282

Arnold, U., Söbke, H., & Reichelt, M. (2019). SimCity in infrastructure management education. *Education Sciences*, *9*(3), Article 209. https://doi.org/10.3390/educsci9030209

Becker, H., Becker, F., Abe, R., Bekhor, S., Belgiawan, P. F., Compostella, J., Frazzoli, E., Fulton, L. M., Guggisberg Bicudo, D., Gurumurthy, K. M., Hensher, D. A., Joubert, J. W., Kockelman, K. M., Kröger, L., Le Vine, S., Malik, J., Marczuk, K., Nasution, R. A., . . . Axhausen, K. W. (2020). Impact of vehicle automation and electric

propulsion on production costs for mobility services worldwide. *Transportation Research Part A: Policy and Practice*, *138*, 105–126. https://doi.org/10.1016/j.tra.2020.04.021

Bello-Maldonado, G. D. (2019). Un videojuego que promueve la participación ciudadana interactiva en las reformas urbanas. *Virtu@lmente*, *7*(2), 95–112. https://doi.org/10.21158/2357514x.v7.n2.2019.2573

Bereitschaft, B. (2015). Gods of the city? Reflecting on city building games as an early introduction to urban systems. *Journal of Geography*, *115*(2), 51–60. https://doi.org/10.1080/00221341.2015.1070366

Bersini, H. (2012). UML for ABM. *Journal of Artificial Societies and Social Simulation*, *15*(1), Article 9. https://doi.org/10.18564/jasss.1897

Bilal, S., Zaatour, W., Alonso, Y., Saha, A., Newcomb, K., Kim, S., Kim, J., Ginjala, R., Groen, D., & Michael, E. (2025). CitySEIRCast: An agent-based city digital twin for pandemic analysis and simulation. *Complex & Intelligent Systems*, *11*, Article 83. https://doi.org/10.1007/s40747-024-01683-x

Carrasco, P. (2023, December 14). "Es necesario": Expertos valoran estudio para definir tranvía, metro o tren subterráneo para Concepción. *Diario Concepción*. https://www.diarioconcepcion.cl/ciudad/2023/12/14/es-necesario-expertos-valoran-estudio-para-definir-tranvia-metro-o-tren-subterraneo-para-concepcion.html

Cartes-Siade, I., Gaete-Feres, H., Baeriswyl-Rada, S., López-Meza, M. I., Sabatini-Downey, F., Bisbal-Grandal, I., Núñez-Cerda, F., Napadensky-Pastene, A., Albornoz-del-Valle, E., & Zazo-Moratalla, A. (2024). Los retos de la planificación urbana. *Urbano*, *27*(50), 114–123. https://revistas.ubiobio.cl/index.php/RU/article/view/6865

Chondrogianni, D., & Karatzas, S. (2023). A systems approach for managing risks with complex interactions in urban spaces. *City and Environment Interactions*, *20*, Article 100117. https://doi.org/10.1016/j.cacint.2023.100117

Crooks, A., Malleson, N., Manley, E., & Heppenstall, A. (2019). *Agent-based modelling and geographical information systems: A practical primer*. Sage.

D'Artista, B. R., & Hellweger, F. L. (2007). Urban hydrology in a computer game? *Environmental Modelling & Software*, *22*(11), 1679–1684. https://doi.org/10.1016/j.envsoft.2006.09.004

de Andrade, B., Poplin, A., & de Sena, Í. S. (2020). Minecraft as a tool for engaging children in urban planning: A case study in Tirol Town, Brazil. *ISPRS International Journal of Geo-Information*, *9*(3), Article 170. https://doi.org/10.3390/ijgi9030170

Devisch, O. (2008). Should planners start playing computer games? Arguments from SimCity and Second Life. *Planning Theory & Practice*, *9*(2), 209–226. https://doi.org/10.1080/14649350802042231

Escudero, N. (2017). *Movilidad urbana y ciudad sustentable: Las experiencias de los casos de Curitiba y de Nantes, desde la perspectiva de la sustentabilidad*. Fondo de Cultura Económica.

Evans, G. (2015). Accessibility and user needs pedestrian mobility and urban design in the UK. *Proceedings of the Institution of Civil Engineers*, *168*(1), 32–44. https://doi.org/10.1680/muen.14.00012

González-Méndez, M., Olaya, C., Fasolino, I., Grimaldi, M., & Obregón, N. (2021). Agent-based modeling for urban development planning based on human needs. Conceptual basis and model formulation. *Land Use Policy*, *101*, Article 105110. https://doi.org/10.1016/j.landusepol.2020.105110

Gordon, E., Schirra, S., & Hollander, J. (2011). Immersive planning: A conceptual model for designing public participation with new technologies. *Environment and Planning B: Planning and Design*, *38*(3), 505–519. https://doi.org/10.1068/b37013

Guzmán, L. A., Oviedo, D., & Cantillo-Garcia, V. A. (2024). Is proximity enough? A critical analysis of a 15-minute city considering individual perceptions. *Cities*, *148*, Article 104882. https://doi.org/10.1016/j.cities.2024.104882

Hammady, R., & Arnab, S. (2022). Serious gaming for behaviour change: A systematic review. *Information*, *13*(3), Article 142. https://doi.org/10.3390/info13030142

Haufe, N., Millonig, A., & Markvica, K. (2016). Developing encouragement strategies for active mobility. *Transportation Research Procedia*, *19*, 49–57. https://doi.org/10.1016/j.trpro.2016.12.067

Heppenstall, A., Crooks, A., See, L., & Batty, M. (Eds.). (2012). *Agent-based models of geographical systems*. Springer. https://doi.org/10.1007/978-90-481-8927-4

Herrmann-Lunecke, M. G., Mora, R., & Véjares, P. (2020). Identificación de elementos del paisaje urbano que fomentan la caminata en Santiago. *Revista de Urbanismo*, 43, 4–25. https://doi.org/10.5354/0717-5051.2020.55975

Herrmann-Lunecke, M. G., Mora, R., & Vejares, P. (2021). Perception of the built environment and walking in pericentral neighbourhoods in Santiago, Chile. *Travel Behaviour and Society*, *23*, 192–206. https://doi.org/10.1016/j.tbs.2021.01.002

Huang, S.-L., Yeh, C.-T., & Chang, L.-F. (2010). The transition to an urbanizing world and the demand for natural resources. *Current Opinion in Environmental Sustainability*, *2*(3), 136–143. https://doi.org/10.1016/j.cosust.2010.06.004

Hudson-Smith, A., & Shakeri, M. (2022). The future's not what it used to be: Urban wormholes, simulation, participation, and planning in the metaverse. *Urban Planning*, *7*(2), 214–217. https://doi.org/10.17645/up.v7i2.5893

Jirón, P., & Mansilla, P. (2013). Atravesando la espesura de la ciudad: vida cotidiana y barreras de accesibilidad de los habitantes de la periferia urbana de Santiago de Chile. *Revista de Geografía Norte Grande*, 56, 53–74. https://doi.org/10.4067/S0718-34022013000300004

Jirón, P., & Mansilla, P. (2014). Las consecuencias del urbanismo fragmentador en la vida cotidiana de habitantes de la ciudad de Santiago de Chile. *EURE (Santiago)*, *40*(121), 5–28. https://doi.org/10.4067/S0250-71612014000300001

Jirón, P., & Rivas, A. (2020). ¿Qué hay detrás de las intervenciones urbanas? Elementos históricos para develar las racionalidades urbanísticas en Chile. *Revista de Geografía Norte Grande*, 77, 109–132. https://doi.org/10.4067/S0718-34022020000300109

Jolly, R., & Budke, A. (2023). Assessing the extent to which players can build sustainable cities in the digital city-builder game "Cities: Skylines." *Sustainability*, *15*(14), Article 10780. https://doi.org/10.3390/su151410780

Juraschek, M., Herrmann, C., & Thiede, S. (2017). Utilizing gaming technology for simulation of urban production. *Procedia CIRP*, *61*, 469–474. https://doi.org/10.1016/j.procir.2016.11.224

Kavouras, I., Sardis, E., Protopapadakis, E., Rallis, I., Doulamis, A., & Doulamis, N. (2023). A low-cost gamified urban planning methodology enhanced with co-creation and participatory approaches. *Sustainability*, *15*(3), Article 2297. https://doi.org/10.3390/su15032297

Khan, T. A., & Zhao, X. (2021). Perceptions of students for a gamification approach: Cities Skylines as a pedagogical tool in urban planning education. In D. Dennehy, A. Griva, N. Pouloudi, Y. K. Dwivedi, I. Pappas, & M. Mäntymäki (Eds.), *Responsible AI and analytics for an ethical and inclusive digitized society* (pp. 761–774). Springer. https://doi.org/10.1007/978-3-030-85447-8_64

Koens, K., Klijs, J., Weber-Sabil, J., Melissen, F., Lalicic, L., Mayer, I., Önder, I., & Aall, C. (2020). Serious gaming to stimulate participatory urban tourism planning. *Journal of Sustainable Tourism*, *30*(9), 2167–2186. https://doi.org/10.1080/09669582.2020.1819301

Kong, H., Wu, J., & Li, P. (2024). Impacts of active mobility on individual health mediated by physical activities. *Social Science & Medicine*, *348*, Article 116834. https://doi.org/10.1016/j.socscimed.2024.116834

Krath, J., Schürmann, L., & von Korflesch, H. F. O. (2021). Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning. *Computers in Human Behavior*, *125*, Article 106963. https://doi.org/10.1016/j.chb.2021.106963

Le Gouais, A., Bates, G., Callway, R., Kwon, H. R., Montel, L., Peake-Jones, S., White, J., Hasan, M. N., Koksal, C., Barnfield, A., Bondy, K., & Ayres, S. (2023). Understanding how to create healthier places: A qualitative study exploring the complex system of urban development decision-making. *Health & Place*, *81*, Article 103023. https://doi.org/10.1016/j.healthplace.2023.103023

León, J., Núñez, F., & Albornoz, E. (2019). Participación ciudadana y movilidad sostenible: El caso del área metropolitana de Concepción, Chile. *Revista de Urbanismo*, *40*. https://doi.org/10.5354/0717-5051.2019.52227

Liu, Y., Zhang, L., Philippopoulos-Mihalopoulos, A., Chappin, E., & van Dam, K. H. (2021). Integrating agent-based modeling, serious gaming, and co-design for planning transport infrastructure and public spaces. *Urban Design International*, *26*(1), 67–81. https://doi.org/10.1057/s41289-020-00117-7

López-Soler, J., Christidis, P., & Vassallo, J. (2023). Evolution of teleworking and urban mobility changes driven by the Covid-19 pandemic across European cities. *Transportation Research Procedia*, *69*, 488–495. https://doi.org/10.1016/j.trpro.2023.02.199

Markvica, K., Millonig, A., Haufe, N., & Leodolter, M. (2020). Promoting active mobility behavior by addressing information target groups: The case of Austria. *Journal of Transport Geography*, *83*, Article 102664. https://doi.org/10.1016/j.jtrangeo.2020.102664

Martínez-Bello, N., Cruz-Prieto, M. J., Güemes-Castorena, D., & Mendoza-Domínguez, A. (2021). A methodology for designing smart urban living labs from the university for the cities of the future. *Sensors*, *21*(20), Article 6712. https://doi.org/10.3390/s21206712

Mayer, I. S., Carton, L., de Jong, M., Leijten, M., & Dammers, E. (2004). Gaming the future of an urban network. *Futures*, *36*(3), 311–333. https://doi.org/10.1016/S0016-3287(03)00159-9

Mayer, I. S., van Bueren, E. M., Bots, P. W. G., van der Voort, H., & Seijdel, R. (2005). Collaborative decision-making for sustainable urban renewal projects: A simulation–gaming approach. *Environment and Planning B: Planning and Design*, *32*(3), 403–423. https://doi.org/10.1068/b31149

Minnery, J., & Searle, G. (2014). Toying with the city? Using the computer game SimCity™4 in planning education. *Planning Practice & Research*, *29*(1), 41–55. https://doi.org/10.1080/02697459.2013.829335

Mohammadi, N., & Taylor, J. E. (2017, November 27-December 1). *Smart city digital twins* [Paper presentation]. 2017 IEEE Symposium Series on Computational Intelligence (SSCI), Honolulu, HI, United States. https://doi.org/10.1109/SSCI.2017.8285439

Morales, I., Segalás, J., & Masseck, T. (2023). Urban living labs: A higher education approach to teaching and learning about sustainable development. *Sustainability*, *15*(20), Article 14876. https://doi.org/10.3390/su152014876

Muehlhaus, S. L., Eghtebas, C., Seifert, N., Schubert, G., Petzold, F., & Klinker, G. (2023). Game.UP: Gamified urban planning participation enhancing exploration, motivation, and interactions. *International Journal of Human–Computer Interaction*, *39*(2), 331–347. https://doi.org/10.1080/10447318.2021.2012379

Mueller, C., Klein, U., & Hof, A. (2018). An easy-to-use spatial simulation for urban planning in smaller municipalities. *Computers, Environment and Urban Systems*, *71*, 109–119. https://doi.org/10.1016/j.compenvurbsys.2018.05.002

Nijkamp, P., & Kourtit, K. (2013). The "new urban Europe": Global challenges and local responses in the urban century. *European Planning Studies*, *21*(3), 291–315. https://doi.org/10.1080/09654313.2012.716243

Núñez, F., Albornoz, E., Gutiérrez, M., & Zumelzu, A. (2022). Socially sustainable accessibility to goods and

services in the Metropolitan Area of Concepción, Chile, post-Covid-19. *Sustainability*, *14*(21), Article 14042. https://doi.org/10.3390/su142114042

Núñez, F., Albornoz, E., León, J., & Zumelzu, A. (2022). Socially sustainable mobility: Strategic analysis to identify accessibility barriers. *Sustainable Cities and Society*, *76*, Article 103420. https://doi.org/10.1016/j.scs.2021.103420

Núñez Cerda, F. J., Albornoz del Valle, E., & Zumelzu Scheel, A. (2024). Alternativas para desplazamientos sostenibles en Concepción, Chile: percepciones pre y durante la pandemia de Covid-19. *ACE: Architecture, City and Environment*, *19*(56). https://doi.org/10.5821/ace.19.56.13248

Olszewski, R., Cegiełka, M., Szczepankowska, U., & Wesołowski, J. (2020). Developing a serious game that supports the resolution of social and ecological problems in the toolset environment of Cities: Skylines. *ISPRS International Journal of Geo-Information*, *9*(2), Article 118. https://doi.org/10.3390/ijgi9020118

Papageorgiou, G., Tsappi, E., & Wang, T. (2024). Smart urban systems planning for active mobility and sustainability. *IFAC-PapersOnLine*, *58*(10), 261–266. https://doi.org/10.1016/j.ifacol.2024.07.350

Piños, J., & Burian, J. (2022). The application of city-building games in spatial planning. In J. Panek (Ed.), *Geoparticipatory spatial tools* (pp. 147–185). Springer. https://doi.org/10.1007/978-3-031-05547-8_8

Piños, J., Vozenilek, V., & Pavlis, O. (2020). Automatic geodata processing methods for real-world city visualizations in Cities: Skylines. *ISPRS International Journal of Geo-Information*, *9*(1), Article 17. https://doi.org/10.3390/ijgi9010017

Poplin, A. (2011). Games and serious games in urban planning: Study cases. In B. Murgante, O. Gervasi, A. Iglesias, D. Taniar, & B. O. Apduhan (Eds.), *Computational Science and Its Applications—ICCSA 2011* (pp. 1–14). Springer. https://doi.org/10.1007/978-3-642-21887-3_1

Poplin, A., de Andrade, B., & de Sena, Í. (2020). Geogames for change: Cocreating the future of cities with games. In D. Leorke & M. Owens (Eds.), *Games and play in the creative, smart and ecological city* (pp. 64–93). Routledge. https://doi.org/10.4324/9781003007760

Poplin, A., de Andrade, B., & de Sena, Í. (2022). Let's discuss our city! Engaging youth in the co-creation of living environments with digital serious geogames and gamified storytelling. *Environment and Planning B: Urban Analytics and City Science*, *50*(4), 1087–1103. https://doi.org/10.1177/23998083221133828

Poplin, A., & Vemuri, K. (2018). Spatial game for negotiations and consensus building in urban planning: YouPlaceIt! In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay* (pp. 63–90). Springer. https://doi.org/10.1007/978-3-319-22774-0_4

Portugali, J. (2000). *Self-organization and the city*. Springer. https://doi.org/10.1007/978-3-662-04099-7

Prajapati, S. P., Bhaumik, R., & Kumar, T. (2023). An intelligent ABM-based framework for developing pandemic-resilient urban spaces in post-Covid smart cities. *Procedia Computer Science*, *218*, 2299–2308. https://doi.org/10.1016/j.procs.2023.01.205

Raghothama, J., Baalsrud Hauge, J., & Meijer, S. (2022). Curating player experience through simulations in city games. *Urban Planning*, *7*(2), 253–263. https://doi.org/10.17645/up.v7i2.5031

Rahman, M. T. (2016). Detection of land use/land cover changes and urban sprawl in Al-Khobar, Saudi Arabia: An analysis of multi-temporal remote sensing data. *ISPRS International Journal of Geo-Information*, *5*(2), Article 15. https://doi.org/10.3390/ijgi5020015

Ramírez-Saiz, A., Alonso, A., Jiménez-Martín, D., & Lamíquiz, P. (2022). Can proximal environments prevent social inequalities amongst people of all ages and abilities? An integrative literature review approach. *Sustainability*, *14*(19), Article 12911. https://doi.org/10.3390/su141912911

Rejeb, R., Bouscasse, H., Chalabaev, A., & Mathy, S. (2023). What is the role of active mobility habits in the relationship between self-determination and modal shift intentions? A mediation analysis. *Transportation Research Part F: Traffic Psychology and Behaviour*, *99*, 289–305. https://doi.org/10.1016/j.trf.2023.10.004

Ribeiro-Rodrigues, E., & Bortoleto, A. (2024). A systematic review of agent-based modeling and simulation applications for analyzing pro-environmental behaviors. *Sustainable Production and Consumption*, *47*, 343–362. https://doi.org/10.1016/j.spc.2024.04.017

Robinson, G. M., Hardman, M., & Matley, R. J. (2021). Using games in geographical and planning-related teaching: Serious games, edutainment, board games and role-play. *Social Sciences and Humanities Open*, *4*(1), Article 100208. https://doi.org/10.1016/j.ssaho.2021.100208

Rodríguez, L. G. (2018). Contribución a la crítica de la teoría de los sistemas complejos: Bases para un programa de investigación. *Estudios Sociológicos de El Colegio de México*, *36*(106), 73–98. https://doi.org/10.24201/es.2018v36n106.1530

Roumpani, F. (2022). Procedural cities as active simulators for planning. *Urban Planning*, *7*(2), 321–329. https://doi.org/10.17645/up.v7i2.5209

Roy, J. (2019, March 5). Must reads: From video game to day job: How 'SimCity' inspired a generation of city planners. *Los Angeles Times*. https://www.latimes.com/business/technology/la-fi-tn-simcity-inspired-urban-planners-20190305-story.html

Rufat, S., & Ter Minassian, H. (2012). Video games and urban simulation: New tools or new tricks? *Cybergeo: European Journal of Geography*, *2012*, Article 622. https://doi.org/10.4000/cybergeo.25561

Ruiz, J. (2002). *La enseñanza del urbanismo y la enseñanza de la práctica del urbanismo: Un proyecto docente en el marco de la realidad urbana compleja* (Cuadernos de Investigación Urbanística, 35). Universidad Politécnica de Madrid. https://polired.upm.es/index.php/ciur/article/view/249

Ruiz-Tagle, J. (2007). Modeling and simulating the city: Deciphering the code of a game of strategy. *International Journal of Architectural Computing*, *5*(3), 571–586. https://doi.org/10.1260/147807707782581747

Ruiz-Tagle, J., Cox, T., & Gurovich, A. (2009). *Modelos de simulación urbana: Aproximación experimental a los fenómenos de la ciudad*. Universidad de Chile.

Ruiz-Tagle, J., & Gurovich, A. (2007). Modelos de simulación urbana: Experiencia a partir de un juego de estrategia. *Revista de Arquitectura*, *13*(15), 61–66. https://doi.org/10.5354/0719-5427.2007.28230

Scacchi, W. (2010). Computer game mods, modders, modding, and the mod scene. *First Monday*, *15*(5). https://doi.org/10.5210/fm.v15i5.2965

Semeraro, T., Nicola, Z., Lara, A., Sergi Cucinelli, F., & Aretano, R. (2020). A bottom-up and top-down participatory approach to planning and designing local urban development: Evidence from an urban university center. *Land*, *9*(4), Article 98. https://doi.org/10.3390/land9040098

Senior, C., Temeljotov Salaj, A., Cepuran, A., Gabriela Diaconu, M., & Johansen, A. (2023). Sustainable decision-making game for the next generation of smart citizens. *IOP Conference Series: Earth and Environmental Science*, *1196*, Article 012087. https://doi.org/10.1088/1755-1315/1196/1/012087

Shakeri, M. (2022). Unstable wormholes: Communications between urban planning and game studies. *Urban Planning*, *7*(2), 218–228. https://doi.org/10.17645/up.v7i2.4953

Shi, H., Li, Y., Kong, Y., Ji, Y., Liu, Q., Huang, H., & Zhao, M. (2025). Cities in electronic games: How they present and impact real urban areas? *Journal of Asian Architecture and Building Engineering*, *24*(5), 4517–4531. https://doi.org/10.1080/13467581.2024.2399688

Sotamaa, O. (2010). When the game is not enough: Motivations and practices among computer game modding culture. *Games and Culture*, *5*(3), 239–255. https://doi.org/10.1177/1555412009359765

Sousa, M. (2023). Modeling urban spaces with cubes: Building analogue serious games for collaborative planning. *International Journal of Film and Media Arts*, *8*(1), 8–35. https://doi.org/10.24140/ijfma.v8.n1.01

Tan, E. (2022). Network of games: An ecology of games informing integral and inclusive city developments. *Urban Planning*, *7*(2), 264–277. https://doi.org/10.17645/up.v7i2.5136

Tromaras, A., Aggelakakis, A., Hoppe, M., Trachsel, T., & Anoyrkati, E. (2019). Future technologies in the EU transport sector and beyond: An outlook of 2020–2035. In E. Nathanail & I. Karakikes (Eds.), *Data analytics: Paving the way to sustainable urban mobility* (pp. 722–729). Springer. https://doi.org/10.1007/978-3-030-02305-8_87

UN-Habitat. (2007). *Inclusive and sustainable urban development planning: A guide for municipalities* (Vol. 1). https://unhabitat.org/a-guide-for-municipalities-inclusive-and-sustainable-urban-development-planning-volume-1

Vega-Gonzalo, M., Gomez, J., & Christidis, P. (2023). How has Covid-19 changed private car use in European urban areas? An analysis of the effect of socio-economic characteristics and mobility habits. *Transportation Research Part A: Policy and Practice*, *172*, Article 103679. https://doi.org/10.1016/j.tra.2023.103679

Vélez, A. (2019). Modelación y simulación basada en agentes en ciencias sociales: Una aproximación al estado del arte. *Polis*, *18*(53), 186–202. https://polis.ulagos.cl/index.php/polis/article/view/449

Vieira, L., & Coutinho, C. (2016). Urban games: How to increase the motivation, interaction and perceived learning of students in the schools. *International Journal of Mobile and Blended Learning*, *8*(2), 55–72. https://doi.org/10.4018/IJMBL.2016040105

Waddell, P. (2002). UrbanSim: Modeling urban development for land use, transportation, and environmental planning. *Journal of the American Planning* Association, *68*(3), 297–314. https://doi.org/10.1080/01944360208976274

Wang, S.-M., & Vu, L. H. (2023). The integration of digital twin and serious game framework for new normal virtual urban exploration and social interaction. *Journal of Urban Management*, *12*(2), 168–181. https://doi.org/10.1016/j.jum.2023.03.001

Weil, C., Bibri, S. E., Longchamp, R., Golay, F., & Alahi, A. (2023). Urban digital twin challenges: A systematic review and perspectives for sustainable smart cities. *Sustainable Cities and Society*, *99*, Article 104862. https://doi.org/10.1016/j.scs.2023.104862

Yuen, B., Bhuyan, M. R., Ho, D., & Joyce, S. (2024). Redefining active mobility from spatial to social in Singapore. *Journal of Transport & Health*, *38*, Article 101869. https://doi.org/10.1016/j.jth.2024.101869

Zumelzu, A., Estrada, M., Moya, M., & Troppa, J. (2022). Experiencing public spaces in southern Chile: Analysing the effects of the built environment on walking perceptions. *International Journal of Environmental Research and Public Health*, *19*(19), Article 12577. https://doi.org/10.3390/ijerph191912577

Zumelzu, A., & Herrmann-Lunecke, M. G. (2021). Mental well-being and the influence of place: Conceptual approaches for the built environment for planning healthy and walkable cities. *Sustainability*, *13*(11), Article 6395. https://doi.org/10.3390/su13116395

Zumelzu, A., Heskia, C., Herrmann-Lunecke, M. G., Vergara, G., Estrada, M., & Jara, C. (2024). Street design elements that influence mental well-being: Evidence from southern Chile. *Land*, *13*(9), Article 1398. https://doi.org/10.3390/land13091398

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From City-Builder to Geogame: A Geodesign Process for Participatory Urban Planning

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Abstract

City-building games (CBGs) have a long history of focusing on societal simulation and urban management gameplay, including *The Sumerian Game* (1964), *Micropolis*, later named *SimCity* (1989), and *Utopia: Creation of a Nation* (1991). In this article, we present the outcomes of a pilot study through which we have developed an innovative process that transfers CBGs' gameplay actions into real-world planning systems. To evaluate the interplay between CBG simulation and the real world, we delivered workshops to 140 young people and adults to design their local community in South Lancaster, UK, using *Cities: Skylines I and II*. A novel approach using GIS and machine learning tools was developed to analyse young people's planning decisions and needs in the area, focusing on the act of "play" within the game. These analytical tools, which involved the semantic classification of game imagery, yielded insights into land-use decisions. Through game updates released during the study of *Cities: Skylines II*, we explored new analytical potential and established a process to extract gameplay results that provide additional urban block and street-level tools for analysis, from CBG to geogame. The limitations of these approaches include the "black box" nature of the game and its planning model, such as zoning and focus on car-based infrastructure. However, *Cities: Skylines* has a large player community and strong potential to turn into a geogame in support of real-world planning and consultation, engaging communities. This article contributes to the literature with a novel and replicable process and case study. When geogames are applied to real-world problems, the result is a demonstration of the ability of simulations to inform real-world decisions.

Keywords

city-building games; geodesign; geogames; participatory planning; urban analytics

1. Introduction

Cities are complex systems, and it is impossible to model every aspect of them and develop potential futures, as modeling always requires abstractions, uncertainties, and simulation. The rise of the computable city, as expertly charted by Batty (2024), has identified the range of digitisation and modeling initiatives for cities. Concurrently, the increased attention to city-building games (CBGs), CAD, and architectural visualisation has supported these initiatives, as well as the development of graphical and interactive capabilities. Simulation games play a unique role in urban planning contexts, offering high educational potential. Some simulation games, such as *Micropolis* (later named *SimCity*, 1989), have been explored as abstractions of urban systems and have been the subject of numerous discussions in urban planning contexts, particularly regarding potential bias. Critiques of *SimCity*, for example, cite a lack of mixed-use zones and a preference—in the game—for car-based systems (Bereitschaft, 2015; Kim & Shin, 2015). The role of urban planning has oscillated between a housing delivery model and a much more expansive remit, incorporating community concerns in terms of health and wellbeing, participation, encompassing regions, and other aspects. CBGs have the potential to address this more expansive remit of urban planning in terms of participation. Visualisation and CAD production within architectural and urban design have converged in terms of production workflows, with a recent number of prominent examples, including Zaha Hadid Architects and Epic Games' Unreal Engine collaboration to create the procedural builder Re: Imagine London to be played in the digital game *Fortnite* (2024). The convergence between real-world design processes rests on a sharing of computer graphics and models, evidenced by early geographic open worlds such as *Cyan World's Myst Adventure* (1993), CBGs such as *Utopia: Creation of a Nation* (1991) and *CitiesXl* (2009), and 3D CAD such as *Builder* (1981), amongst many others. This article does not provide an extensive inventory of simulation games for urban systems (de Freitas, 2008). Instead, it seeks to frame a sustained interest in "play" and simulation in CBGs, as well as the potential for transforming CBGs into geogames for urban planning contexts and worldbuilding.

Worldbuilding is a practice that occurs in various forms of media, including literature, film, television, and games. It describes the construction of an imaginary world or setting in which a fictional story or activity can take place. The extent of worldbuilding is highly dependent on its use in storytelling and can include developing the world's history, geography, culture, and ecology. More recently, it has been adopted as a practice within "futuring" (Coulton et al., 2017), and games have been highlighted as a valuable approach to considering systemic responses to future challenges (Coulton et al., 2016a). Rather than a traditional CBG, whose mechanics revolve around either representing or affirming social structures, or optimizing resource management, the geogame processes presented here are essentially a worldbuilding sandbox to explore potential future planning decisions from a wide variety of perspectives from different stakeholders. Furthermore, whereas games often abstract reality to focus primarily on gameplay, worldbuilding employs a combination of diegesis (Kirby, 2010) and formats chosen to resonate with a particular audience (Coulton et al., 2016b), allowing them to envision such futures as a plausible reality in their own lives. We identified a research gap in the use of CBGs adapted for worldbuilding among young people to be utilized as geogames in planning processes.

Since the definition of "serious games" by Abt (1987), the purpose of "play" has been redefined. The field of geogames has been established, functioning in three dimensions: first, as applied to real-world problems; second, concentrating on urban planning issues; and third, utilized to engage youth (Poplin et al., 2023,

p. 1090). Geogames can act as a central mode of communication, engagement, and realignment of planning systems (Schlieder et al., 2005). We identify the opportunities presented by the three aspects of geogames to align with initiatives in digital and participatory planning in the UK and frame our research article accordingly. There is a unique role for geogames as geographic procedural game systems to unlock placemaking and provide structured learning about spatial change (Poplin et al., 2021). In addition, geogames can be enhanced through the use of generative AI and extended reality to create both tangible worlds for players, generate new levels, or provide biometric feedback (Poplin, 2024).

There is arguably a correlation between CBGs, geogames, digital planning, and citizen engagement. Alexander Wilson and Mark Tewdwr-Jones have presented the history of citizen engagement in planning, which was limited in early planning history, in relation to the current contemporary position in the UK National Planning Policy Framework (Wilson & Tewdwr-Jones, 2022). Other countries' planning systems also feature significant adaptations to systems and remits, particularly in the development of participatory aspects and community consultation in the delivery of development. In the UK, the role of digital planning has the potential to deliver participatory practice. The Ministry of Housing, Communities and Local Government (MHCLG), formerly the Department for Levelling Up, Housing and Communities (DLUHC), defines improved participation in digital planning through four strands (DLUHC, 2020):

1. It implies better access to planning data through the creation of a national planning data platform.
2. Implies faster and more efficient planning decisions through the introduction of streamlined services to speed up decision-making for applicants and planning officers.
3. Implies improved local community engagement through new community engagement toolkits, both digital and analogue.
4. Implies simpler, faster, more accessible plan-making through improved digital tools and data to speed up plan production.

The four strands of digital planning feature both the adoption of new technologies and the definition of key aims related to planning and planning engagement. Focusing on engagement, the area is highly complex. A Royal Town Planning Institute (RTPI) Practice note by Sarah Lewis discusses the limitations in the UK planning system regarding young people, both in terms of local plan consultation and provision in the built environment across play spaces, mobility, public realm, and other areas (Lewis, 2021). The RTPI in the UK stated that "response rates to a typical pre-planning consultation are around 3% of those directly made aware of it. In Local Plan consultations, this figure can fall to less than 1% of the population of a district" (Manns, 2017, para. 3). A range of projects have sought to address these deficits, such as the Voice, Opportunity, Power project (ZCD Architects et al., n.d.), in cities such as London, with planning toolkits and virtual cities (Hudson-Smith et al., 2005). In other countries, initiatives have been implemented to involve children in planning and decision-making. In child-friendly cities, as well as these works, extensive state-of-the-art reviews have been conducted (Mansfield et al., 2021; Powell, 2024; Rodela & Norss, 2022). As a working term, we adopt the term "digital planning" after Wilson and Tewdwr-Jones (2022, p. 3), which consists of:

> [The] design, deployment, and adoption of technology to provide innovative ways that assist professional planners, elected politicians, businesses, community groups and citizens: to understand changes in urban and rural areas; to help communicate change to all those interested in their places, past, present, and future.

The convergence of digital planning and the policy context, along with the lack of targeted mechanisms for underrepresented groups, created a research motivation for the conversion of CBGs to geogames for citizen engagement in local plan consultation to frame this study. This article is comprised of two parts: Part one explores the transformation of a CBG into a geogame to engage young people—the game *Cities: Skylines I* (CSI) and *Cities: Skylines II* (CSII; the two combined will hereafter be referred to as CSI&II) by Paradox Interactive and Colossal Order. The second part of the article is about analyzing gameplay and informing digital planning and local plan consultation. A pilot study explored the broad application of geogames in an applied case study of Lancaster, UK, using modified versions of CSI with 140 young people and adult carers. Results were analysed using supervised and unsupervised machine learning to extract gameplay decisions and classify percentages of land use. The study also established a workflow from new game updates and modifications for CSII that appeared during the project pilot. This stage enabled further analytical possibilities beyond land use allocation, increasing accessibility and replicability as a geogame for real-world local plan consultations, with the potential to improve young people's engagement. The purpose of the article is not to conduct an extensive qualitative evaluation or detailed examination of worldbuilding approaches, as can be found in prior published work, but rather to contribute to interrelated processes that have the potential to iterate between CBGs' worldbuilding and geogames for real-world planning decisions (Cureton & Coulton, 2024; Cureton & Hartley, 2025). This article's hypothesis aims to create a novel proof of concept and process that demonstrates games cannot reveal individual player motivations but rather reveal several play-based decisions through worldbuilding. Through this worldbuilding, using the CSI&II geospatial design game, results can be extracted and potentially fed back into real-world planning consultations. We believe that establishing processes that transform CBG results of gameplay into a geogame for real-world digital planning can significantly advance the state of the art. This article, thus, poses two research questions.

1. How can real spatial data be integrated into CSI&II and transform a CBG into a geogame to support public engagement in urban planning?
2. How can game-generated city designs be captured, analysed, and translated into useful input for professional planners?

To address these questions, we utilized the geodesign research framework originally formulated by Carl Steinitz for a pilot study in Lancaster, UK (Steinitz, 2012). The geodesign framework emerged through the development of GIS at Harvard University and the establishment of the Environmental Systems Research Institute (ESRI). Geodesign brings together the built environment and natural sciences and coalesces around maps and "models" in phases. An example of this geodesign approach and alignment between the parameters of geogames and geodesign can be seen in the Craft-My-Street project led by Chiara Cocco from University College Dublin, Ireland. In this project, young people participate in various climate scenarios through tabletop games and *Minecraft*. *Minecraft* supports OpenStreetMap (OSM) imports, allowing the block-based open-world builder to be formed using tools such as Arnis (2025) or Google Maps 3D tiles via RenderDoc. *Minecraft* is one of many popular games that incorporate real-world geographic modifications for enhanced engagement, as seen in the case of Tirol Town, Brazil (de Andrade et al., 2020). Numerous geo-maps have appeared in *Minecraft*, notably some of the UK produced by the Ordnance Survey (n.d.), National Mapping Agency. The procedural aspects of CSI&II game, along with its mechanics, align with the procedural stages and facilitation of geodesign, utilizing maps and game applications as "dialogic" devices. The site being investigated should be subject to the questions outlined below, which we applied to our Lancaster case. The six "model" geodesign phases are: representation models; process models; evaluation models; change models; impact models; and decision

models. The geodesign framework comprises six iterative procedural model steps, with three steps involving assessment and three steps involving intervention.

Six procedural steps of the geodesign framework:

Assessment

1. "How should the study area be described?" (Representation models)
2. "How does the study area function?" (Process models)
3. "Is the current study area working well?" (Evaluation models)

Intervention

4. "How might the study area be altered?" (Change models)
5. "What differences might the changes cause?" (Impact models)
6. "How should the study area be changed?" (Decision models; Steinitz, 2012, p. 3).

We mapped the transformation of CSI&II into a geogame following the six phases of the geodesign framework. In Figure 1, we gathered real-world data to construct a replica of Lancaster, UK, for use in CSI&II, specifically during the geodesign representation model phase.

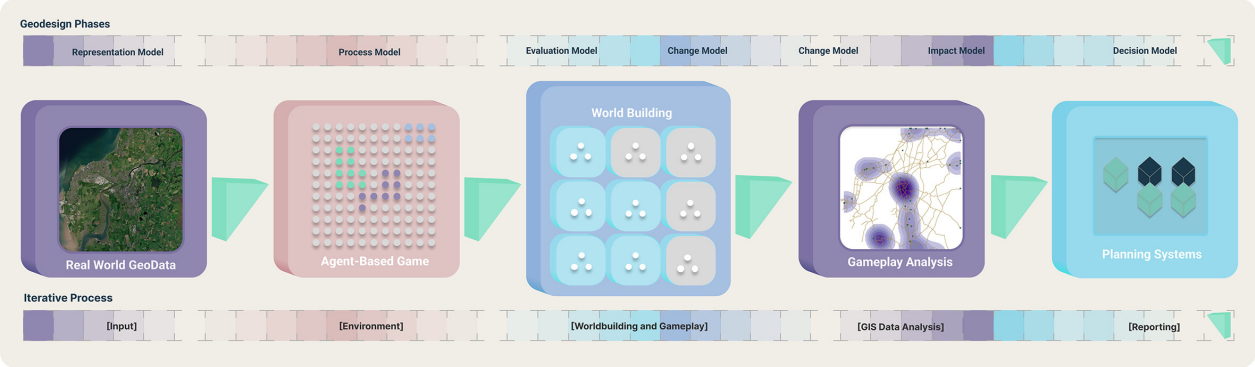

Figure 1. Geodesign framework and phases for research (top row); applied to the geogame CSI&II by Paradox Interactive and Colossal Order (middle row), an agent-based game connected to participatory planning, and exported gameplay results analysed in GIS and Rhino to formulate a report for real-world local plan consultation; the replicable research process (bottom row).

CSI&II is both an agent-based game and the process model being utilized. Young people and their adult carers played the game, and this was our evaluation model phase. The results of the gameplay were exported in the change model phase, and the analysis of the gameplay was the impact model phase. Finally, the decision model phase resulted in a report produced from the research for professional planning teams alongside training. This study addresses a critical gap in how citizen-generated spatial insights, originating from a simulated CBG planning environment, can be systematically translated into formal planning processes as a geogame that incorporates citizen feedback during local plan consultations, extending beyond traditional survey methods. By integrating GIS-based spatial evaluation with the principles of translational geodesign, we aim to demonstrate a clear process for incorporating these insights into local plan consultations and decision-making frameworks that address long-standing engagement issues among young people. Thus, we argue that geogames play a vital role in creating an ecosystem for underrepresented

groups, provide agency, are constructed based on real-world geo-data, are portable for GIS analysis and reports to inform real-world planning systems, and can create critical feedback loops.

2. CBGs, Game Engines, and Convergence

At the time of writing, CSI has been actively played for ten years, with around 10–17 million owned copies. Its sequel, CSII, has around 1.6–2.3 million owned copies (Steam Charts, n.d.-a, n.d.-b). This is important because a widely popular and modified game, with a large play community, contributes numerous real-world 1:1 scale maps and model replicas (assets), providing rich resources that would otherwise be costly and time-intensive to produce via Steam Workshop and Paradox Interactive mods. CSI is an agent-based city model builder where players respond to scenarios, grow ideal cities, and cultivate land and industry. Real-world population modifications, networks, and city governance are also available, as well as a virtual reality spin-off, *Cities VR* (2022). Researchers have also discussed the game as an educational tool (Khan & Zhao, 2021), the extent and limitations of simulation and planning (Bereitschaft, 2015), the importation of geodata, and the relationship of the game to the SDGs and sustainability (Jolly & Budke, 2023; Olszewski et al., 2020). Notably, Cañete Sanz et al. (2025) developed a card-based game based on the parameters of CSI and identified the potential of the game as a ludic tool in urban planning education. The game was identified as an important representation and process model phase in geodesign. We expand the state of the art through the addition of gameplay analysis tools and processes, enabling a game to provide feedback and connect as part of a formalised real-world planning system during the planning consultation phase. We identify a potential for CSI&II to offer meaningful citizen feedback as a geogame (Gordon & Baldwin-Philippi, 2014).

In CSI, its game mechanics remain the same, even though it may share a level of modelled "realism" by importing models of pubs, restaurants, and supermarkets, as well as players using regional "building style" packs and expansions. The gameplay provides recognizable and symbolic structures, a level of realism, and a simulated day environment that helps players relate to real-world contexts. However, its limitations on gameplay remain constrained by the game's black box play (the design of the game's agents) and mechanics, thus limiting the real-world connections. This could be improved, for example, if the agent grid parameters for residential housing could be a mixture of around four or seven attributes, with varying aesthetics, such as low-density residential housing, mixed-use, medium-density, and high-density, followed by terraced, semi-detached, or detached houses. In real-world planning, housing delivery could be much more complex and require attributes beyond the game parameters. These "black box" parameters also reveal inherent biases in terms of urban layout and housing density, and the extent to which players are aware of these aspects is hard to understand without additional evaluative steps. The game simulation also does not reflect the systems and regulatory mechanisms of planning in and of itself, nor can it; fundamentally, it is an abstraction. Further, all game worlds are subject to the rules chosen and assumptions made by their designers and are thus "self-contained universes ticking along with preprogrammed logic" (Clancy, 2024, p. 255), so assumptions drawn must critically analyse what is embodied in the rules of the game. While planning systems vary dramatically, they are typically guided by a set of frameworks for development that span urban and environmental contexts, involve stakeholders from government to industry, and include statutory phases and legislation. For this research, gameplay motivations and levels of identifiable urban realism are turned towards real-world planning, requiring players to affect a current system through their own designs. This marks a crucial phase in the geodesign process, involving the evaluation of current conditions and the creation of change models.

3. Analysis of the Gameplay in CSI

The import of geographical data features for several games, such as *Minecraft*, *Fortnite*, *Roblox*, and *Cities: Skylines*, is well-documented, along with numerous modifications to game mechanics. These features add value to the field of geogames in providing tangible environments to players. However, the critical area of transforming CBGs into geogames is the decision framework and evaluation possibilities that emerge through play. In geodesign, this constitutes the change and impact model phases, by stakeholders. In this research, we aimed to explore the potential for analyzing gameplay after workshop events, anonymised and with all identifying data removed, in accordance with ethical procedures. We utilized CSI at two events: Campus in the City, in Lancaster, UK (April 13, 2024), where we ran two-hour workshops on gaming laptops with researchers and members of the Lancaster City Council (LCC); and at the Windermere Science Festival (based in the Lake District), running open sessions (May 12, 2024). Participant information sheets and consent forms for workshop photography, featured for ethics ($N = 140$).

For the workshops, players generated feature cities based on a real-world map of Lancaster, North-West, UK. The geo-data import consisted of OSM, Digital Terrain Model (DTM), and Satellite Imagery using an importer. The game map creation process involved manually laying out game assets, such as roads and forestry, and copying satellite imagery overlays provided by the author (Figure 2). Through CSL, the CBG can be displayed with real-world urban terrain, infrastructure, natural landscapes, and roads, providing a reflective device for players to make informed decisions and choices in gameplay. Game resources were added, and the water bodies were set using spawn points. The Lancaster Map was published via a STEAM workshop (CSI) and Paradox Mods (CSII). Notably, these real-world map copies are then played, developing the built environment, agriculture, and industry, which are then often shared with the same workshops. Thus, CSI & CSII have both open unbuilt gameplay modes and gameplay based on a 1:1 scale copy of a place, mimicking real-world planning constraints. These workshops were conducted using open, unbuilt gameplay.

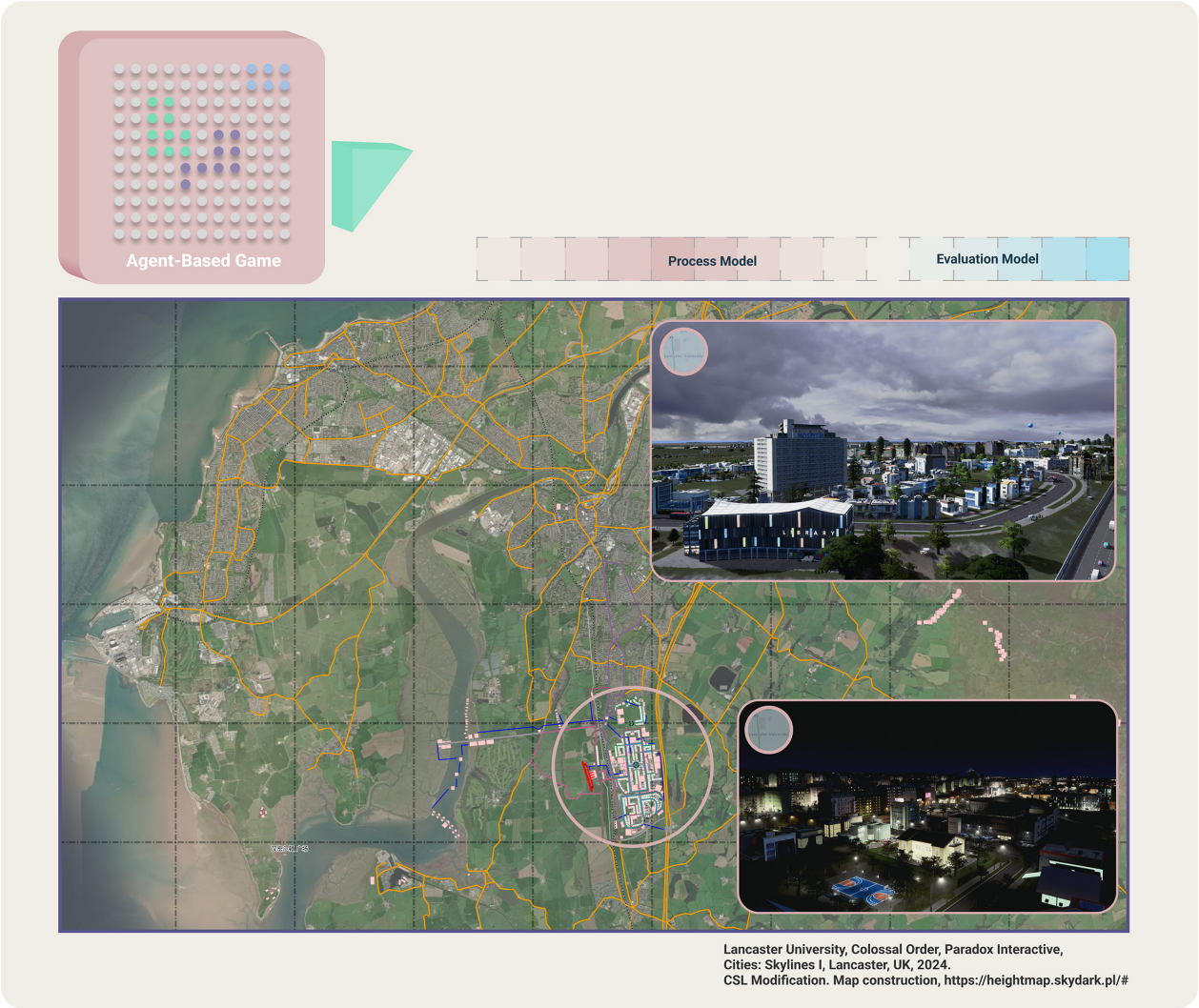

Figure 2. Example produced by the authors with CSL map modification (Lancaster University). Note: CSI map construction using the Heightmap tool and perspective images of gameplay and worldbuilding (https://heightmap.skydark.pl/)

After the workshop events, we collected anonymized screenshots of the gameplay. The resolution of screenshots was crucial for subsequent analysis, ensuring higher confidence in the results. We proceeded to georeference the game images using ESRI ArcGIS Pro through a first-order polynomial transformation to align the game images to the Ordnance Survey, Open Data map. The margin for error was high, given that the Cities: Skylines map contained various errors resulting from manual terrain modeling. As a research team, our aim was to demonstrate the viability and proof of concept pilot to Local council planners. We held a demonstration and training workshop on September 22, 2024, in preparation for the new local plan consultation for the LCC, which was scheduled to begin at the end of 2025. We present a training sample of the process here (see Figures 3 and 4).

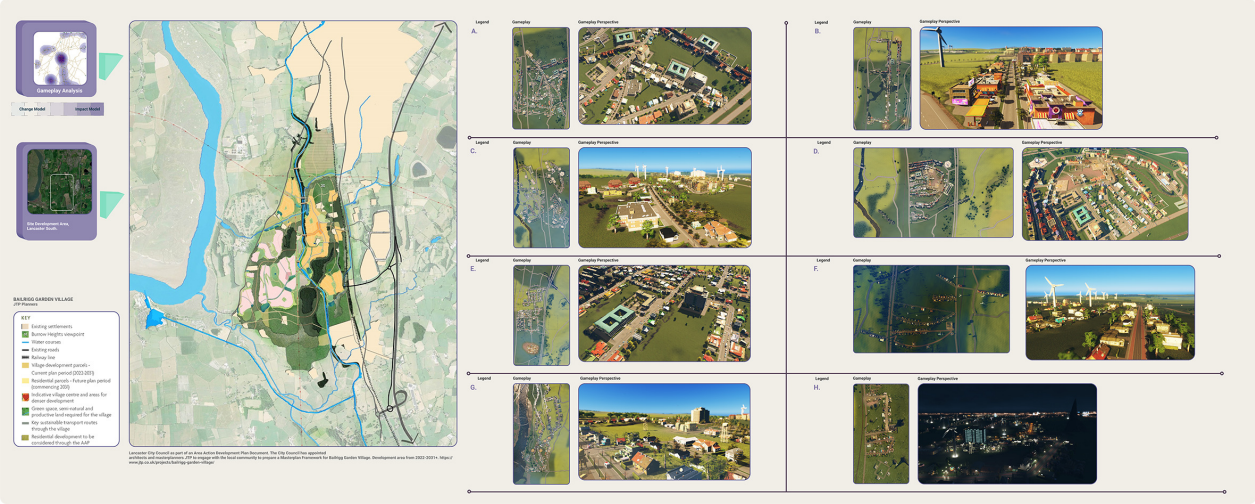

Figure 3. Juxtaposition of LCC, Local Development Plan, Bailrigg Garden Village, 5,000 mixed-tenure homes alongside green spaces and a mixed-use local centre. Notes: SPD Scheme by JTP Masterplanning Architects; Lancaster South Area Action Plan, UK, and Sample Study Game Images (A-H).

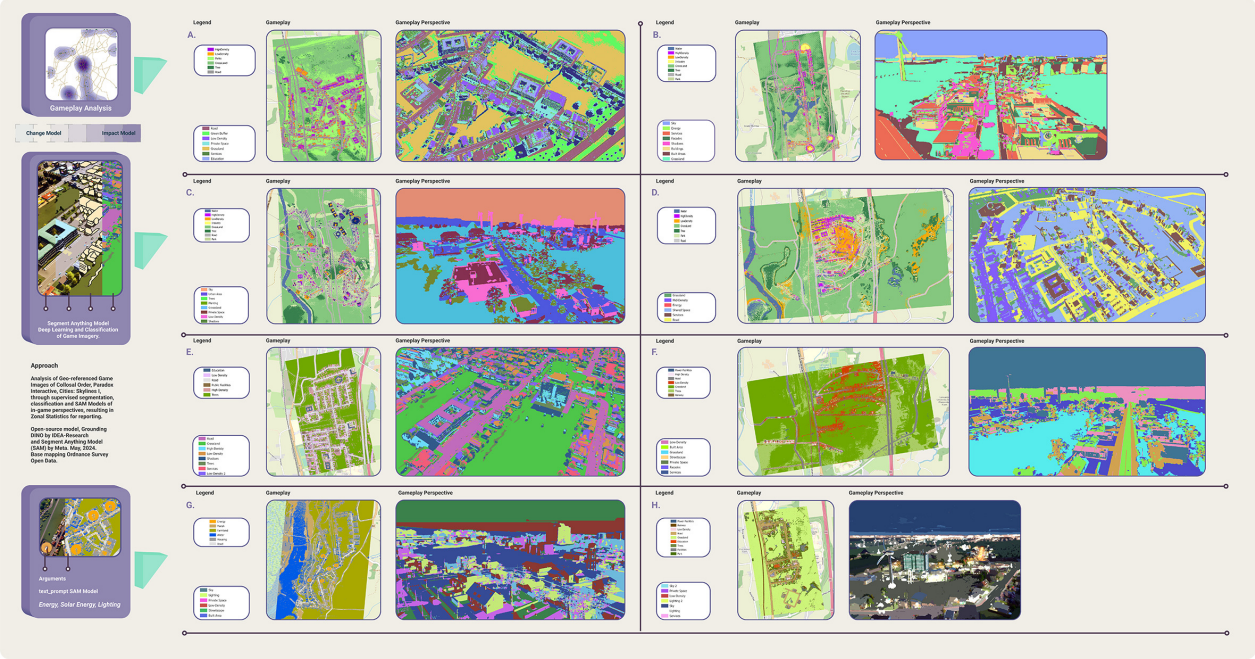

Figure 4. Game images generated using supervised (label A-F) and unsupervised classification (label G-H) and deep learning models (from CSI).

Based on this foundation, we analysed gameplay plans and in-game perspectives (Figure 3). For the gameplay plans, after sorting and georeferencing, we undertook remote sensing segmentation and classification using a combination of supervised and unsupervised learning on the game images captured from a top-down viewpoint using ESRI ArcGIS Pro. When using a supervised approach for the plan game imagery, we manually trained pixels based on the agent-based mechanics (ABM) of CSI, consulting the Paradox Wikis page on "Cities: Skylines Wiki" (https://skylines.paradoxwikis.com/Cities:_Skylines_Wiki). The supervised training utilised the land use classification schema from the 2011 National Land Cover

Database (Homer et al., 2015). A range of objects were trained, with the output completed as Random Trees or by selecting K-Nearest Neighbour to validate and assess model differences (Figure 4, images labelled A through F). This process workflow is standardized and well-accepted in satellite remote sensing and land use classification; however, it has been novelly applied to a digital game. We experimented with a range of classification and segmentation workflows for the in-game perspective images, including the Segment Anything Model (SAM; Kirillov et al., 2023). An updated version of ESRI text_SAM (2024), which the authors utilized in the extraction of energy networks built in the game. We utilized the text_SAM model (2024) in unsupervised learning, using the following prompts: energy, solar energy, and lighting. The text-based prompt segmentation model is suitable for the extraction of distinct objects (Figure 4, images labelled G through H) as an additional process. The analytical capability enables an assessment following the geodesign phase, in which impact models are created. This is then followed by the decision model phase, where a range of scenarios is collaboratively assessed and ranked.

For example, in the game, once planning zones are established, it allows players to choose between low-density and high-density housing options. The ABM then morphologically generates the buildings. We trained the imagery based on knowledge of the two possible game mechanics. For example, low-density housing requires training on the colouration of rooftops within the game asset group, as well as identifying scales demonstrated in the various legends shown. We experimented with other unsupervised classification methods, such as energy networks and marshlands, a key ecological area for Lancaster, through this workflow and the use of machine learning. Once computed, we used the classified game images to generate zonal statistics tables and charts that can form a report for planning professionals as part of consultation. The allocated land use in young people's games can be viewed statistically by examining the frequency of all cells that contain the majority value in the value raster [Count], which determines the total area of each unique zone [Area] (see Supplementary File). The SAM proved effective in segmenting perspective game images at various points of play within the game's time systems and simulated weather. The SAM was then classified and an attribute table provided confidence figures through the process.

4. Gameplay Results

The SAM analysis provides a rigorous level of confidence and a granular level of detail in decision-making for land use by young people, as the worldbuilding CBG is transformed into a geogame, which is not necessarily evident in the composition of local plan consultation surveys (Figure 4). Results also provide user data on street-level urban design choices. GIS analysis of gameplay using remote sensing techniques adds rigour to the interpretation of CBGs. It is an essential method in linking simulation games to geogames for real-world planning systems. The Lancaster South Area Action Plan sought to develop the vision and masterplan for a mixed-use site between 5–7k homes. JTP Masterplan Architects proposed Bailrigg Garden Village and was endorsed by the LCC in 2022 (JTP, 2021). Participants designed a number of areas, including this area. The masterplan comprises village parcels and a centre, with residential areas interspersed with a range of green buffers and Green Infrastructure, totalling 69% of the site. Delivery includes schools, retail spaces, and multi-model transport infrastructure, among other elements. The work was suspended by the council in 2023 due to rising inflationary costs, particularly the addition of a motorway junction (M6). In the sample, a classification of land use observed during gameplay can be analyzed. This analysis presents various spatial principles and optimal scenarios, which are part of the decision model phase in geodesign. The gameplay results observed four principles designed by young people in CSI&II:

1. Ecological networks: Grassland, parks, forests, supporting sustainability and livability, related to the GI goals of JTP.
2. Balanced residential density: Equal high- and low-density zones ensure comfortable living without overcrowding.
3. Moderate road network: Sufficient and improved connectivity (East–West) with some focus on public transit.
4. Waterfront integration: Refines urban landscape and ecological resilience, with participants building out to the Lune river, with potential flood-management benefits.

Since the workshops took place, LCC has developed a Climate Emergency Local Plan Review Adopted Policies Map, based on the Strategic Policies and Land Use adopted plan from 2020 (LCC, 2020, 2025). The gameplay models align with a range of real-world issues outlined in the latest policy document. The ABM game does not wholeheartedly align with the complexity of real-world planning systems—it cannot do so as a simulation; however, we argue that a correlation exists between the choices modeled in gameplay and a number of the future policies of LCC, namely:

1. Ecological networks, which correlate with the LCC's efforts towards biodiversity net gain.
2. Residential densities; to be achieved through a study of residential housing needs (LCC, 2015).
3. Gameplay for a moderate road network: There has been a scoping study to improve bus links through the construction of the Bus Rapid Transit, amongst many other transport improvements, including road networks and major junctions (LCC, 2021, p. 7).
4. Waterfront integration through the Shoreline Management Plan (EA, 2011), which has a matrix of active intervention, hold or advance the line, seaward or landward (managed retreat), managed realignment, and no active intervention.

These principles could potentially change through extended periods of gameplay, though across the sample there was a notable emphasis on the value of greenspace (Figure 2, images A and B), play space and local facilitates for residents such as schools (Figure 2, images C and E), as well as the use of renewable energy through wind turbine systems and solar panels (Figure 2, images G and H). Transport and mobility issues were also highlighted (Figure 2, images B, C, D). This is not an exhaustive comparison. The use of the SAM model in analysing game imagery worked particularly well for in-game perspectives, with resultant segmentation screened at a confidence level of >60% and a low number of exclusions (see Supplementary File, Table 1). In CSI & CSII, the "black box" of the game is either a blank, open-world starter or a scale replica of an existing city. However, through extracting outcomes between simulation and real-world planning maps, a different form of reflection emerges. The reflectivity helped the authors identify design flaws and issues in the outcome, such as traffic congestion, air pollution, and inadequate medical provision, alongside topography, infrastructure, and the distribution of resources in relation to the local development plan.

5. GIS Analysis in CSII

The second phase of the research project identified new processes to streamline the three phases of geodesign: change models, impact models, and decision models that transform a CBG into a geogame. Since the workflow and analysis, several updates have taken place, notably the release of the second edition of the game, CSII, and the introduction of a new map editor in Beta. Additionally, new community modifications can enhance this

analytical capability. We wished to explore analytical capability beyond ML segmentation and classification. The potential of geogames for regional and urban planning arguably stems from their capabilities for analysis and feedback, creating a connective loop with real-world systems and processes.

Since the research of the first workshop events, CSII features two modifications called CARTO (https://mods.paradoxplaza.com/mods/87428/Windows) and OSM Export (https://mods.paradoxplaza.com/mods/87422/Windows), which improve the analytical capabilities of the gameplay. CARTO exports gameplay as ESRI shape files, while OSM Export exports gameplay as OSM data. These improvements enhance the impact and decision-making models of geodesign, as well as the potential of this pilot study for integration within planning consultations. The modifications export the gameplay as vector data, OSM data, and ESRI shapefiles, allowing analysis in GIS and Rhino software via the Quantum Geographic Information System (QGIS) and ESRI ArcGIS Pro. In Figure 5, the area for gameplay is represented by the top map grid system, satellite image, and DTM. The gameplay is cartographically styled to Open Street Map Data (bottom left), allowing juxtapositions between real-world OSM and gameplay OSMs. The modeling choices in the game were primarily based on existing routes, networks, and settlements, with minor modifications at the urban block level and the addition of custom buildings. The model was therefore not entirely developed for the real-world settlement. Among the gameplay, two significant areas were redeveloped in a scenario: White Lund Industrial Estate, an industrial estate that was formerly a munitions shell factory during World War I, and the Stone Jetty and promenade of Morecambe Bay, which is expected to be regenerated through

Figure 5. Example of transport, green space, commercial, residential, and industrial zones from a "worldbuild" of Morecambe Bay, Lancashire, North West UK. Notes: Map of gameplay created in CSII using the OSM Export mod, cartographically styled to an OSM layer via *Maperitive*; Includes in-game screenshots from the author's gameplay.

the 2025 Eden Project Morecambe initiative (https://www.edenproject.com/new-edens/eden-project-morecambe-uk). The authors selected distributed improvements and services, such as green spaces, play areas, high-quality retail, healthcare, and education, across the seaside town, rather than the real-world proposal involving the concentrated Eden Project Morecambe structure.

The geodesign impact model in this second phase consists of two complementary methods: a GIS-based spatial analysis and a Rhino-based environmental performance analysis (Figure 6). The first method, the GIS-based spatial test, aims to identify different types of spatial matching, providing a basis for refined urban planning. We used the Office for National Statistics (2021), Lower-Super Output Areas (LSOAs) as analytical units, clipping them in ESRI ArcGIS Pro to define the study area. The analysis calculated building density (Jiang et al., 2022; Lee & Kang, 2022) and road density (Chen et al., 2023; Jiang et al., 2022) for each unit. Building on Anselin's (1995) introduction to the Local Indicators of Spatial Association, and its application in a real city (Chen et al., 2022), the team employed bivariate spatial autocorrelation to examine the spatial relationship between road and service facility densities, identifying significant patterns of clustering. This process classifies sub-regions into four types, such as "hotspots" with high road and facility density, or areas with high facility density but a sparse road network. These classifications directly inform subsequent design decisions around potential transport strategies. Second, the collection of these texts functions as a predictive tool. The parameters exported from these design solutions can generate 2D and 3D proposals that also display quantitative information. The benefit of this approach is that researchers can re-analyse these quantitative parameters to produce more interpretable results. For instance, we can evaluate the rationality of road networks and building layouts, or assess the advantages and limitations concerning sunlight, air circulation, and viewsheds, key considerations in designing real-world urban blocks. These analytical outcomes then guide the formulation of the final decision in the subsequent step of the geodesign process and the CBG to geogame transformation. Each design solution represents a possible future scenario,

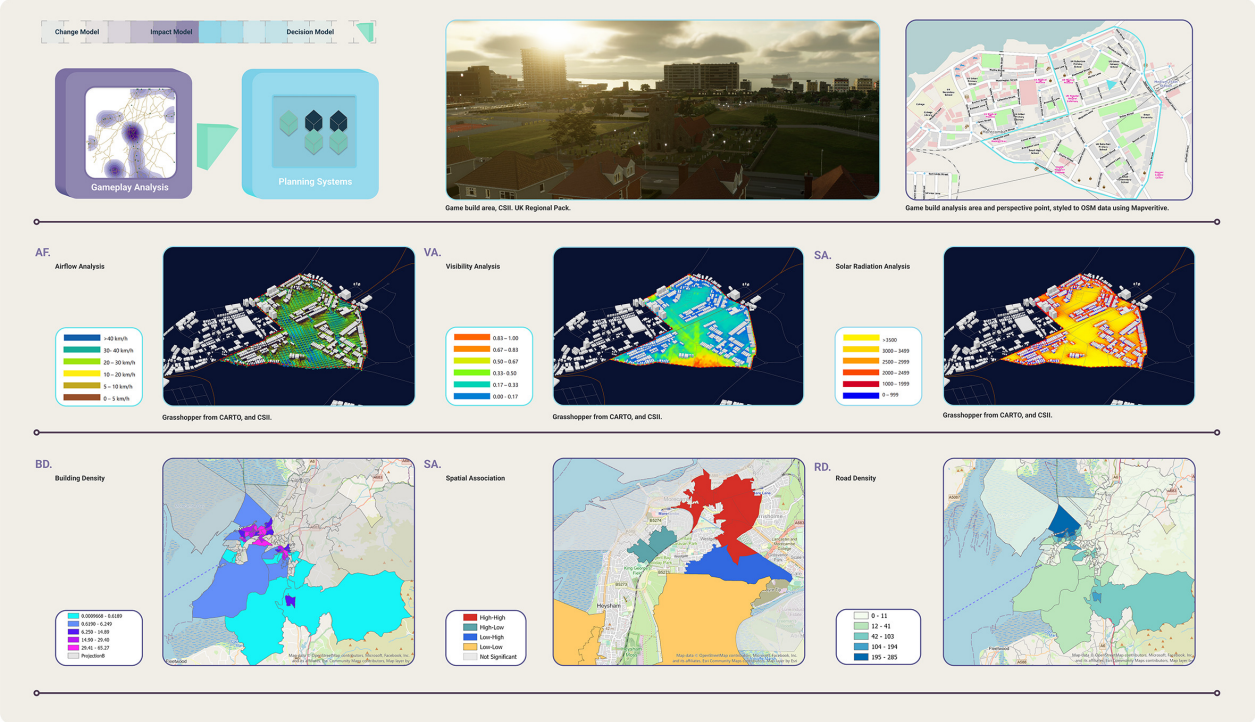

Figure 6. Analysis of gameplay using ArcGIS Pro, QGIS, and Rhino/Grasshopper.

enabling researchers and stakeholders to explore the potential consequences of different planning decisions. This aligns perfectly with the predictive capacity of geodesign impact models, which are often used to reveal possible future outcomes under changed conditions (Afrooz et al., 2018; Caglioni & Campagna, 2021). Because this spatial text can be seamlessly integrated with professional GIS and other analytical models, it serves as a robust and accessible medium for stakeholders to understand and evaluate the potential impacts of design.

At the operational level, a Rhino-based environmental analysis was implemented through modeling with the following three software tools. Simulations were conducted using Grasshopper plug-ins within Rhino to analyse three key environmental factors: airflow, using computational fluid dynamics methods (Kabošová et al., 2020); visibility, through ray-tracing techniques (Koltsova et al., 2013); and cumulative solar radiation, using the Ladybug tool (Shirinyan & Petrova-Antonova, 2024). Rhino directly visualised these environmental factors on three-dimensional models, enabling designers to intuitively understand how each design alternative impacted environmental conditions, such as lighting, airflow, and visual openness. These evaluations can potentially inform refined, data-driven urban design decisions in the future.

6. Results

The authors' design reveals a significant mismatch between its building density and transportation infrastructure, reflecting their own implicit planning priorities and biases. For example, the "high–high" cluster in central Morecambe indicates the participant's preference for an integrated, compact development model. In contrast, the "high–low" cluster near Heysham, characterised by a well-developed road network but sparse buildings, suggests a design approach that prioritised infrastructure without leveraging it to stimulate land development, potentially implying underutilised resources. Furthermore, the "low–high" area in south Morecambe highlights a disconnect where dense development lacks sufficient road capacity, foreshadowing future challenges to mobility and accessibility. These spatial patterns offer a quantitative insight into a single designer's logical focus and unconscious biases during the planning process, a key ethical consideration in CSII gameplay.

The key contribution of this case study is its innovative application of spatial matching analysis to a game-generated urban plan. Previously, such analysis was primarily used to evaluate real-world urban systems, such as Changchun City in China (Chen et al., 2022). However, the novelty here lies in successfully translating a creative design from a CBG simulation environment into structured spatial data for objective assessment as a geogame. By embedding this type of analysis into geodesign impact models, researchers and facilitators can move beyond subjective evaluations of CBGs. This enables the systematic comparison of multiple design proposals co-created by stakeholders using spatial indices, providing evidence-based support for subsequent revisions and fostering more scientific collaborative planning.

7. Limitations

We analysed a sample in the research design over the whole dataset output, as our aim was to demonstrate a geogame pilot for adoption by local council planners. Upon completion of the supervised semantic classification of game imagery, the research relies on the statistical interpretation of the worlds that players create. The first stage of this research analysis results only show the intention for land use using the game

system. Given a manually created map in Cities: Skylines, a degree of terrain mapping error is present, which affects the statistical results. Improvements in the map editor, allowing for a range of data imports beyond DTM, satellite, and OSM data, would also enhance these outcomes. CSI rendering engine, time system, and weather system created images that were unreadable using these processes, resulting in a reduced sample for analysis. The quality of imagery captured could be improved by "freezing" the game day cycle and offering a constant sunlight option within the game settings.

This quantifiable analysis does not account for the motivation of play and urban layout by players. Nor does it account for the level at which a player has actively considered a range of real-world planning issues or awareness of the inherent bias in the game system, unless these are rigorously outlined in pre- and post-workshops. This is an important ethical consideration. Additionally, the educational value of playing CBGs of planning systems is not captured using these methods. The research was limited in conducting pre- and post-interviews with participants on their gameplay due to workshop formats and the player group. The research did not systematically link worldbuilding to formal local consultation stages in a standalone event in this pilot study. These limitations will be revised and incorporated into future research designs, including the application of additional GIS analytical capabilities and Rhino modeling tests outlined in our second phase of study.

Our aim was to demonstrate viability and proof of concept to Local council planners in a demonstration workshop hosted on 22 September 2024 in preparation for the new local plan consultation for LCC at the end of 2025. While game results are fully anonymised, there are also ethical considerations to consider regarding the capability of players to use the game and potential limitations in the results. Players need to be part of a wider process and value the educational aspect of gameplay over what could be an extractive exercise. The research design also needs to consider whether open or constrained play modes are utilized. Constrained, as-built play mimics more real-world conditions. However, the gameplay has provided players with the agency to create a large-scale city, including urban extensions and modifications, and to provide figures on the building typologies, industries, and spaces being established, as well as the preferred choices for these, thereby providing a tool for expression in planning consultations.

For the second stage of the research, the new modifications in CSII significantly streamline and make the analytical processes more cost-effective in terms of research time. We have identified a range of analytical possibilities and processes; however, these were outside of the original children's sample in stage one and, as mentioned, not linked to forthcoming local authority planning decisions. For the analysis of LSOAs as spatial units, while ensuring administrative consistency, there may be a sacrifice in spatial precision compared to an equal-area grid system. A more significant constraint is the reliance on only road network and building data, owing to current technical challenges in extracting more complex datasets from CSII. Future studies could dramatically develop the analytical depth and real-world applicability by incorporating more diverse variables, such as simulated population distributions, categorized Points of Interest, or agent-based mobility behaviors, to conduct a more holistic evaluation of a player's design and its performance.

8. Conclusion

In the act of CBG worldbuilding, the setting and environment are critical for play. In this case, through diegesis, we establish an identifiable real-world setting using geodata, allowing players to recognize places, deviate from,

or mimic existing urban layouts, as well as explore agricultural and industrial spaces. Agent-based models "auto" evolved zones set out by the player, as well as allowing custom buildings, some of which were based on the real world. Many geogames lack the analytical capability to evaluate the outcomes of play, requiring consideration of alternative research designs for evaluation, such as questionnaires or interviews. We have demonstrated in two stages a viable process of transforming CBGs into geogames for urban and regional planning within a geodesign framework and articulated critical feedback loops using GIS approaches (as seen in Figure 1).

GIS and modeling techniques provide analytical capabilities and provide critical connectivity to real-world planning systems and decisions. Thus, *Cities: Skylines* provides a platform for worldbuilding and feedback for publics who have not necessarily been engaged with traditional planning consultation, or have the agency or tools to express their ideas for future environments. Through gameplay and worldbuilding, players are provided with opportunities for reflection on underlying planning activities, and this also provides the opportunity for young people to engage in formal systems through geogames that are currently underrepresented, which is a key consideration in future work. Our research has demonstrated how games cannot reveal individual player motivations but can reveal several play-based decisions through worldbuilding using a geospatial design game, which can be extracted for quantifiable analysis. This methodology is but one aspect of the many digital tools in development for planning systems (Cureton & Brown, 2025). Further work includes refining the framing of geogame workshops, ensuring full participation in public consultations for upcoming phases of the new local plan at the LCC, and expanding the number of participants. In addition, the production of bespoke modifications and scenarios in the CBG game would further enhance the field of geogames. Developing bespoke modifications and scenarios related to climate change and green infrastructure within the game could further advance the use of geogames as a medium for spatial planning and environmental education.

The low cost of implementation, in terms of game licenses, open-source modifications, and open-source GIS tools, provides a replicable approach across a wide variety of geographies. However, for large-scale cities, creating 1:1 scale copies can be a resource-intensive process, although many have already been built by the extensive play community. Additional considerations will also need to take into account the representative base and the number of participants in gameplay. We have demonstrated a process and feedback approach through the use of CSI & CSII, as well as community-led modifications, in the form of a geogame that provides tools for worldbuilding. This has been demonstrated on various scales, ranging from detailing streets and furniture to urban blocks, connected regions, and the creation of spatial alternatives or deviations from existing urban patterns and planning principles.

The act of worldbuilding, as we have noted, is enacted within the limitations of a pre-existing rule system, specifically CSI&II, as a CBG and an imaginary world. This simulation abstracts from formal planning systems, but the power of the process lies in its agency in transforming a CBG into a geogame that provides players with educational, reflective, and placemaking benefits. During a period of increasing climate challenges, rapid urbanisation, and digital transformation, long-term community consultation approaches are crucial for addressing groups not represented in the planning system, where geogames play a critical future role.

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The authors declare no conflict of interests.

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No LLMs have been used in the preparation of this article.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

References

Abt, C. C. (1987). *Serious games*. University Press of America.

Afrooz, A., Ballal, H., & Pettit, C. (2018). Implementing augmented reality sandbox in geodesign: A future. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *IV*, 5–12. https://doi.org/10.5194/isprs-annals-IV-4-5-2018

Anselin, L. (1995). Local Indicators of Spatial Association—LISA. *Geographical Analysis*, *27*(2), 93–115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x

Arnis. (2025). *Generate real-life cities in* Minecraft. https://github.com/louis-e/arnis

Batty, M. (2024). *The computable city: Histories, technologies, stories, predictions*. MIT Press.

Bereitschaft, B. (2015). Gods of the city? Reflecting on city building games as an early introduction to urban systems. *Journal of Geography*, *115*(2), 51–60. https://doi.org/10.1080/00221341.2015.1070366

Caglioni, M., & Campagna, M. (2021). Geodesign for collaborative spatial planning: Three case studies at different scales. In E. Garbolino & C. Voiron-Canicio (Eds.), *Ecosystem and territorial resilience: A geoprospective approach* (pp. 323–345). Elsevier. https://doi.org/10.1016/B978-0-12-818215-4.00012-2

Chen, Y., Hu, Y., & Lai, L. (2022). Demography-oriented urban spatial matching of service facilities: Case study of Changchun, China. *Land*, *11*(10), Article 1660. https://doi.org/10.3390/land11101660

Chen, Y., Yu, B., Shu, B., Yang, L., & Wang, R. (2023). Exploring the spatiotemporal patterns and correlates of urban vitality: Temporal and spatial heterogeneity. *Sustainable Cities and Society*, *91*, Article 104440. https://doi.org/10.1016/j.scs.2023.104440

Clancy, K. (2024). *Playing with reality: How games have shaped our world*. Penguin.

Coulton, P., Burnett, D., & Gradinar, A. (2016a, June 27–30). *Games as speculative design: Allowing players to consider alternate presents and plausible features* [Paper presentation]. Future focused thinking—DRS International Conference 2016, Brighton, UK. https://doi.org/10.21606/drs.2016.15

Coulton, P., Lindley, J., & Akmal, H. A. (2016b). Design fiction: Does the search for plausibility lead to deception? In P. Lloyd & E. Bohemia (Eds.), *Proceedings of design research society conference* (Vol. 1, pp. 369–384). Design Research Society. https://doi.org/10.21606/drs.2016.148

Coulton, P., Lindley, J., Sturdee, M., & Stead, M. (2017, March). Design fiction as world building. In *Proceedings of the 3rd Biennial Research Through Design Conference* (pp. 1–16). RTD. https://researchthroughdesign.org/2017/proceedings/index.html

Cureton, P., & Brown, E. (2025). *Little book of digital planning*. Imagination Lancaster. https://eprints.lancs.ac.uk/id/eprint/227028/1/Little_Book_of_Digital_Planning_web_version_remove_inner_cover.pdf

Cureton, P., & Coulton, P. (2024). Game based worldbuilding: Planning, models, simulations and Digital Twins. *Acta Ludologica*, *7*(1). https://doi.org/10.34135/actaludologica.2024-7-1.18-36

Cureton, P., & Hartley, E. (2025). *Geodesign, urban digital twins and futures*. Routledge.

de Andrade, B., Poplin, A., & Sousa de Sena, Í. (2020). Minecraft as a tool for engaging children in urban planning: A case study in Tirol Town, Brazil. *ISPRS International Journal of Geo-Information*, *9*(3), Article 170. https://doi.org/10.3390/ijgi9030170

de Freitas, S. (2008). *Serious virtual worlds: A scoping study*. Serious Games Institute. https://researchportal.murdoch.edu.au/esploro/outputs/report/Serious-Virtual-Worlds-a-Scoping-Study/991005540122507891#file-0

EA. (2011). *Shoreline management plan 2: Great Ormes Head to Scotland*. North West and North Wales Coastal Group.

ESRI. (2024). *Text SAM*. ArcGIS. https://www.arcgis.com/home/item.html?id=8df3bf4167bc4c7b967f677f8b362ec3

Gordon, E., & Baldwin-Philippi, J. (2014). Playful civic learning: Enabling lateral trust and reflection in game-based public participation. *International Journal of Communication*, *8*, Article 28. https://ijoc.org/index.php/ijoc/article/view/2195/1100

Hadid, Z. (2024). *Re:Imagine: London*. zaha-hadid. https://www.zaha-hadid.com/2024/09/19/reimagine-london-in-fortnite-zha-collaborates-with-epic-games

Homer, C., Dewitz, J., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N., Wickham, J., & Megown, K. (2015). Completion of the 2011 National Land Cover Database for the conterminous United States—Representing a decade of land cover change information. *Photogrammetric Engineering & Remote Sensing*, *81*(5), 345–354.

Hudson-Smith, A., Evans, S., & Batty, M. (2005). Building the virtual city: Public participation through e-democracy. *Knowledge Technology & Policy*, *18*, 62–85. https://doi.org/10.1007/s12130-005-1016-9

Jiang, Y., Han, Y., Liu, M., & Ye, Y. (2022). Street vitality and built environment features: A data-informed approach from fourteen Chinese cities. *Sustainable Cities and Society*, *79*, Article 103724. https://doi.org/10.1016/j.scs.2022.103724

Jolly, R., & Budke, A. (2023). Assessing the extent to which players can build sustainable cities in the digital city-builder game "*Cities: Skylines*." *Sustainability*, *15*(14), Article 10780. https://doi.org/10.3390/su151410780

JTP. (2021). *Bailrigg Garden Village, Lancaster*. https://www.jtp.co.uk/projects/bailrigg-garden-village

Kabošová, L., Katunský, D., & Kmet, S. (2020). Wind-based parametric design in the changing climate. *Applied Sciences*, *10*(23), Article 8603. https://doi.org/10.3390/app10238603

Khan, T. A., & Zhao, X. (2021). Perceptions of students for a gamification approach: Cities Skylines as a pedagogical tool in urban planning education. In D. Dennehy, A. Griva, N. Pouloudi, Y. K. Dwivedi, I. Pappas, & M. Mäntymäkiet (Eds.), *Responsible AI and analytics for an ethical and inclusive digitized society* (pp. 763–773). Springer. https://doi.org/10.1007/978-3-030-85447-8_64

Kim, M., & Shin, J. (2015). The pedagogical benefits of *SimCity* in urban geography education. *Journal of Geography*, *115*(2), 39–50. https://doi.org/10.1080/00221341.2015.1061585

Kirby, D. (2010). The future is now: Diegetic prototypes and the role of popular films in generating real-world technological development. *Social Studies of Science*, *40*(1), 41–70.

Kirillov, A., Mintun, E., Ravi, N., Mao, H., Rolland, C., Gustafson, L., Xiao, T., Whitehead, S., Berg, A. C., Lo, W., Dollár, P., & Girshick, R. (2023). *Segment anything*. ArXiv. https://arxiv.org/abs/2304.02643

Koltsova, A., Tuncer, B., & Schmitt, G. (2013). Visibility analysis for 3D urban environments. In *Proceedings of eCAADe Conference 2013* (pp. 375–383). eCAADe; Delft University of Technology. https://doi.org/10.52842/conf.ecaade.2013.2.375

Lancaster City Council. (2015). *Lancaster independent housing requirements study*. https://planningdocs.lancaster.gov.uk/PublicAccess_Live/SearchResult/RunThirdPartySearch?Folder1_Ref=LP05.03.05&FileSystemId=DC

Lancaster City Council. (2020). *Strategic policy and land use adopted policies map*. https://lancaster.maps.arcgis.com/apps/webappviewer/index.html?id=8a956391c7ee4c68a74b31f3732476cb

Lancaster City Council. (2021). *Review of Lancaster district transport assessment: Addendum [June 2021]*. https://www.lancaster.gov.uk/assets/attach/10813/P_15.pdf

Lancaster City Council. (2025). *Climate emergency local plan review adopted policies map*. https://experience.arcgis.com/experience/3ae0af210cea4bc9922bfb46cb444f38

Lee, S., & Kang, J. E. (2022). Impact of particulate matter and urban spatial characteristics on urban vitality using spatiotemporal big data. *Cities*, *131*, Article 104030. https://doi.org/10.1016/j.cities.2022.104030

Lewis, S. (2021). *Children in town planning*. RTPI. https://www.rtpi.org.uk/media/8848/children-and-town-planning-july-2021.pdf

Manns, S. (2017, May 10). *Planning and public engagement: The truth and the challenge*. RTPI. https://www.rtpi.org.uk/blog/2017/may/planning-and-public-engagement-the-truth-andthe-challenge

Mansfield, R. G., Batagol, B., & Raven, R. (2021). "Critical agents of change?": Opportunities and limits to children's participation in urban planning. *Journal of Planning Literature*, *36*(2), 170–186. https://doi.org/10.1177/0885412220988645

Office for National Statistics. (2021). *Lower Super Output Areas (December 2021) Boundaries EW BFE (V10)* [Data set]. https://www.data.gov.uk/dataset/7b2f3f79-b262-49e4-903f-915699e58c4b/lower-layer-super-output-areas-december-2021-boundaries-ew-bfe-v10

Olszewski, R., Cegielka, M., Szczepankowska, U., & Wesolowski, J. (2020). Developing a serious game that supports the resolution of social and ecological problems in the toolset environment of *Cities: Skylines*. *ISPRS International Journal of Geo-Information*, *9*(2), Article 118. https://doi.org/10.3390/ijgi9020118

Ordnance Survey. (n.d.). *Discover Great Britain in* Minecraft. https://www.ordnancesurvey.co.uk/whats-new/minecraft-gb

Poplin, A. (2024). Serious digital geogames and their implementations enhanced by artificial intelligence, mixed- and augmented-reality. In O. Gervasi, B. Murgante, C. Garau, D. Taniar, A. M. A. C. Rocha, & M. N. Faginas Lago (Eds.), *Computational science and its applications—ICCSA 2024 workshops* (Vol. 14817). Springer. https://doi.org/10.1007/978-3-031-65238-7_13

Poplin, A., de Andrade, B., & de Sena, Í. (2023). Let's discuss our city! Engaging youth in the co-creation of living environments with digital serious geogames and gamified storytelling. *Environment and Planning B: Urban Analytics and City Science*, *50*(4), 1087–1103. https://doi.org/10.1177/23998083221133828

Poplin, A., de Andrade, B. A., & de Sena, I. S. (2021). Geogames for change: Co-designing the future of cities with games. In T. Owens & L. Larke (Eds.), *Games and play in the creative, smart and ecological city* (pp. 64–94). Routledge.

Powell, R. (2024). Child-friendly cities and communities: Opportunities and challenges. *Children's Geographies*, *22*(5), 716–729. https://doi.org/10.1080/14733285.2024.2353746

Rodela, R., & Norss, E. (2022). Opening up spatial planning to the participation of children and youth: The Swedish experience. *European Planning Studies*, *31*(2), 252–269. https://doi.org/10.1080/09654313.2022.2041557

Sanz, L., Martens, S., & de la Hera, T. (2025). The case of *Cities: Skylines* versions—Affordances in urban planning education. *Media and Communication*, *13*, Article 8747. https://doi.org/10.17645/mac.8747

Schlieder, C., Kiefer, P., & Matyas, S. (2005). Geogames: A conceptual framework and tool for the design of location-based games from classic board games. In M. Maybury, O. Stock, & W. Wahlster (Eds.), *Proceedings of the First International Conference on Intelligent Technologies for Interactive Entertainment (INTETAIN)* (Vol. 3814, pp. 164–173). Springer. https://doi.org/10.1007/11590323_17

Shirinyan, E., & Petrova-Antonova, D. (2024). *Large-scale solar potential analysis as a use case of urban digital twins*. PrePrints. https://doi.org/10.20944/preprints202405.1310.v1

Steam Charts. (n.d.-a). *Cities: Skylines*. https://steamcharts.com/app/255710

Steam Charts. (n.d.-b). *Cities: Skylines II*. https://steamcharts.com/app/949230

Steinitz, C. (2012). *A framework for geodesign: Changing geography by design*. ESRI Press.

Wilson, A., & Tewdwr-Jones, M. (2022). *Digital participatory planning: Citizen engagement, democracy, and design*. Routledge.

ZCD Architects, Grosvenor, Sport England, & TCPA. (n.d.). *Voice, Opportunity, Power*. https://voiceopportunitypower.com

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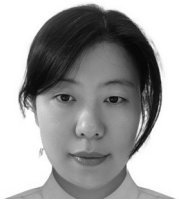

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PaSyMo: Gamifying Communicative Urban Planning With Participatory Systems Modeling

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Abstract

Urban planning increasingly requires navigating complex socio-spatial dynamics and uncertainties, particularly when addressing social challenges where stakeholders hold diverse perspectives and knowledge. This article introduces PaSyMo (Participatory Systems Modeling), a gamified communication support system designed to assist urban planners in communicative and deliberative planning. PaSyMo integrates three conceptual pillars that guided its design: stakeholder engagement, participatory agent-based modeling (ABM), and visualization on tangible interfaces. The system combines a simulation environment grounded in geodata and ABM with discursive elements from scenario workshops and role-playing games, bridging digital and non-digital formats. PaSyMo contributes to the growing field of GAM research (Games and Agent-based Modeling; Szczepanska et al., 2022) by providing a framework that explores the integration of gaming mechanics with urban simulation tools, highlighting their potential to support sustainable urban planning. The approach draws from participatory modeling (Sterling et al., 2019; Voinov & Bousquet, 2010) while leveraging state-of-the-art geospatial simulation and interactive interfaces to facilitate communication and co-production of knowledge among diverse stakeholders. Exploratory findings suggest that combining gaming experience with geospatial data visualization and ABM offers a promising approach to communicate the potential implications and trade-offs of urban planning initiatives. This integration enhances stakeholder engagement, promotes shared understanding, and supports consensus building. By making urban planning processes more interactive, PaSyMo can extend the impact of planning research beyond academic settings. Preliminary insights indicate that PaSyMo can enhance stakeholder understanding, knowledge integration, consensus-building, and proactive planning, especially in contexts of decision-making in complex and uncertain situations; however, these findings need to be substantiated in future studies.

Keywords
agent-based modeling; games; participatory simulation; spatial simulation; urban planning

1. Introduction

Planning and managing urban systems involves high degrees of uncertainty, especially when planners confront social problems, where conventional approaches that aim for single-point solutions often fail to deliver the intended outcomes. Shortcomings of traditional planning solutions can be attributed to a lack of understanding of the underlying complex interdependencies of various interconnected social, ecological, and technological drivers. These challenges are often framed against the backdrop of "wicked problems" that are difficult to define, have multiple possible solutions, and cannot be easily categorized (Rittel & Webber, 1973). Even agreeing on what the problem actually is can become a major challenge, sparking conflicts among groups with differing and sometimes opposing interests (Head, 2022). Under the lens of the wicked problem, problem-solving strategies that do not consider multiple stakeholder viewpoints fail to yield sustainable planning strategies, as they may lead to an imbalanced representation of one interest group at the cost of creating problems for another one.

The communicative turn in planning accordingly transformed the discourse in planning theory at the end of the twentieth century. Rather than claiming to find the "correct" solution, planners use communication, consultation, or deliberation to grasp an understanding of the distinction between observed and desired conditions, investigate different ways of identifying problems in the complex causal networks, and stimulate the exchange between laypersons' experience and planners' expertise (Healey, 1992; Innes, 1995). Planning as a collaborative, interactive, and communicative approach can generate the coordination and innovation that is necessary to respond to complex problems (Innes & Booher, 2010). Batty (2013) echoes these communicative planning ideals, arguing that science and technology should inform dialogue rather than generate definitive answers.

With this aim in mind, we present *PaSyMo* (Participatory Systems Modeling), a gamified simulation and data visualization environment. Its goal is to support communicative planning by providing a mobile simulation lab (MSL) that provides a virtual laboratory for users to interact directly with a simulation model of a relevant urban system. In doing so, stakeholders in planning problems can playtest different interventions and examine their effects on a target system, i.e., aspects of the real-world system that are studied to gain knowledge (Elliott-Graves, 2020), by simulating and visualizing a range of "what-if" scenarios.

We also report on exploratory tests of this environment in a series of participatory workshops with stakeholders on a few urban planning cases in the state of Brandenburg, Germany, between 2017 and 2019. These situated test cases are instructive for the technical development of a frugal and context-sensitive approach and provide some first insights as to how gamified simulation and data visualization can support communicative planning. A future research agenda based on these preliminary observations will allow us to study the impact of urban simulations on communicative planning efforts.

The article is structured as follows. Section 2 describes relevant conceptual background and prior research guiding the development of PaSyMo. Section 3 describes the PaSyMo MSL, considering hardware and

software components but also possible workflows in the context of communicative planning. Section 4 then presents three examples of how PaSyMo was implemented in real-life urban settings, illustrating its intended use. Finally, we discuss limitations and avenues for future systematic research to evaluate the usefulness of the approach.

2. Conceptual Background

Computational tools have supported urban planners in their work since the 1970s. Over time, advances in technology have not only fueled social innovation in spatial planning (Christmann et al., 2018) but also provided effective means for the communicative turn in planning (Diller et al., 2018; Healey, 1992). Existing studies provide a broad range of examples for how tools can be used to foster participants' engagement in urban planning contexts, such as participatory GIS (Dunn, 2007); interactive Web-GIS (Marras et al., 2018; Panagiotopoulou et al., 2020); participatory apps (Desouza & Bhagwatwar, 2012; Ertiö, 2015); e-participation (Aichholzer & Strauß, 2016); online deliberation via platforms (Münster et al., 2017); neighborhood labs (Kontokosta, 2016); or data visualization (Hemmersam et al., 2015). Beyond single approaches, recent work in the field of planning support science has increasingly focused on context-sensitivity and governance to better tackle the implementation gap of planning support systems (Geertman & Stillwell, 2020; Jiang et al., 2020). Our contribution lies in addressing the implementation gap in developing a prototype of a support system that can be tested and refined in a relevant environment, such as participatory workshops in urban planning contexts. PaSyMo integrates three conceptual pillars that guided its design: *stakeholder engagement*, *agent-based modeling* (ABM), and *visualization on tangible interfaces* (Figure 1).

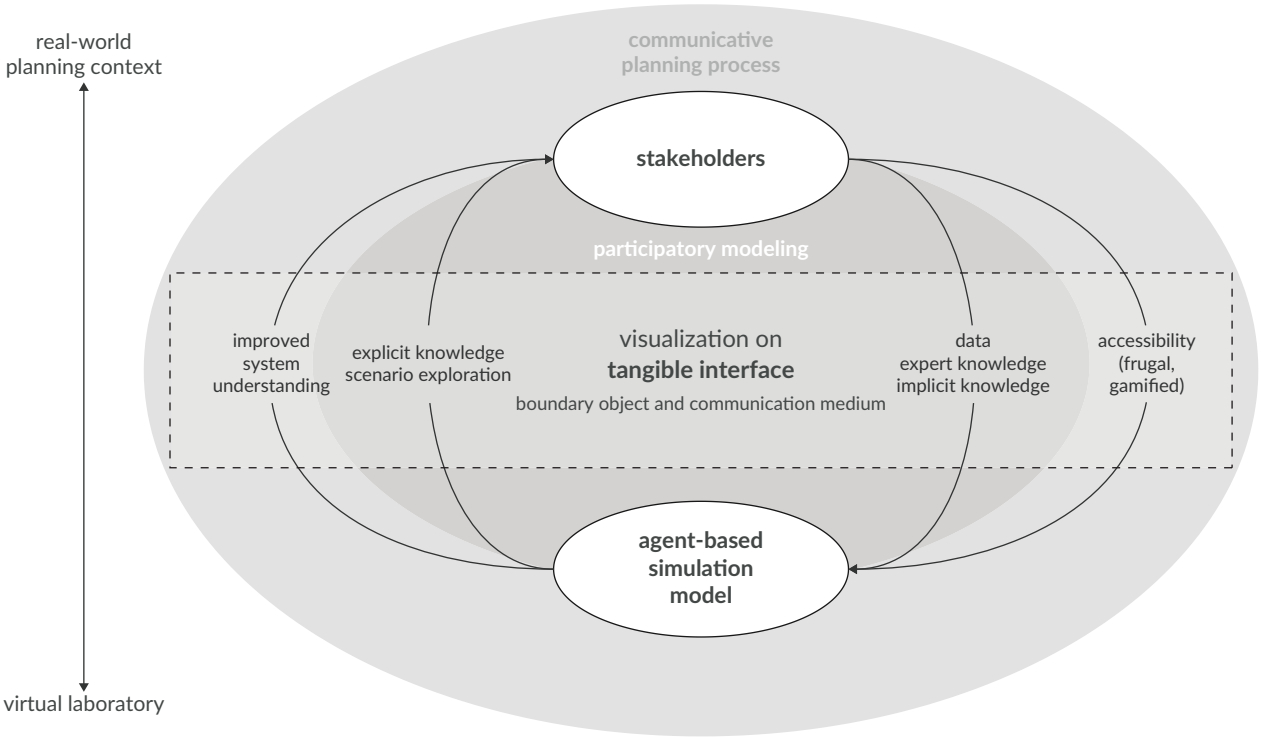

Figure 1. Conceptual design of the MSL.

The communicative turn emphasizes collaborative decision making and *stakeholder engagement* (Healey, 1992; Innes, 1995). Classic works in urban planning, such as Arnstein's (1969) typology for participatory planning, illustrate how policymakers have gradually refrained from claiming objective and definitive solutions to social problems (Diller et al., 2018). Unlike conventional expert-driven approaches, which centralize knowledge and decision-making, participatory planning redistributes power, placing stakeholders at the heart of the process (Cornwall & Jewkes, 1995).

Situated at the intersection between early planning phases (engaged with exploring, scoping, and visioning) and formal planning activities leading to actual zoning, PaSyMo lends itself to public engagement workshops as a structured approach that aims to support stakeholder exchange, rendering planners' domain expertise as well as residents' tacit and local knowledge visible. It provides space for visioning, in which participants' implicit assumptions of the realities and workings behind a specific urban issue at stake are made explicit and represented in a conceptual model that serves the multi-stakeholder focus group as a "boundary object" (Star & Griesemer, 1989). In the case of PaSyMo, the boundary object constitutes a communicative space and interactive visualization that helps to generate shared meaning, prompts participants to make assumptions explicit, while at the same time sustaining interpretive flexibility (Figure 1).

Participants are not passive recipients of expert advice; they actively contribute to defining problems, setting objectives, and designing potential interventions. Their involvement is a crucial element as it counters the danger of creating a system of corporatism, technocracy, and surveillance that is often raised as a concern in smart city discourse (Greenfield, 2013; Hollands, 2015; Vanolo, 2016). PaSyMo follows this principle by enabling stakeholders in co-creating knowledge throughout a planning process. They might define relevant scenarios and contribute both explicit and tacit knowledge to inform the simulation models, exploring what-if scenarios to co-create insights collaboratively. This approach aims to create meaningful dialogue, integrate diverse perspectives, and enhance the relevance and legitimacy of planning interventions.

Recognizing the complex nature of cities has led to the development of methodological approaches that aim for better insight into their underlying dynamics (Batty, 2013; Crooks et al., 2021). ABM is a powerful method for studying complex adaptive systems, capturing dynamic behaviors through the interactions of individual components. In ABMs, the components of a system are instantiated as software agents, each characterized by multiple attributes and guided by formal decision-making rules (Miller & Page, 2007). Simulation outcomes can therefore be traced back to individual agent characteristics and behaviors, making ABMs particularly suitable for systematically exploring counterfactual development scenarios and understanding emergent system-level phenomena (Heppenstall et al., 2012). ABMs also contribute to theory development by providing an experimental platform to investigate social processes from the individual to the societal level (Epstein, 2008; Gilbert & Troitzsch, 2005). Within computational social science, ABM has increasingly been combined with participatory and gaming approaches to support collaborative learning and engagement. Participatory ABMs integrate methods ranging from role-playing games to fuzzy cognitive mapping, providing technology-supported avenues for public involvement in planning and decision-making (Voinov et al., 2018). These models have a long-standing application in disciplines concerned with emergent phenomena in complex systems, including environmental sciences (Barreteau et al., 2013; Carmona et al., 2013; Gray et al., 2017), landscape planning (Becu et al., 2017; Van Berkel & Verburg, 2012), and organizational studies (Andersen et al., 2007).

In PaSyMo, participatory ABM serves as the computational backbone for the simulation environment. By integrating ABM with stakeholder participation, the system allows users to define scenarios, contribute both explicit and tacit knowledge, and explore "what-if" interventions collaboratively. This combination of ABM and participatory design ensures that the simulations reflect real-world dynamics, support collaborative learning, and provide an accessible platform for co-creating knowledge in complex urban planning contexts.

While ABMs are conceptually powerful, they are often difficult for laypersons to interpret and challenging to apply in collaborative group settings. Participatory modeling approaches address this limitation by combining ABMs with *tangible interfaces*, enabling stakeholders to engage directly with models in an intuitive, interactive manner (Shaer & Hornecker, 2010). In recent years, technological advancements such as virtual and/or augmented reality (VR/AR), touch interfaces, and other innovative input devices have contributed to more immersive user experiences that blur the lines between the simulated world and reality (Marto & Gonçalves, 2022). Such tangible interfaces have found various applications in communicative planning, education, and science communication efforts, with modes of user interaction within physical and digital realities through direct manipulation, gesture recognition, or real-time scanning of printed code snippets (Hermansdorfer et al., 2020). In spatial setups, the tangible table is a well-suited arrangement to simplify the complexity of a design process by combining intuitive user input through physical interfaces with simulation and visualization (Petrasova et al., 2018) on 3D printed maps, sandboxes, or laser cut maps (Salim, 2014).

Tangible interfaces for ABMs bridge the physical world of participants with the virtual dynamics of the model, allowing users to manipulate variables, explore interventions, and visualize and debate outcomes. Such approaches have been employed in diverse contexts, including tabletop simulations of urban management practices for mobility and air quality interactions (Minh Duc et al., 2020) or as testbeds for alternative physical interfaces such as LEGO bricks in the CityScope platform (Alonso et al., 2018; Noyman et al., 2017). In PaSyMo, we employ a multitouch table to combine the flexibility of virtual objects with intuitive, hands-on interaction. Virtual objects can be easily adapted to different scenarios, reducing dependency on physical artifacts designed for specific use cases. This setup allows participants to collaboratively manipulate and explore simulation models, supporting both engagement and co-creation of knowledge.

The conceptual design of PaSyMo situates it within the domain of *geogames*. Ahlqvist and colleagues defined geogames as digital or hybrid games that use real-world spatial data and GIS to mediate interaction with geographic environments, emphasizing authentic geography (Ahlqvist et al., 2012; Ahlqvist & Schlieder, 2018). Recent research on geogames in the domain of urban design and planning explores how interactive play, geospatial data, and simulation can foster civic participation and engagement (Poplin, 2012, 2025). PaSyMo contributes to this area of research by embedding an ABM directly within the game setup. GAM-Research (Games and Agent-based Models) has been proposed as a methodological framework for systematically combining gaming approaches with ABM to study complex social phenomena (Szczepanska et al., 2022). In GAM research, Games provide accessible and engaging environments for eliciting human decision-making, while ABMs contribute formal, dynamic representations of system behaviors. GAM-Research distinguishes six design types, which differ according to the sequencing and integration between the game and the model. PaSyMo corresponds to a GAM design type 5, in which the ABM is embedded directly into the game environment (Szczepanska, 2023). Framing PaSyMo as a GAM design type

5 emphasizes its dual function: as an analytical instrument for studying urban processes and as a participatory medium for collaborative sense-making. By combining ABM, tangible interaction, and real-world geodata, PaSyMo presents a framework to operationalize geogames for deliberative, participatory settings for communicative planning. Its geodata-driven design enables stakeholders to experience and explore case-specific what-if scenarios, test potential interventions, and collaboratively interpret their impacts.

3. The PaSyMo MSL

The MSL is the physical implementation of PaSyMo. Its design is guided by two fundamental principles. First, the MSL introduces state-of-the-art spatial simulation and visualization technologies into participatory planning processes. Second, it follows a frugal approach, requiring minimal financial investment and technical expertise. This frugal approach acknowledges the financial and expertise constraints faced by smaller municipalities, which are often excluded from costly technological innovations. Frugal innovation seeks to "do more with less" (Bhatti, 2012), a principle that extends to both the hardware and software components of the MSL. All hardware components are consumer electronics, while the software relies solely on open-source tools and publicly available data. Additionally, the system is flexible and reusable, featuring adaptable simulation models and a mobile setup that can be deployed in diverse planning contexts.

3.1. Hardware and Software Components

The *physical setup* of the MSL (Figure 2) consists of a server, an ultra-short-throw projector, an infrared touch sensor, a flat-screen display, and a foldable projection table with integrated mounts for all components. Each element was chosen to support the compact design of the MSL while remaining powerful enough to operate under varying lighting conditions and handle simulations of different levels of complexity. For mobility, the

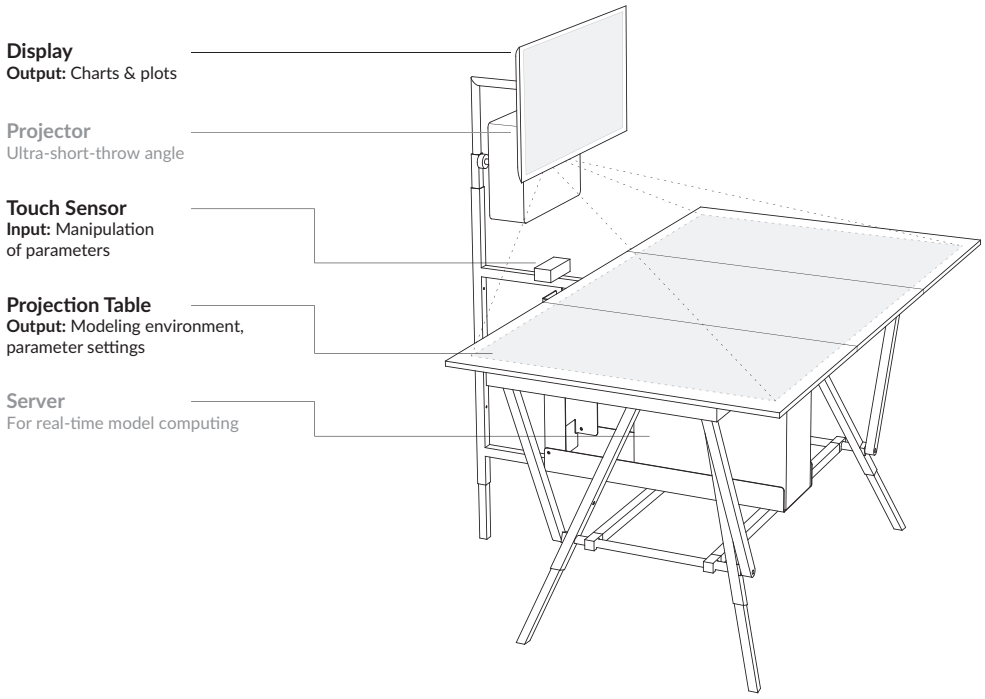

Figure 2. Technical illustration of the physical setup of the MSL.

setup is complemented by a custom-made e-bike trailer, which allows compact stowage of all components and easy transportation.

In functional terms, the PaSyMo MSL combines a simulation model, data visualization for information aggregation, and tangible interfaces to support intuitive human–computer interaction. During workshops, the spatial modeling environment is projected directly onto the table surface and controlled via finger touch. Complementary information, such as data or graphs linked to selected objects on the table, is displayed on the flat screen, providing participants with both interactive and detailed views of the simulation.

The *simulation component* of the MSL is designed to create spatially explicit, interactive models that stakeholders can easily connect to by encountering virtual representations of their physical surroundings. This spatial grounding supports engagement and fosters intuitive understanding of complex dynamics in urban systems.

At its core is the GAMA Platform (GIS Agent-based Model Architecture; Taillandier, Gaudou, et al., 2019). GAMA provides a comprehensive modeling language, a well-structured graphical user interface (GUI), and flexible options for user–model interaction, which enable experts to develop spatial simulations with limited training (Taillandier, Grignard, et al., 2019). Its strong integration with GIS data allows for responsive visualizations. Agents can be generated and informed directly from geospatial data, including objects such as roads, buildings, land use, elevation, waterways, and administrative borders, as well as continuous fields such as population density or environmental indicators.

Interaction with the simulation is supported through multiple channels (Table 1). The projection table allows direct manipulation via finger touch, enabling participants to take workshop role-specific actions like adding or removing objects, modifying parameters, and changing spatial characteristics in real time. Predefined functions can also be triggered via buttons, sliders, or drop-down menus, while pointer movements in the visualization can influence agents and objects dynamically. For instance, users can block or open roads, alter

Table 1. Modes of interaction with the MSL.

Mode of Interaction	Interface	Time	Purpose
Model environment interaction	Touch on projected simulation environment	During simulation run	Take workshop role-specific actions and influence or setup model objects or agents (e.g., insert a new building)
Parameter manipulation	Buttons/sliders/drop-down menus of integrated modeling environment's GUI	Before simulation setup or during simulation run	Take workshop role-specific actions (e.g., insert a new building), trigger predefined functions
Digital surveys	PaSyMo survey app for geographically explicit statements or Google Forms	Before simulation setup	Inform simulation parameters (e.g., set of agents)
Indirect interaction via workshop setting	Role play, graphical tracking of discussions and model runs, e.g., on posters	During simulation workshop	Embed simulation model in thematic discussion and enhance model workshop findings

land-use characteristics, or construct and demolish buildings. These interventions are simulated in real time, allowing participants to observe consequences for social structures, population dynamics, or environmental conditions. Participants can also inform simulation parameters through digital surveys before the simulation setup. The modeling workshop setting, featuring role play and graphical tracking of discussions and model runs, represents an indirect mode of interaction with the MSL.

3.2. PaSyMo Workflow

The MSL workflow consists of a four-step process (Figure 3) in which the MSL is adapted to the challenge ahead: (1) the assessment and requirement analysis, (2) the data acquisition and preparation, (3) the modeling phase including simulation model design and calibration, and (4) the workshop with stakeholders (in an interim exploration phase, surveys can be utilized to capture additional insights on agent or spatial perceptions).

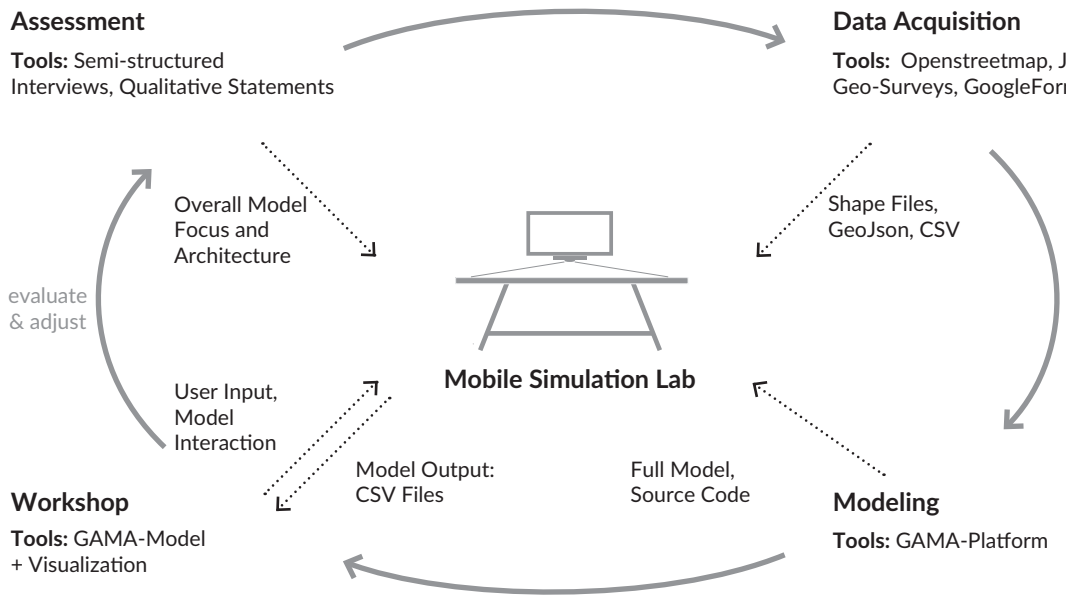

Figure 3. The four phases of the PaSyMo workflow.

The PaSyMo process starts with an *assessment* phase pursuing multiple objectives via desk research and field studies: researching a topic and local requirements, setting goals of the process, and conducting semi-structured interviews and field visits to gain expert insights from various points of view, such as needs of policymakers, expert knowledge, or the interests of citizen initiatives. Alongside the assessment, a model-concept draft is created that is continuously updated over several iterations, considering the results and feedback from field studies.

The second phase is *data acquisition* to create a virtual spatial representation of the target urban system (Figure 4). To this end, two main data sources are required: GIS data to construct the spatial dimension of the model, and census data to generate a synthetic population of agents for the simulation.

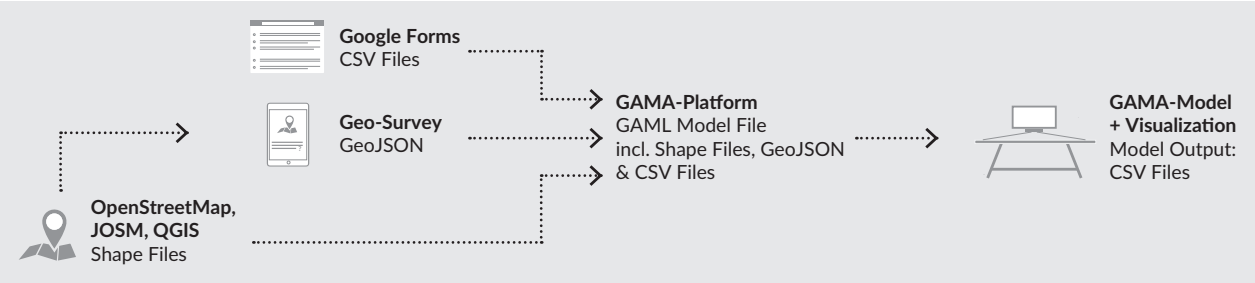

Figure 4. Data acquisition workflow.

The primary source of geospatial data is OpenStreetMap (OSM; https://www.openstreetmap.org), which provides open-access data in the form of nodes, paths, relations, and metadata attributes. The completeness of OSM data for the case study areas needs to be checked and, where necessary, improved through armchair mapping sessions using the JOSM editor (https://josm.openstreetmap.de). GAMA allows direct parsing of OSM files via its API, enabling seamless integration into the simulation environment. Additional preparation and editing of geospatial attributes performed in QGIS (https://www.qgis.org) ensures the datasets are cleaned, structured, and ready for import into GAMA.

On the demographic side, census data from official state providers (e.g., https://www.statistikportal.de) or municipal administrations was used to construct a synthetic population of human agents. Typically, population statistics are aggregated at the district level and stored as CSV files containing district names, identification numbers, and total inhabitants. Since PaSyMo uses an ABM approach, this data must be disaggregated to finer spatial units, such as apartment units in residential buildings, to accurately inform individual agent placement and characteristics. This process enables spatially explicit modeling of socio-demographic dynamics and interactions.

In addition to GIS and census data, the MSL supports the integration of geo-referenced survey data to incorporate stakeholder perspectives directly into the model. This can be achieved via an open-source application that generates JSON files from survey responses or by using tools such as Google Forms to export CSV data. These inputs can be dynamically imported into the simulation server during workshops, enriching the model with participant-generated knowledge in real time.

All model processes and GIS data are stored locally on the server, which ensures portability and reusability of the simulation environment. Compatibility with open-source software and widely available GIS data reduces technical and financial barriers, making advanced simulation accessible even in municipalities or citizen initiatives with limited resources or expertise.

In the *modeling* phase, a spatially explicit ABM is created in the GAMA platform. Each element of the city is translated into an agent with different abilities to interact or contribute information to other agents. Depending on the use case of the model, agents equipped with particular rules can be applied to the model with the aim of simulating phenomena such as migration patterns, rental price trends, or transportation (to name a few examples). GIS data can be imported to create a data-driven model of the urban area in question, containing building, traffic infrastructure, and land use information. Buildings, roads, and other shapes are created as separate agents with a 3D visualization that have properties and can be interacted with. Once the spatial realm is created, a synthetic population is implemented by placing software agents via iterative fitting

of local population statistics, utilizing GIS attributes as a means of spatially explicit disaggregation (Moeckel et al., 2003). If, due to data scarcity, socio-economic data are not available for the testbed location, disaggregation is confined to accurately distributing households to apartment blocks, which are identified by land use types via their GIS attributes. Optional additional spatial layers can be added to the model to create special places of interest. For example, to inform them at a later stage using supplementary data generated during the workshop by connecting to web services like Google Docs or the PaSyMo server.

In the *workshop* phase, stakeholders of urban planning problems interact with the model (for specific examples, refer to the following section). The researchers and modelers stay in the background. They guide the group process and make on-the-fly changes to the model if necessary. The participants utilize the PaSyMo MSL as a common point of reference. Together, they discuss the topic by first engaging in rather open reflections of their personal beliefs and opinions. Once faced with the MSL, participants are then urged to become more explicit and operationalize their arguments in the form of quantifiable what-if statements that can be tested by simulation. The aim of this interaction between group discussants and the MSL is to increase transparency of the thought processes and mental models underlying stakeholders' perceptions of the planning problem, as well as to create a more scientific mindset where opinions become hypotheses to be tested rather than rigid solutions to which the stakeholder is committed.

In the last phase of the workshop, participants engage in collective meaning-making of the visualized simulation outcomes. They discuss what has changed, whether the issue has been addressed, and make sense of the causality between their input and the visualized effects. The researchers and modelers facilitate this discussion and provide insights into the causal mechanics at work in the MSL. The aim of this gamified interaction is to debate different perceptions and ideas of causal links inherent in the model and to improve the collective knowledge about the complex planning problem—a core idea of communicative urban planning. This approach is supposed to foster systems thinking and challenge partisan beliefs by forcing humans to think beyond simple one-cause one-effect explanations. It is important to mention here that workshop participants need to be guided not to interpret the simulation outcomes as unavoidable certainties, but as contingent what-if scenarios.

The selection of stakeholders that participate in the group process is important and should be appropriate to the planning problem at hand (examples in Section 4). The selection of participants should consider group size and diversity. While there is no prescribed limit on the number of participants, the group should be optimized for high performance through face-to-face exchanges (Pentland, 2012). That means it should be big enough to include multiple viewpoints while still allowing every participant to join the discussion in a "one at a time" principle (Schegloff, 2017). Like in every participatory process, the cooperation of stakeholders is context-sensitive. Humans who join the process might have competing interests that result in active conflicts. Attention should also be given to power asymmetries in the group since this strongly influences how topics can be discussed, which humans raise their voices, and how transparent participants are about their beliefs on a topic (Voinov et al., 2018).

4. Implementation Examples of PaSyMo

PaSyMo was designed to support urban development in small and mid-sized municipalities in the state of Brandenburg, which surrounds the metropolitan area of Berlin. Since the German reunification,

municipalities in Brandenburg have faced tremendous transitional challenges. Steeply rising rents in Berlin, improved transportation infrastructure, and a movement towards more flexible working concepts such as remote work offer new growth opportunities for small and mid-sized towns in the state after two decades of shrinking populations following the fall of communism. However, considerable uncertainty makes urban planning in this dynamic environment challenging, calling for simulation-based scenario approaches. We thus had a good opportunity to test the frugal PaSyMo MSL in different workshop settings with varying degrees of participant involvement. Table 2 displays an overview of the cases, while Figure 6 conveys impressions of various workshops.

The research was of an exploratory nature, aimed firstly at testing the technological viability of the setup, but also providing us with an opportunity for some first observations regarding the usefulness of the approach in the context of the communicative planning paradigm, thus generating hypotheses to be more systematically pursued in future research.

The first case was aimed at estimating the impact of future development of inner-city mobility choices due to road usage changes in the town of Eberswalde, northeast of Berlin. The simulation model consisted of a virtual representation of the central district and its road network. The simulation implemented stylized daily schedules and commutes of virtual agents during repeating day cycles. The simulation model was based on the open-source simulation "Game IT" developed by Grignard et al. (2018). For the commute, the agents decide individually on what mode of transportation they take to travel to their next destination. The decision they make is dependent on the trade-off between their goals to minimize the time, effort, and cost of the trip.

The dynamics represented in the models and the impact of user interaction with the models are visualized in real-time on the table-top interface (Figure 5, left). The statistical output of the model showed data on the chosen mode of transportation (public transport, car, bike, or foot), and it kept track of different subsets of the local population (schoolchildren, students, employees, non-working adults, and pensioners). The simulation table served the heterogeneous group of participants (citizens, representatives from the local planning authorities, students, and researchers) as a common point of reference where adjustments to road usage changes were tested, compared, and discussed. The discussions were summarized in the form of three scenarios of the future development of inner-city traffic.

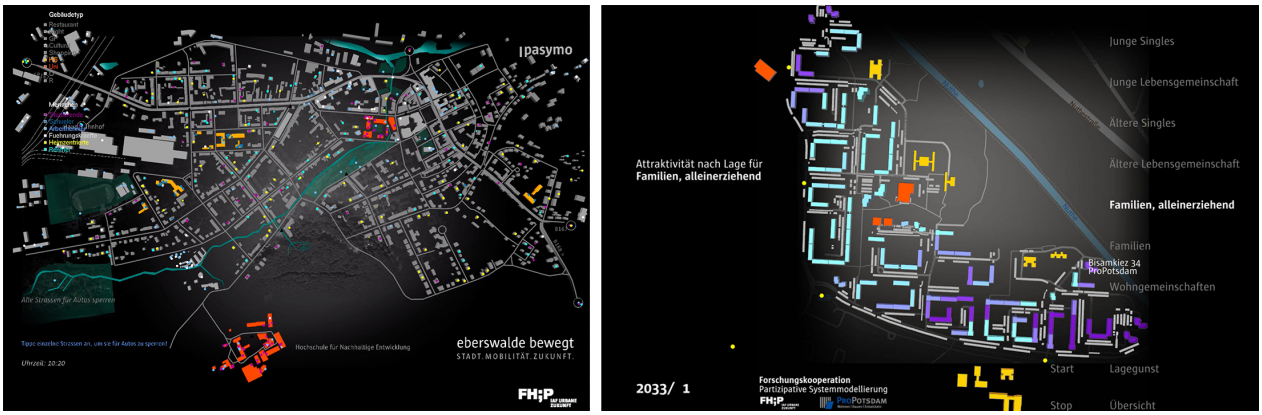

Figure 5. PaSyMo GUI showing the spatial simulation environment of the Eberswalde Models (use cases 1 & 2, left) and the Schlaatz Model (use case 3, right).

The second case addressed residential mobility and rising rents under a population-growth scenario. The simulation model consisted of a virtual representation of Eberswalde as buildings and households. During the simulation phase, the effects of different policies on the rent increase were simulated. Stakeholders count changes to a limited set of parameters that reflect the respective role, including spatial interaction on the projected map. Statistical output comprises changes regarding the composition of different household types in the building chosen on the map screen, building-specific flat numbers per size, calculated attractivity per household type, and the development of rents in the chosen building. When stakeholders agreed on a compromise, the model was run, and results concerning specific rent increases were plotted and added to the graphical workshop poster. The results of each model run were discussed, and three policy scenarios were developed. Participants were interviewed before and after the workshop. The results suggested that the developed workshop concept was well-received, the modeling principles were transparent and understandable, and the MSL format was accessible to the target group (general experts on urban development).

Table 2. Characteristics of use case workshops with increasing application focus.

Use Case No.	Thematic Focus	City of Use Case	Workshop Setting	Participants	Participant Involvement	Purpose
1	Inner-city mobility choices	Eberswalde	Municipal street festival and presentation in municipal administration	Citizens, representatives from local planning authorities, students, and researchers *n* = ca. 25	Presentation and discussion	Test spontaneous reactions and feedback on general modeling for urban development
2	Residential mobility and rent increase	Eberswalde	Expert workshop	Urban development experts from practice and academia, graduate students (M. A. Urban Futures) *n* = ca. 40	Active workshop participation, incl. survey input, role-play, and live model interaction	Test approach in custom workshop setting with hypothetical urban development task, discuss practicability with experts
3	Residential mobility and socio-demographic population development	Potsdam, Schlaatz neighborhood	Series of 4 expert workshops as part of a 6-month research cooperation with municipal housing corporation	Experts and CEOs from municipal housing corporation and several further housing cooperatives, researchers; Bi-weekly collaboration meetings: *n* = 2; Workshops: *n* = 5 to 10	Live model interaction, discussion	Test approach in real-world conditions for expert use and with real-world use case

The third application of the MSL was conceived as part of a collaboration with a municipal housing company in the city of Potsdam to study the refurbishment process of the Schlaatz neighborhood of approximately 9,500 inhabitants from 2020 to 2035. Over six months, several workshops were held to generate a common understanding among different company experts (CEOs, the Strategic Unit for Energy, Environment and Neighborhood Development, the Financial Department, and the heads of collaborating housing cooperatives) of the influencing factors and mechanisms that characterize the future development of the neighborhood's social structure. The model (Higi, 2019) showed a virtual representation of the Schlaatz neighborhood that was calibrated using data from publicly accessible statistical data and the company's database (Figure 5, right). The simulation allowed for intuitive real-time user interaction to test different scenarios and parameter settings: user interaction comprises the ability to explore different (dynamic) layers of visualization (property, energy consumption, state of refurbishment, wheelchair accessibility, and household type-specific attractivity according to the soft criteria mentioned above). The table-top interface allowed us to simulate the construction of new buildings and to add assumptions about possible groups of renters.

The interactive model visualization, including data from the company's different departments, led to participants expressing new insights and a more holistic view of the development project. Model interaction phases on the table revealed an "icebreaker effect" of the interactive touch-sensitive map projection—practitioners who were initially somewhat skeptical of an academic framing of their "daily business" became

Figure 6. Workshop setting and impressions. Top left: MSL Setup; Top right and bottom left: Use Case 2; Bottom right: Use Case 3. Sources: Pictures 1–3: Courtesy of Potsdam University of Applied Sciences, 2019; Picture 4: Courtesy of Nicole Stäbler, ProPotsdam GmbH.

more open to model discussion and interaction, discovering the ludic moment of exploring models and simulations.

5. Discussion

We presented the PaSyMo MSL as a frugal approach aimed at gamifying communicative urban planning with participatory ABM equipped with a tangible user interface. We presented three case studies, lending support not only to the technological viability of the setup but also allowing us to gain first exploratory experience with its application in a real-world context. This project has attracted actors from different domains, which has led to various follow-up projects in the infrastructure sector (e.g., Dametto et al., 2022), attesting to the face value of the approach in the eyes of urban planning stakeholders. Although we have only conducted limited formal user studies due to the exploratory nature of the case studies, our observations led us to formulate a few guiding questions for future impact assessment, which we discuss here.

One relevant design question is whether the MSL setup can indeed encourage creative and transparent communication. Across the workshops, especially in the third case, the tangible interface was perceived as an enabler for creative thinking and collaborative ideation. The hands-on nature of the MSL lowered participation thresholds and supported the shift from overtly relying on implicit assumptions to explicit communication and the convergence of assumptions. The possibility to interact directly with the model and observe outcomes in real time created a shared space for experimentation. Participants were able to test assumptions, make suggestions, and explore potential futures in a setting that blended the strategic with the ludic. These sessions made visible many ideas that would likely remain implicit in conventional formats. Here, future research should study more systematically our impression that the workshops with the MSL prompted a more experimental and creative mindset in the participants, opening the potential for more creative and effective solutions to the "wicked problems" of urban planning.

A key design concern was whether users would be engaged with the system and process. Participants' self-reported impressions, as well as the level of activity during sessions, suggest an increased motivation to participate in communicative planning groups with the MSL setup. Several participants stated that the simulation table helped them explore the topic more deeply, gain insights into the actors involved, and understand the conceptual background of the urban challenges under discussion. Particularly in the first workshop, some participants raised concerns about the representational quality of the model and expressed a desire for more empirical grounding. This feedback led to stronger data integration in the later sessions, including the use of municipal databases and disaggregated census data. Improved model calibration and increased transparency in how parameters were constructed helped mitigate concerns and enhanced participant trust in the process.

Finally, we assessed whether and how the MSL improves collaborative planning processes. The system was effective in providing a *shared* visual and spatial language that supported joint problem framing and exploration. Discussions became more grounded and explicit as participants adjusted parameters, compared scenarios, and debated the consequences of simulated outcomes. However, the sessions also revealed a recurring challenge: the risk of misinterpreting the simulation as predictive rather than exploratory. Despite repeated clarification, some participants saw model outcomes as projections rather than hypotheses. This techno-optimism needs to be actively addressed in participatory settings. It has yet to be proven that facsimile models—those that

reproduce a targeted phenomenon as exactly as possible with the intention to make predictions of the target's future state—can be obtained, let alone provide accurate predictions. For now, it is more likely that models of social phenomena that exactly match observations will be rare and restricted to very special cases (Yang & Gilbert, 2008).

The prototype testing of PaSyMo led us to assume that social-psychological aspects of group dynamics play a crucial and too often underestimated role in public engagement initiatives. To better account for effects that potentially sabotage communicative planning actions, such as confirmation biases, we have concluded that a thorough socio-psychological impact assessment must be regarded as an integral part of participatory modeling. This could help to better understand which impact the tangible simulation can have in (re-)framing and (re-)shaping participants' perceptions of local issues, local urban planning discourses as a whole, and the making or breaking of trust between different stakeholder groups.

6. Conclusions

We have presented the PaSyMo MSL that combines ABM with a tangible interface to support human-centered discursive workshops. Based on the argument that such a gamified approach provides possibilities for fostering novel forms of communicative planning, we demonstrated how stakeholders performed impact and scenario analysis for development strategies while interacting with a digital city landscape. In that process, the MSL acted as a common point of reference, a test ground for envisaged projects, and a boundary object for increasing transparency and explicitness during communication, consultation, or deliberation. The interplay of open-source software, consumer hardware, and spatially explicit tangible ABM is a gateway to inexpensive solutions for integrated and collaborative decision-making in cities.

Fully aware of the exploratory nature of the described case studies and the considerable research needs outlined above, we nevertheless think that the PaSyMo MSL is a promising approach to complexity reduction to better deal with uncertainty in communicative urban planning. However, we need to be aware of the dangers of potential misinterpretation and manipulation that might arise from the use of simulation. By emphasizing the notion of participatory settings, we aim to use data, games, and simulations as tools for an unbiased systems-thinking pedagogy that enables genuine commitment and collaboration of heterogeneous urban actors.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

An agent-based model supporting the findings of this study is published in Higi (2019).

References

Ahlqvist, O., & Schlieder, C. (2018). *Geogames and geoplay*. Springer. https://doi.org/10.1007/978-3-319-22774-0

Ahlqvist, O., Loffing, T., Ramanathan, J., & Kocher, A. (2012). Geospatial human-environment simulation through integration of massive multiplayer online games and geographic information systems. *Transactions in GIS*, *16*(3), 331–350.

Aichholzer, G., & Strauß, S. (2016). Collaborative forms of citizen (e-)participation. In G. Aichholzer, H. Kubicek, & L. Torres (Eds.), *Evaluating e-participation: Frameworks, practice, evidence* (pp. 109–122). Springer. https://doi.org/10.1007/978-3-319-25403-6_6

Alonso, L., Zhang, Y. R., Grignard, A., Noyman, A., Sakai, Y., ElKatsha, M., Doorley, R., & Larson, K. (2018). CityScope: A data-driven interactive simulation tool for urban design. Use case Volpe. In A. J. Morales, C. Gershenson, D. Braha, A. A. Minai, & Y. Bar-Yam (Eds.), *Unifying Themes in Complex Systems IX* (pp. 253–261). Springer. https://doi.org/10.1007/978-3-319-96661-8_27

Andersen, D. F., Vennix, J. A. M., Richardson, G. P., & Rouwette, E. A. J. A. (2007). Group model building: Problem structuring, policy simulation and decision support. *Journal of the Operational Research Society*, *58*(5), 691–694. https://doi.org/10.1057/palgrave.jors.2602339

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, *35*(4), 216–224. https://doi.org/10.1080/01944366908977225

Barreteau, O., Bots, P., Daniell, K., Etienne, M., Perez, P., Barnaud, C., Bazile, D., Becu, N., Castella, J.-C., Daré, W., & Trebuil, G. (2013). Participatory approaches. In B. Edmonds & R. Meyer (Eds.), *Simulating social complexity: A handbook* (pp. 197–234). Springer. https://doi.org/10.1007/978-3-540-93813-2_10

Batty, M. (2013). *The new science of cities*. MIT Press.

Becu, N., Amalric, M., Anselme, B., Beck, E., Bertin, X., Delay, E., Long, N., Marilleau, N., Pignon-Mussaud, C., & Rousseaux, F. (2017). Participatory simulation to foster social learning on coastal flooding prevention. *Environmental Modelling & Software*, *98*, 1–11. https://doi.org/10.1016/j.envsoft.2017.09.003

Bhatti, Y. A. (2012). *What is frugal, what is innovation? Towards a theory of frugal innovation* (SSRN Scholarly Paper No. 2005910). Social Science Research Network. https://doi.org/10.2139/ssrn.2005910

Carmona, G., Varela-Ortega, C., & Bromley, J. (2013). Participatory modelling to support decision making in water management under uncertainty: Two comparative case studies in the Guadiana river basin, Spain. *Journal of Environmental Management*, *128*, 400–412. https://doi.org/10.1016/j.jenvman.2013.05.019

Christmann, G., Ibert, O., Jessen, J., & Walther, U.-J. (2018). How does novelty enter spatial planning? In W. Rammert, A. Windeler, H. Knoblauch, & M. Hutter (Eds.), *Innovation society today: Perspectives, fields, and cases* (pp. 247–272). Springer. https://doi.org/10.1007/978-3-658-19269-3_12

Cornwall, A., & Jewkes, R. (1995). What is participatory research? *Social Science & Medicine*, *41*(12), 1667–1676.

Crooks, A., Heppenstall, A., Malleson, N., & Manley, E. (2021). Agent-based modeling and the city: A gallery of applications. In W. Shi, M. F. Goodchild, M. Batty, M.-P. Kwan, & A. Zhang (Eds.), *Urban informatics* (pp. 885–910). Springer. https://doi.org/10.1007/978-981-15-8983-6_46

Dametto, D., Michelini, G., Higi, L., Schröder, T., Klaperski, D., Popiolek, R., Tauch, A., & Michel, A. (2022). Developing a stakeholder-centric simulation tool to support integrated mobility planning. In M. Czupryna & B. Kamiński (Eds.), *Advances in social simulation* (pp. 65–78). Springer. https://doi.org/10.1007/978-3-030-92843-8_6

Desouza, K. C., & Bhagwatwar, A. (2012). Citizen apps to solve complex urban problems. *Journal of Urban Technology*, *19*(3), 107–136. https://doi.org/10.1080/10630732.2012.673056

Diller, C., Hoffmann, A., & Oberding, S. (2018). Rational versus communicative: Towards an understanding of spatial planning methods in German planning practice. *Planning Practice & Research*, *33*(3), 244–263. https://doi.org/10.1080/02697459.2018.1430410

Dunn, C. E. (2007). Participatory GIS—A people's GIS? *Progress in Human Geography*, *31*(5), 616–637. https://doi.org/10.1177/0309132507081493

Elliott-Graves, A. (2020). What is a target system? *Biology and Philosophy*, *35*(2), 28. https://doi.org/10.1007/s10539-020-09745-3

Epstein, J. M. (2008). Why model? *Journal of Artificial Societies and Social Simulation*, *11*(4), 12. https://www.jasss.org/11/4/12.html

Ertiö, T.-P. (2015). Participatory apps for urban planning—Space for improvement. *Planning Practice & Research*, *30*(3), 303–321. https://doi.org/10.1080/02697459.2015.1052942

Geertman, S., & Stillwell, J. (2020). Planning support science: Developments and challenges. *Environment and Planning B: Urban Analytics and City Science*, *47*(8), 1326–1342. https://doi.org/10.1177/2399808320936277

Gilbert, N., & Troitzsch, K. (2005). *Simulation for the social scientist*. Open University Press.

Gray, S., Jordan, R., Crall, A., Newman, G., Hmelo-Silver, C., Huang, J., Novak, W., Mellor, D., Frensley, T., Prysby, M., & Singer, A. (2017). Combining participatory modelling and citizen science to support volunteer conservation action. *Biological Conservation*, *208*, 76–86. https://doi.org/10.1016/j.biocon.2016.07.037

Greenfield, A. (2013). *Against the smart city*. Do projects.

Grignard, A., Alonso, L., Taillandier, P., Gaudou, B., Nguyen-Huu, T., Gruel, W., & Larson, K. (2018). The impact of new mobility modes on a city: A generic approach using ABM. In A. Morales, C. Gershenson, D. Braha, A. Minai, & Y. Bar-Yam (Eds.), *Unifying Themes in Complex Systems IX* (pp. 272–280). Springer. https://doi.org/10.1007/978-3-319-96661-8_29

Head, B. W. (2022). *Wicked problems in public policy: Understanding and responding to complex challenges*. Springer. https://doi.org/10.1007/978-3-030-94580-0

Healey, P. (1992). Planning through debate: The communicative turn in planning theory. *The Town Planning Review*, *63*(2), 143–162.

Hemmersam, P., Martin, N., Westvang, E., Aspen, J., & Morrison, A. (2015). Exploring urban data visualization and public participation in planning. *Journal of Urban Technology*, *22*(4), 45–64. https://doi.org/10.1080/10630732.2015.1073898

Heppenstall, A. J., Crooks, A. T., See, L. M., & Batty, M. (Eds.). (2012). *Agent-based models of geographical systems*. Springer. https://doi.org/10.1007/978-90-481-8927-4

Hermansdorfer, M., Skov-Petersen, H., & Fricker, P. (2020). Bridging tangible and virtual realities: Computational procedures for data-informed participatory processes. *Journal of Digital Landscape Architecture*, *2020*(5), 354–365. https://doi.org/10.14627/537690036

Higi, L. (2019). *Agent-based model of residential mobility and socio-demographic development Schlaatz, Potsdam, Germany: Schlaatz Neighborhood Model v1.0* [Computer software]. Zenodo. https://doi.org/10.5281/zenodo.17107975

Hollands, R. G. (2015). Critical interventions into the corporate smart city. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 61–77. https://doi.org/10.1093/cjres/rsu011

Innes, J. E. (1995). Planning theory's emerging paradigm: Communicative action and interactive practice. *Journal of Planning Education and Research*, *14*(3), 183–189. https://doi.org/10.1177/0739456X9501400307

Innes, J. E., & Booher, D. E. (2010). *Planning with complexity: An introduction to collaborative rationality for public policy*. Routledge. https://doi.org/10.4324/9780203864302

Jiang, H., Geertman, S., & Witte, P. (2020). Avoiding the planning support system pitfalls? What smart governance can learn from the planning support system implementation gap. *Environment and Planning B: Urban Analytics and City Science*, *47*(8), 1343–1360. https://doi.org/10.1177/2399808320934824

Kontokosta, C. E. (2016). The quantified community and neighborhood labs: A framework for computational urban science and civic technology innovation. *Journal of Urban Technology*, *23*(4), 67–84. https://doi.org/10.1080/10630732.2016.1177260

Marras, M., Manca, M., Boratto, L., Fenu, G., & Laniado, D. (2018). BarcelonaNow: Empowering citizens with interactive dashboards for urban data exploration. In *Companion Proceedings of the Web Conference 2018* (pp. 219–222). International World Wide Web Conferences Steering Committee. https://doi.org/10.1145/3184558.3186983

Marto, A., & Gonçalves, A. (2022). Augmented reality games and presence: A systematic review. *Journal of Imaging*, *8*(4), 91. https://doi.org/10.3390/jimaging8040091

Miller, J. H., & Page, S. E. (2007). *Complex adaptive systems*. Princeton University Press.

Minh Duc, P., Chapuis, K., Drogoul, A., Gaudou, B., Grignard, A., Marilleau, N., & Tri, N.-H. (2020). HoanKiemAir: Simulating impacts of urban management practices on traffic and air pollution using a tangible agent-based model. In *2020 RIVF International Conference on Computing and Communication Technologies* (pp. 1–7). IEEE. https://doi.org/10.1109/RIVF48685.2020.9140787

Moeckel, R., Spiekermann, K., & Wegener, M. (2003). Creating a synthetic population. In *Proceedings of the 8th International Conference on Computers in Urban Planning and Urban Management (CUPUM)* (pp. 1–18).

Münster, S., Georgi, C., Heijne, K., Klamert, K., Noennig, J. R., Pump, M., Stelzle, B., & van der Meer, H. (2017). How to involve inhabitants in urban design planning by using digital tools? An overview on a state of the art, key challenges and promising approaches. *Procedia Computer Science*, *112*, 2391–2405. https://doi.org/10.1016/j.procs.2017.08.102

Noyman, A., Holtz, T., Kröger, J., Noennig, J. R., & Larson, K. (2017). Finding places: HCI platform for public participation in refugees' accommodation process. *Procedia Computer Science*, *112*, 2463–2472. https://doi.org/10.1016/j.procs.2017.08.180

Panagiotopoulou, M., Somarakis, G., & Stratigea, A. (2020). Smartening up participatory cultural tourism planning in historical city centers. *Journal of Urban Technology*, *27*(4), 3–26. https://doi.org/10.1080/10630732.2018.1528540

Pentland, A. S. (2012). The new science of building great teams. *Harvard Business Review*, *90*(4).

Petrasova, A., Harmon, B., Petras, V., Tabrizian, P., & Mitasova, H. (2018). *Tangible modeling with open source GIS*. Springer. https://doi.org/10.1007/978-3-319-89303-7

Poplin, A. (2012). Playful public participation in urban planning: A case study for online serious games. *Computers, Environment and Urban Systems*, *36*(3), 195–206.

Poplin, A. (2025). Geogames: An expanded definition, application areas, geogame types, and a proposed research agenda. *Environment and Planning B: Urban Analytics and City Science*. Advance online publication. https://doi.org/10.1177/23998083251382383

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169. https://doi.org/10.1007/BF01405730

Salim, F. (2014). Tangible 3D urban simulation table. In *Proceedings of the Symposium on Simulation for Architecture & Urban Design* (pp. 1–4). Society for Computer Simulation International.

Schegloff, E. A. (2017). Conversation analysis. In Y. Huang (Ed.), *The Oxford handbook of pragmatics* (pp. 435–450). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199697960.013.26

Shaer, O., & Hornecker, E. (2010). Tangible user interfaces: Past, present, and future directions. *Foundations and Trends® in Human–Computer Interaction*, *3*(1/2), 4–137. https://doi.org/10.1561/1100000026

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. *Social Studies of Science*, *19*(3), 387–420. https://doi.org/10.1177/030631289019003001

Sterling, E. J., Zellner, M., Jenni, K. E., Leong, K., Glynn, P. D., BenDor, T. K., Bommel, P., Hubacek, K., Jetter, A. J., Jordan, R., Olabisi, L. S., Paolisso, M., & Gray, S. (2019). Try, try again: Lessons learned from success and failure in participatory modeling. *Elementa: Science of the Anthropocene*, *7*(9). https://doi.org/10.1525/elementa.347

Szczepanska, T. (2023). *Foundations of GAM research. Methodological guidelines for designing and conducting research that combines games and agent-based models* [Unpublished doctoral dissertation]. UiT The Arctic University of Norway. https://hdl.handle.net/10037/31866

Szczepanska, T., Antosz, P., Berndt, J. O., Borit, M., Chattoe-Brown, E., Mehryar, S., Meyer, R., Onggo, S., & Verhagen, H. (2022). GAM on! Six ways to explore social complexity by combining games and agent-based models. *International Journal of Social Research Methodology*, *25*(4), 541–555. https://doi.org/10.1080/13645579.2022.2050119

Taillandier, P., Gaudou, B., Grignard, A., Huynh, Q.-N., Marilleau, N., Caillou, P., Philippon, D., & Drogoul, A. (2019). Building, composing and experimenting complex spatial models with the GAMA platform. *GeoInformatica*, *23*(2), 299–322. https://doi.org/10.1007/s10707-018-00339-6

Taillandier, P., Grignard, A., Marilleau, N., Philippon, D., Huynh, Q.-N., Gaudou, B., & Drogoul, A. (2019). Participatory modeling and simulation with the GAMA platform. *Journal of Artificial Societies and Social Simulation*, *22*(2), 3. https://www.doi.org/10.18564/jasss.3964

Van Berkel, D. B., & Verburg, P. H. (2012). Combining exploratory scenarios and participatory backcasting: Using an agent-based model in participatory policy design for a multi-functional landscape. *Landscape Ecology*, *27*(5), 641–658. https://doi.org/10.1007/s10980-012-9730-7

Vanolo, A. (2016). Is there anybody out there? The place and role of citizens in tomorrow's smart cities. *Futures*, *82*, 26–36. https://doi.org/10.1016/j.futures.2016.05.010

Voinov, A., & Bousquet, F. (2010). Modelling with stakeholders. *Environmental Modelling & Software*, *25*(11), 1268–1281. https://doi.org/10.1016/j.envsoft.2010.03.007

Voinov, A., Jenni, K., Gray, S., Kolagani, N., Glynn, P. D., Bommel, P., Prell, C., Zellner, M., Paolisso, M., Jordan, R., Sterling, E., Schmitt Olabisi, L., Giabbanelli, P. J., Sun, Z., Le Page, C., Elsawah, S., BenDor, T. K., Hubacek, K., Laursen, B. K., . . . Smajgl, A. (2018). Tools and methods in participatory modeling: Selecting the right tool for the job. *Environmental Modelling & Software*, *109*, 232–255. https://doi.org/10.1016/j.envsoft.2018.08.028

Yang, L., & Gilbert, N. (2008). Getting away from numbers: Using qualitative observation for agent-based modelling. *Advances in Complex Systems*, *11*(02), 175–185. https://doi.org/10.1142/S0219525908001556

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Nested Urban Scales: A Pervasive Geogame Model for Collective Energy Efficiency and Action

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Abstract

As global energy demand continues to rise, energy efficiency remains one of the most cost-effective strategies for managing consumption, and behavioral energy efficiency (BEE) plays a crucial role in reducing energy use in buildings. Energy games designed to address BEE through real-life actions typically focus on a location or a singular building typology such as homes, offices, or schools. While these games provide location-appropriate energy-reducing actions, they rarely focus on the simultaneous and multiple identities players hold in location-based games. For example, players may be part of a household in a residential game while simultaneously being a neighbor at the block scale, and part of the larger community at the city scale. In this article, we begin by defining serious pervasive energy geogames (GeoSPEGs) at the intersection of serious games, pervasive games, energy games, and geogames. Then, we present a case study analysis of efargo, a residential GeoSPEG, where the players (homeowners or renters) hold simultaneous identities and allegiances related to their household, their neighborhood block, and their city. The game structure allows for aligned individual and collective game incentives, creating potential for cooperative and competitive play. Next, we compare and synthesize the pervasive game design models utilized for the efargo case study with the "unified geogame design patterns." We conclude our analysis with a proposal for a GeoSPEG design model that intersects and combines existing design frameworks for pervasive and geogames utilized during the design of the efargo game, and we introduce "nested urban scales" as a fundamental geogame design pattern.

Keywords

behavioral energy efficiency; game design model; geogame; pervasive game; serious energy game

1. Introduction

Global warming and climate change form the critical context for evaluating existing buildings' energy efficiency. Data suggest that the building and construction sectors collectively account for 34% of final energy use and 37% of energy-related CO_2 emissions, while energy used for building operations accounted for 32% of global demand in 2023, and between two-thirds and three-fourths of building-related emissions are associated with operations (United Nations Environment Programme, 2024). Reducing operational energy use and increasing building energy efficiency could result in significant reductions in global warming (Granade et al., 2009). Building energy efficiency may be achieved through investing in building improvements and encouraging energy-use behavior by building occupants to prevent energy waste. Altering household members' behavior can rapidly reduce carbon emissions, making behavioral energy efficiency (BEE) programs promising for reducing operating costs and leading to persistent behavioral change (Allcott & Mullainathan, 2010; Allcott & Rogers, 2014; Andor & Fels, 2018; Aydin et al., 2018; Dietz et al., 2009; Kamal et al., 2019; Nolan et al., 2008). Tools that encourage energy-saving behavior are found to be more effective when offered in synergistic combinations (Composto & Weber, 2022; Khanna et al., 2021). Frequency, medium, duration, and achievability, combined with the challenge of interventions, also have an impact on BEE effectiveness (Boncu et al., 2022; Karlin et al., 2015). Behavioral interventions can be most effective when they are offered in combination with social influence and relationship-building (Abrahamse, 2019; Staddon et al., 2016). Social groups such as family, friends, neighbors, and community members can be influential through influence mechanisms (Abrahamse & Steg, 2013; Grilli & Curtis, 2021; Rau et al., 2022).

Serious energy games designed to address BEE through real life energy-saving actions typically focus on a singular building typology such as homes, as in games like HomeRUN (Agusdinata et al., 2024), Apolis Planeta (Csoknyai et al., 2019), PowerSaver (Fijnheer & van Oostendorp, 2015; Fijnheer et al., 2021), PowerAgent (Gustafsson et al., 2010), Power Explorer (Gustafsson et al., 2009), and Energy Battle (Geelen et al., 2012); or offices, as in games like Energy Chickens (Orland et al., 2014) and GResBAS (Barbosa et al., 2017); or schools and universities, as in Gamified HMI (Méndez et al., 2021), Battle of the Buildings (Inman, 2011), and the K-12 Energy Challenge (Srivastava, 2019). While these spatially-aware games successfully provide location-appropriate energy-reducing actions and engagement, they typically focus on action items in immediate surroundings (Laato et al., 2020). In serious energy games, competitive play is typically between individuals and their homes or households (in residential games), and cooperative play opportunities typically present within individual households (Nasrollahi et al., 2023) or individual building types such as offices or schools. These games typically do not take advantage of inter-household or multiplayer cooperative play.

Geogames, a game typology that involves real-world locations, can engage players in meaningful play that helps them learn about their local environments, and have cooperative in-person interactions with the local community members and game participants (Laato et al., 2020; Schlieder et al., 2006). Geogames have the potential to expand to local contexts and communities. In games like Pokémon Go, where real-world locations are utilized, players have the potential to make a positive contribution by engaging in environmentally friendly behaviors, adopting eco-friendly habits, supporting environmental initiatives, and advocating for environmental-protection policies (Kordyaka et al., 2024). The simultaneous, multiple identities players hold in geogames are typically not the focus of serious energy game structures.

For example, residential serious energy game players simultaneously hold identities as neighbors at the neighborhood scale and members of the larger community at the city scale, but games do not typically focus on all these identities and usually limit their focus on one of the identities. These simultaneously held multiple identities by players across urban scales (neighborhoods, blocks, districts, and cities) have the potential to prompt multiple identity-based, location-based interventions, maximizing potential for social influence.

In this article, we propose a design model for games at the intersection of serious games, pervasive games, energy games, and geogames that aims to address BEE while taking advantage of nested urban scales, that we define as simultaneous identities that players may hold in geogames, based on their location and the context referenced at various spatial scales. For example, the player may identify as a homeowner or renter at the scale of their residence but may identify as a neighbor at the scale of the block within which their residence is located or as a community member at the scale of the neighborhood or city. Geogames designed around the concept of nested urban scales recognize that players simultaneously hold multiple identities, shaped by the geographic scale associated with their location.

2. Methodology

We begin by defining serious pervasive energy geogames (GeoSPEGs) as a special category of games that exist at the intersection of serious games (games with goals beyond entertainment), pervasive games (games that blur ordinary life and game actions), energy games (games that reduce energy use), and geogames (location-based play in which a player's real-world geographic position is intrinsic to the game experience). Then, we present a case-study analysis of efargo, a GeoSPEG that allowed for aligned individual and collective game incentives, thus creating the potential for simultaneous cooperative and competitive play due to multiple player identities aligned with nested location scales and areas. Designed and implemented by a team led by this article's corresponding author, the efargo game included structures that allowed for aligned individual and collective game incentives, where the players (homeowners or renters) held simultaneous identities related to nested urban scales. Next, we discuss the design frameworks utilized for the efargo case study: Poplin's game elements (Poplin, 2011, 2012), Srivastava's extensions of Poplin's game elements (Srivastava, 2016), Harteveld's triadic game design (TGD) model (Harteveld, 2011), and unified geogame design patterns (UGDPs) which are based on the work by Ahlqvist and Schlieder (2018). Ahlqvist and Schlieder (2018) proposed a "unified vocabulary that cuts across the realms of Geo and Game" by studying the alignments and differences between unified core and extended geographic concepts (Janelle & Goodchild, 2011; Kuhn, 2012; Kuhn & Ballatore, 2015) with game components identified by Holopainen (2011) and key game elements proposed by Järvinen (2008). We adapt and utilize the unified vocabulary proposed by Ahlqvist and Schlieder as UGDPs. We follow a similar synthesis methodology to compare the UGDPs with the frameworks that informed the efargo design. On this basis, we propose an expanded game design model for GeoSPEGs, building on Harteveld's three fundamental principles of Reality, Meaning, and Play, and adding three design elements, namely, Representations (Interfaces), Resources, and Networks.

3. Game Types and Overlaps

The efargo case study has overlapping characteristics of pervasive games, serious pervasive energy games (SPEGs), and geogames (Srivastava, 2020). Here we position the efargo case study as a GeoSPEG. We first define the overlapping game typologies to define GeoSPEGs and propose the GeoSPEG game model.

3.1. Pervasive Games

Pervasive games blur the boundaries between everyday life and gameplay, creating experiences that unfold within real-world settings. Often, these games extend gameplay into the real world with the use of hybrid interfaces and technologies such as mobile devices, wireless networking, and positioning systems (Kasapakis & Gavalas, 2015). Huizinga (1949) proposes the "magic circle," i.e., the boundary created by games where their rules apply. Pervasive games extend a game's boundaries beyond the magic circle into ordinary life (Montola et al., 2009; Nieuwdorp, 2005). Gameplay is therefore enmeshed with the real world (Benford et al., 2005). Pervasive games may be location-specific, such as Pac Manhattan (Poplin, 2012), location-aware, such as Your Way Your Missions (Chen et al., 2013), or trans-locational, such as Barbarossa (Kasapakis & Gavalas, 2017a, 2017b). These games allow players to contribute to game objectives through real-life actions; in this way, they have the potential to facilitate the transfer of game knowledge to the real world, thus giving players the potential to achieve serious goals. By including hands-on tasks in real-world applications that require player engagement, pervasive games may induce behavior change (McGonigal, 2006), further narrowing the gap between the game world and reality (Gustafsson et al., 2010), due to the quality of existing simultaneously in-game space and ordinary life and space.

3.2. SPEGs

Serious games serve purposes beyond entertainment (Michael & Chen, 2006). Deterding et al. (2011) identify "serious pervasive games" at the intersection of serious games (i.e., games used in non-game contexts for serious purposes) and games that are extended beyond entertainment. These games have demonstrated enhanced user engagement, comprehension of complex concepts, and application of knowledge through practical interventions (Ahmadov et al., 2025; Lamb et al., 2018). SPEGs, then, are games serving the serious purpose of aiming to reduce energy use and enhance energy efficiency in the real world (Srivastava, 2020). In these games, players can work to reduce impacts by applying their game knowledge. However, knowledge gained through gameplay only becomes impactful when it informs real-life situations: for example, when game players take real-world actions as part of their gameplay to conserve energy. SPEGs utilize physical space as the gaming platform, often blending digital and physical elements. SPEGs began in 2007 with Power Agent, implemented by Gustafsson, Katzeff, and Bång, to encourage teenagers and their families to reduce energy consumption in Sweden (Gustafsson et al., 2010). Serious energy games designed for BEE in households positively influence player motivation and engagement in energy conservation (Agusdinata et al., 2024; Boncu et al., 2022; Csoknyai et al., 2019; Fijnheer, 2022; Geelen et al., 2012; Gustafsson et al., 2010).

3.3. Geogames

Geogames are a form of location-based play in which a player's real-world geographic position is central to the game experience. Supported by geographic information technologies which make the physical environment an active part of gameplay (Ahlqvist et al., 2019), geogames require players to navigate real-world settings—such as neighborhoods or cities—while engaging with game elements that are triggered or shaped by localization technologies like GPS (Heinz & Schlieder, 2019; Schlieder et al., 2006). Geogames can strengthen players' connections to nature and deepen understanding of environmental issues (Schneider & Schaal, 2018; Schneider et al., 2017). Several mobile geogames, such as Origami, Ingress, Geo TicTacToe,

and others, are multiplayer games that develop spatial competencies (Bartoschek et al., 2017). The use of advanced technologies in geogames can dynamically alter game environments, generate new content, and adapt experiences based on player behavior or feedback, thereby expanding the possibilities for personalized and context-sensitive gameplay (Poplin, 2024). Extending the genre of geogames to a technology-independent concept (Järvinen, 2008), Ahlqvist and Schlieder (2018) define geogames as games that emphasize spatial relationships and patterns.

3.4. The Case Study, efargo, a GeoSPEG

The efargo case study is a residential GeoSPEG (Figure 1, #15) at the intersection of serious energy games (Figure 1, #6), pervasive games (Figure 1, #1), and geogames (Figure 1, #4), designed and implemented with the goal of reducing energy use in all homes in Fargo, North Dakota. Working from the assertion that games in general and pervasive games in particular have the potential to create community, action, and participation, the efargo residential game, implemented in 2016, was a part of the larger eponymous efargo effort for the City of Fargo's participation in the Georgetown University Energy Prize (GUEP).

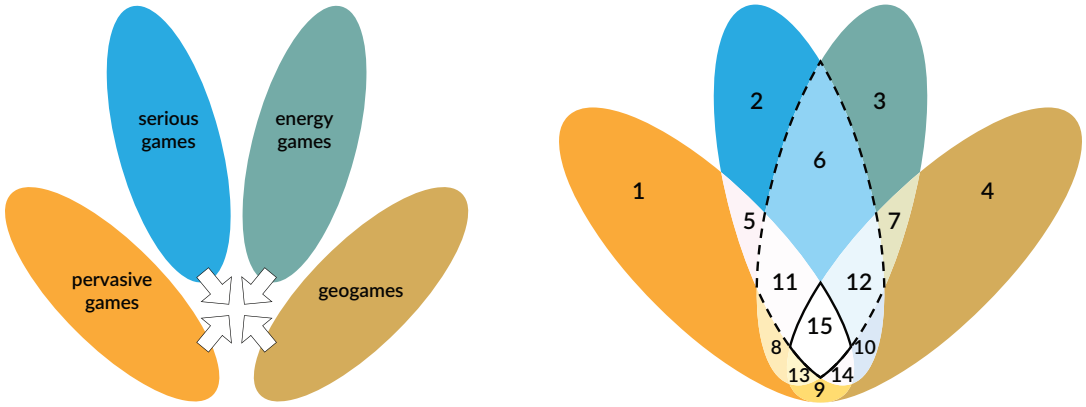


Figure 1. efargo game at the intersection of serious, pervasive, energy, and geogames (#15 on the right). Notes: (1) pervasive games; (2) serious games; (3) energy games; (4) geogames; (5) pervasive serious games; (6) serious energy games; (7) energy geogames; (8) pervasive energy games; (9) pervasive geogames; (10) serious geogames; (11) SPEGs; (12) serious energy geogames; (13) pervasive energy geogames; (14) serious pervasive geogames; (15) GeoSPEGs.

The nationwide GUEP competition, announced in 2014, was aimed at improving energy efficiency and reducing energy use in cities with populations ranging from 5,000 to 250,000 people (Srivastava & Nelson, 2017). This competition presented an opportunity to examine whether playing games can reduce energy use through BEE efforts ("$5 million Georgetown Energy Prize," 2014; Brandes et al., 2018; GUEP, 2018). The competition lasted from January 2015 to December 2016. Energy use data collection in 2015 and 2016 was compared against baseline energy use for 2013–2014. Fifty cities in the United States participated in the GUEP. A competition team was established at North Dakota State University under the identity and trademark of "efargo" (Srivastava, 2019; Srivastava & Nelson, 2017). In partnership with municipal government and utility providers, the team researched, designed, and implemented several serious energy games incorporating building-improvement- and behavior-based approaches, playful interactions, and other awareness-building opportunities. This article's corresponding author led the team and its research, design, and implementation efforts. In the GUEP energy-use data, efargo's work resulted in Fargo being ranked as the fourth-highest energy saver (achieving an aggregated city-wide 6.84% energy-use reduction

over the two-year competition period, normalized and compared to baseline energy use for the competition-preceding two-year period). Fargo was declared the overall winner of the GUEP based on a multi-criteria evaluation (Brandes et al., 2018; Srivastava & Nelson, 2017).

The efargo residential GeoSPEG had the serious goal of enabling participants to overcome the informational and behavioral challenges of the energy-efficiency gap (Hirst & Brown, 1990) and thereby adopt environmentally beneficial behavior with proven outcomes (Head & Hunt, 2014) to reduce their energy use. As a pervasive game, efargo fostered direct engagement with place (players' homes, blocks, and neighborhoods), structuring real-time behaviors and actions that blurred the boundary between everyday behaviors and gameplay. As a GeoSPEG, efargo made players' geographic location intrinsic to their roles or identities (homeowner or renter, neighbor, or community member), and the players' cooperative and competitive real-time actions were related to incentives at different scales or areas (player's household or residence, player's block, and player's neighborhood). Players' geographic locations and their identities—both as Fargo community members and as part of the GUEP, competing against 50 other cities in the semi-finals and 10 other cities in the finals stage—played an important role, making nested urban scales instrumental as a design concept in spurring engagement during the efargo game.

4. The efargo Game

The efargo game was released to the City of Fargo community over nine weeks (Srivastava, 2016), from February 2016 until April 2016. Three hundred and one players signed up for the game and were part of the initial nine-week game implementation for which data were collected. The game remained accessible through the efargo website (http://efargo.org/game) after the nine-week implementation and was utilized by the community, although data were collected only during the initial nine-week period. Of the 301 initial players, 299 players progressed beyond the initial sign-up.

The efargo game interface was a web- and mobile-based game board consisting of two equal areas. The left side was the efargo game board and leaderboard (Figure 2a). The right side was the informational section, which educated and instructed players in the game, and provided information about energy use and energy actions, community dialogue, and social media links (Figures 2b, 2c, 2d, 2e, 2f, and 2g). The right side changed frequently based on the players' actions and position.

The primary game mechanism was for players to advance game activity tokens (blue circles in Figures 2a and 2b) to the highest levels of the game board by completing real-life energy-saving actions and responding to surveys and quizzes about energy efficiency. Nine tokens were released at the rate of one token per week (Figure 2b). The players' goal was to capture Waste-a-Watt, a character developed in co-design efforts with the community. Waste-a-Watt personified energy waste and was embedded throughout the upper levels of the game board (Figures 2a, 2c, and 2d). Each horizontal row of cubes was a level: Yellow and orange levels were lower (easier challenges and fewer points), and red levels were higher (more difficult challenges and greater points; Figure 2a). There were seven levels in total, and each week's blue token could be advanced to a higher level every week. Game activities were embedded in the cubes, revealed when players moved the weekly tokens to the colorful cube surface. The weekly tokens, when placed and advanced on the game board, unlocked information about energy waste and quizzes about energy efficiency and provided energy-saving actions for player completion (Figures 2e, 2f, and 2g).

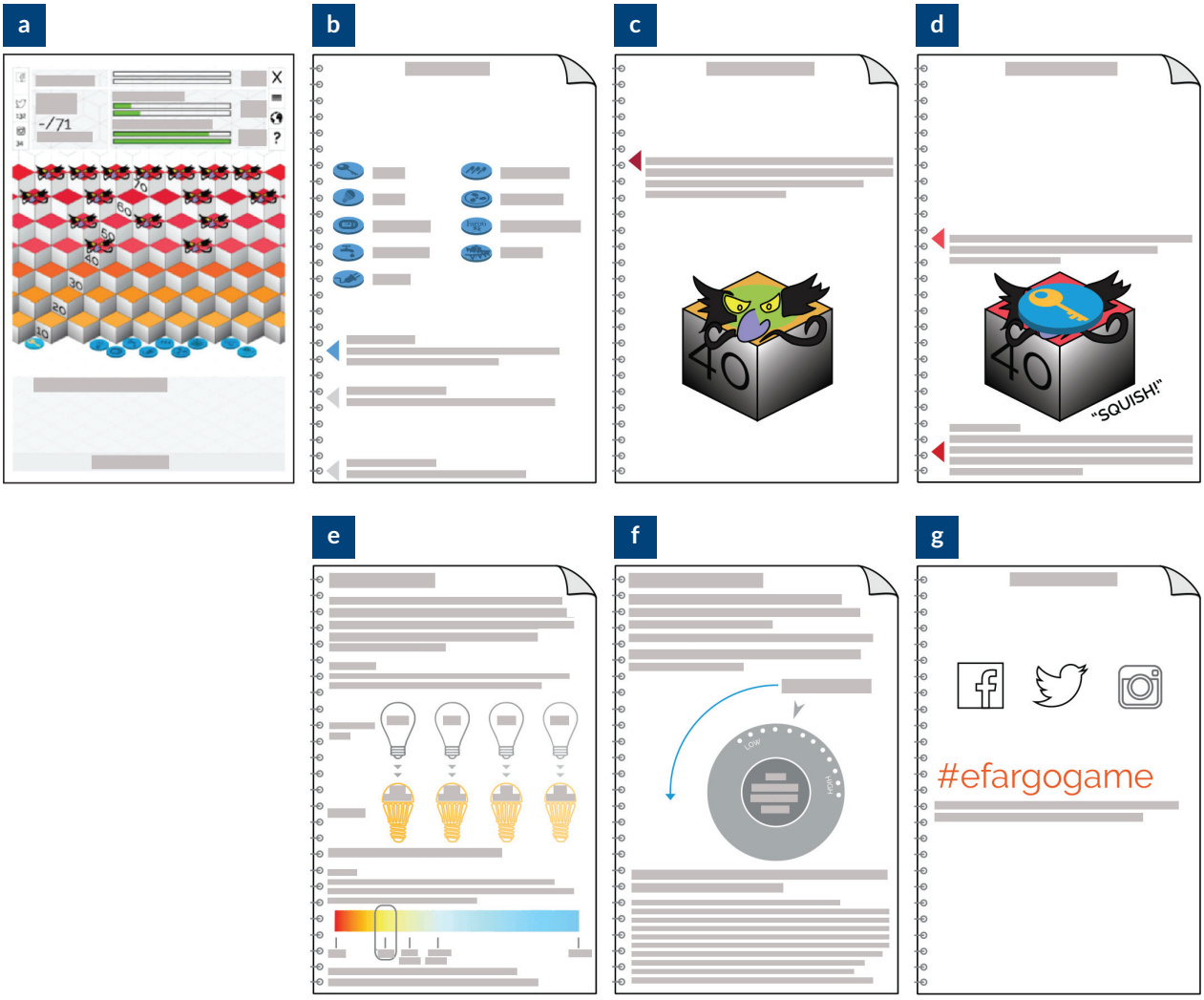


Figure 2. efargo game board examples. Sources: Srivastava (2019, 2020).

Each week's token focused on a particular area of residential energy efficiency (Figure 2b). For example, the Week 1 Lighting token involved quizzes and information about lighting and lighting-related energy-saving activities (replacing inefficient light bulbs with LED bulbs, etc.) that were embedded in the cubes, revealed when tokens were advanced by the player. Of all the tokens or topic areas, Lighting (Week 1) had the most engagement (as measured by the number of players who earned points), followed by Space Heating (Week 2), Water Heating (Week 3), Devices (Week 4), Controls (Week 5), Cooling & Ventilation (Week 6), and Player's Choice (Week 7). In the Civic token (Week 8), players were asked to leave the game portal and enter an app called mySidewalk to suggest ways in which the city could address energy waste, energy savings, and climate change (mySidewalk, n.d.). In the last token (Week 9), efargo organized a celebratory in-person event where players could earn points by visiting interactive booths and engage directly with each other and stakeholders. The attendance at the event was approximately 275 people over the course of four hours.

The efargo game objectives included engaging homeowners and renters in (a) learning about energy waste in their homes (learning and awareness); (b) acting to reduce energy use (behavior); (c) investing time and financial resources to reduce energy use (investment); and (d) completing energy-saving actions (engagement and action).

4.1. Geography-Based Structures, Incentives, and Interfaces in the efargo Game

There were five ways in which player location and geography played important roles in the efargo game design. First, the efargo effort's co-design process incorporated the community and was dispersed around various locations (public library, zoo, and schools) to welcome participation and engagement. The team conducted biweekly community meetings at the Fargo Public Library in an ongoing design process, garnering community input for events and engagement. The efargo narrative was developed with public participation. Early sketches of stories and characters were presented to the community; children and adults responded to initial sketches with feedback and their own versions of the characters. Members of the efargo team combined and developed these sketches into the final character version. Waste-a-Watt, the monster that personified energy waste and inefficiency that emerged from these efforts, provided an easily communicable and visual theme for efargo (Srivastava, 2019, 2020; see Figure 3).

Figure 3. Waste-a-Watt character and narrative development for efargo with community participation in multiple public locations. Sources: Srivastava (2019, 2020).

Second, the efargo game structure expanded player agency as the game progressed. Weeks 1–6 incorporated actions and engagement at the household and neighborhood scale. During the later weeks of the game (Weeks 7–9), the weekly tokens (civic and public) had activities that encouraged community dialogue during community events, and engagement with the municipality, utilities, and other organizations, expanding player social identities from individual players or household members to community members at the city scale (Figure 4).

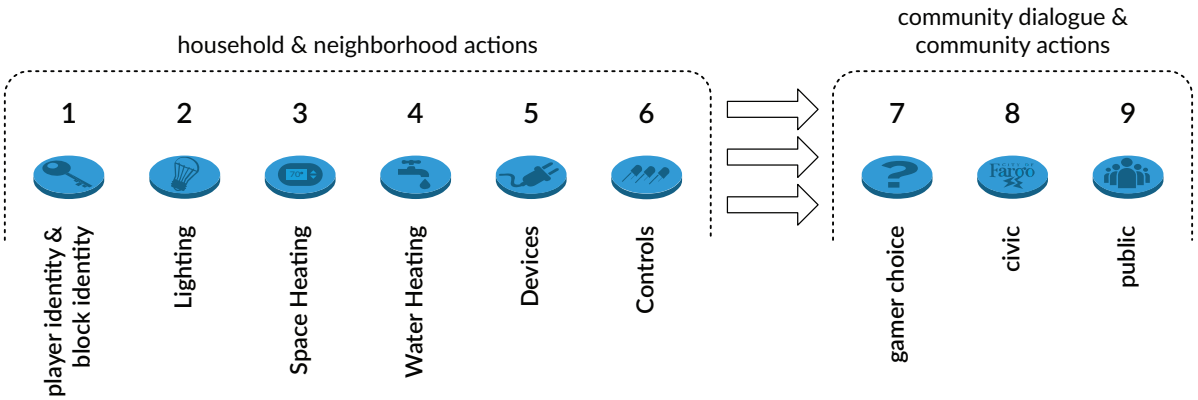


Figure 4. efargo weekly tokens that expanded players' nested social and spatial identities (from household and block to community and city) during the progression of the weekly gameplay.

Third, the design of the game incentives allowed players to cooperate and compete for winning the game as individuals or household players, as neighborhood members, and as community members of the City of Fargo. The game incentivized players with weekly prizes randomly selected from the highest-scoring winning blocks. The overall 10 highest-scoring players received smart thermostats as grand prizes. There were three ways of winning the efargo game that related to players' multiple and nested identities. The first two ways related to each player's block-based identity. Points earned through advancing the game tokens through challenge levels determined weekly game scores for each player or household. To determine the weekly champion player, the scores of all neighborhood-block players were aggregated. The block with the highest score was declared that week's winner. A weekly individual champion was identified by randomly selecting a player from the week's winning block. To increase their chances of being selected as the weekly champion, each player needed to contribute as many points as possible to the block score while helping their neighbors achieve high scores through cooperative play (outreach and networking). The third method of winning the game was based on the highest individual or household game score, awarded competitively to the highest-scoring 10 players in the city at the end of nine weeks. This allowed the game designers to selectively verify game actions within a small subset of finalists while also requiring them to submit individual household energy-use information.

Fourth, the efargo game results interface included a leaderboard and a frequently updated city map (Figure 5). The leaderboard included each player's individual scores and rank and their neighborhood block's scores and ranks. The city map showed each block's score, i.e., the aggregated scores of individual household players. The map also showed the past week's winner, i.e., the block with the highest aggregate score.

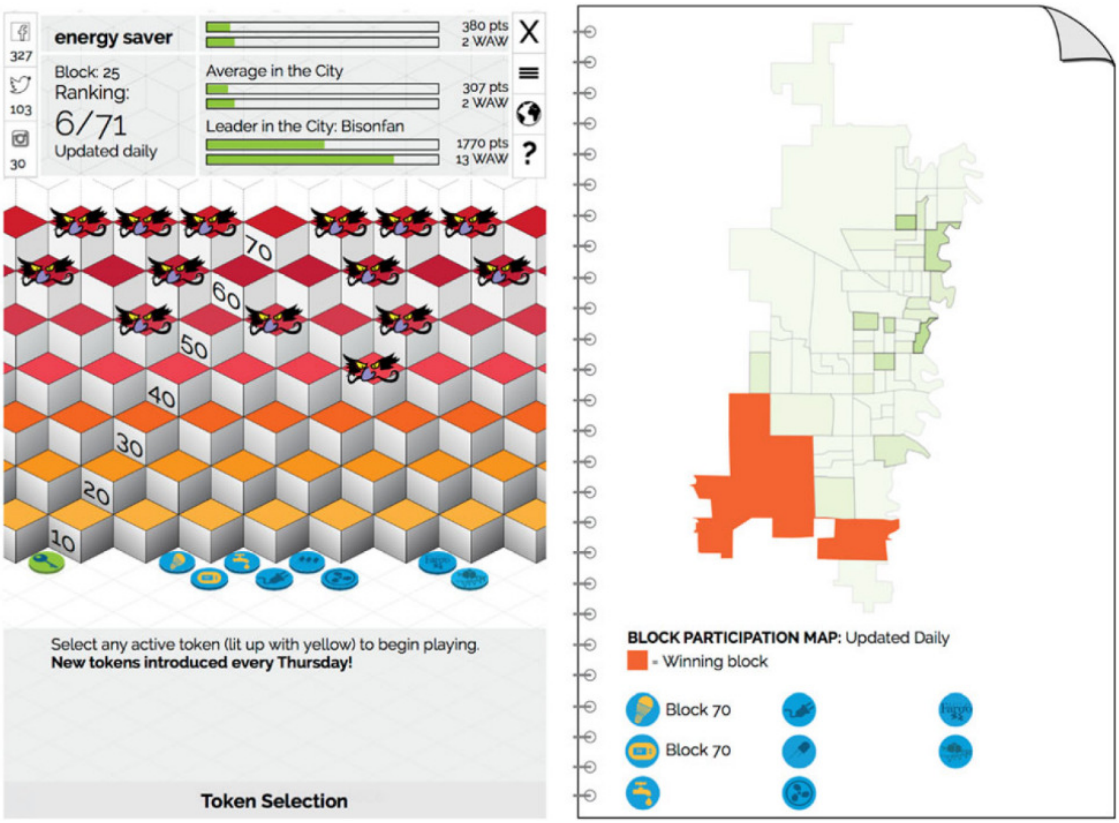


Figure 5. efargo game board and block score map which was updated daily during the nine-week gameplay. Source: Srivastava (2020).

Lastly, to achieve city-wide energy use reductions for the GUEP competition, the city as a whole needed to lower overall energy use as much as possible. Therefore, while individual wins created competitive incentives, ultimately the incentive structures that allowed for cooperatively achieving maximum reductions and highest engagements were considered essential. Each individual player's identity was also associated with, and nested within, the City of Fargo community as a whole, which provided a unifying motivation and meaning for the community.

4.2. Summarized efargo Game Results

The following results from the implementation of the nine-week game are summaries of game results reported by Srivastava (2020), who led the efargo research, design, and implementation. Data collection methods for the nine-week game period included in-game quizzes and documentation of player participation and completion metrics. Additionally, the efargo team conducted pre- and post-game surveys and energy use data collection.

Of the 301 people who joined the efargo game during the nine-week implementation, 56 people completed the pre-game survey and 64 people completed a post-game survey (Srivastava, 2020). Through an analysis of survey responses, efargo players reported learning about energy savings ($N = 56$, $p < 0.01$), willingness to engage in energy-saving behavior ($N = 56$, $p < 0.01$), and willingness to invest in energy savings ($N = 56$, $p < 0.05$; Srivastava, 2020). Twenty-six people gave permission to access the energy use data through their utility. Utilities were able to locate and provide complete energy-use data sets for 13 players. Data revealed energy-use reductions that began during the game and increased in the eight-month period after the game implementation. A monthly total savings of 1,273 kWh, or 12%, was observed ($N = 13$, $p = 0.25$; Srivastava, 2020).

It was possible for any player to earn a maximum of 3,600 points. Of the players, 5% achieved the maximum number of points, 10% had a high range of points, 27% had a medium range of points, 31% had a low level of points, and 27% did not progress to earning points. Four hundred and twenty-eight information summaries and related quiz responses were completed throughout the game for various weekly tokens. Of all the tokens, Lighting (339) earned the greatest number of completed energy-saving actions, followed by Heating (288). Most other tokens had similar levels of activity such as 239 actions for the Water token or 197 actions for the Controls token. The Civic token had the least number of actions (180) reported as completed. Overall, the players reported completing a total of 2,375 energy-saving actions through the game interface.

The relationship of players' willingness to invest in energy savings with specific behaviors, actions, or investments was assessed by means of specific action-related questions from the efargo post-game survey. Respondents were asked to indicate whether they had completed several different behaviors or home improvement tasks because of playing the efargo game. For each of these items, participants could select the following response options: "Implemented during or after [the game]," "Planning to complete," "Had already completed [before the game]," "Willing to consider," or "Not willing to consider."

The action item with the greatest percentage of respondents was "low-medium cost investments for replacing old incandescent bulbs with LED bulbs": 42.9% of respondents ($N = 56$) completed this action item during or after the game, and 21.4% indicated that they planned to implement the item during or after the game. The two action items with the next best results were respondents' willingness to turn down their thermostat 2 degrees

Fahrenheit in the winter, and their willingness to use the "air dry" selection on their dishwasher. The former had 41% respondents who had either completed or were planning to complete the action item, and the latter had 39.3% respondents who had either completed or were planning to complete the action item. The next action item, replacing old holiday lights with LED light strings, was reported as completed (21.4%) or as something that players were willing to complete (14.3%), for a total of 35.7% of the respondents.

The next 10 action items, ranging from 28.6%–21.4% of respondents who had either implemented or were willing to implement the action items, were a mix of no-cost behavior change efforts and low-cost investment efforts such as washing clothes in cold water, turning up the thermostat 5 degrees Fahrenheit in the summer, putting on an extra sweater and slippers instead of turning up the heat, switching off power strips, unplugging a second or third refrigerator, and hanging clothes inside to dry in the winter.

Finally, the no-cost behavior-changing action items that garnered affirmative responses from 14.3%–19.7% respondents (N = 56) who had either completed implementation or expressed willingness to implement during or after the game included switching off lights (19.7% of respondents) and hanging clothes outside to dry in the summer (17.9%). Players also invested in low-medium cost action items related to energy efficiency controls, such as installing timers on exhaust fans (19.6%), installing solar-powered outdoor lighting (landscaping or holiday; 14.3%), installing occupancy/motion sensors or timers on outdoor lighting (14.3%), and installing dimmers on the most-used lighting (14.3%). For the no-cost and low-cost measures, the percentage of respondents who had either implemented the action item during or after the game, as well as the percentage of players who were planning to implement the action item during or after the game, were more substantive than for the high-cost action items.

5. Game Design Model, Elements, and UGDPs

5.1. efargo Design Model and Elements

efargo's game structure was based on the TGD model (Harteveld, 2011), which proposes balancing the attributes of Meaning (player motivation), Reality (contextual agency), and Play (immersion, entertainment, and fun) during pervasive game design (Figure 6a). Per Harteveld, the consideration of reality within a pervasive game design allows the game to connect to something familiar in the player's real world. Additionally, per Harteveld, if the pervasive game is a serious game, then it must contribute some meaningful value. The notion of meaning and generated value in Harteveld's model is often represented as feedback to the community for achievement in the game or value from the game. In efargo's case, the value and achievements for players and their communities were aligned and focused on the overall reduction of energy use in Fargo. Harteveld's model further sets apart games from other environmental cultural expressions or awareness efforts by including game structures that allow engagement, fun, competition, storytelling, role-play, and rules that create the game's magic circle, and which together form the third TGD attribute, Play. Play allows the game to incorporate qualities of immersion and fun, distinct from other cultural media. Immersion is a particularly important aspect in a pervasive game with a serious purpose, because gameplay that spans between the game environment and the real world requires players to move between one and the other, which can otherwise be disruptive to the game's immersive quality.

Poplin's game elements, extended by Srivastava's game tools and narratives (Srivastava, 2016), served as primary guiding elements for efargo's design. These include Environment, Objects, Goals, Rules, and Players (Poplin, 2011, 2012). The game Environment, which for Poplin (2012) means a geographical location, was the City of Fargo for the efargo game. Game Objects for Poplin (2012) are physical objects such as buildings, and stakeholders (their moods, satisfaction) and the events they participate in as part of gameplay. Srivastava (2016) proposed Tools as a way of extending Poplin's game Objects to any activity that has a representation (physical or digital) in the game, or on which there is a material impact of the game. Poplin's game Rules define how the games are played and how activity is rewarded (Poplin, 2012), and Players are the game participants (Poplin, 2012). Needing the Fargo community to align around the goal of winning the GUEP competition, Srivastava (2016) proposed Narrative as an addition to Poplin's game elements, to include storytelling or other narrative representations as an intrinsic part of a location-based, identity-building concept in pervasive geogames (Poplin, 2024).

5.2. UGDPs

Ahlqvist and Schlieder (2018) emphasize geogame patterns—recurring design structures that support the transfer of ideas across contexts, with the understanding that the interaction between geographic and game design concepts could improve the design of future spatial games and geogames. They examine two influential frameworks from geography: first, Kuhn (2012) and Kuhn and Ballatore (2015), which focus on spatial information through 10 core concepts, and second, Janelle and Goodchild (2011), which emphasizes spatial thinking and reasoning. Ahlqvist and Schlieder (2018) further draw on two complementary game design frameworks, Holopainen's game components (2011) and Järvinen's game elements (2008). They conclude that the two approaches differ in perspective, with the former representing a game design perspective, and the latter representing a user-oriented perspective. Collectively, their synthesis forms the basis for proposing a unified vocabulary for geogames. We utilize this proposed vocabulary as UGDPs (Tables 1 and 2). In their analysis, the authors note several key correspondences. For example, Location in geography aligns with game components like Environment and Objects. They suggest that Rules from game design mirror spatial simulation models and processes in geography, while Agents in games relate to entities that carry out actions or goals, like players or agents in GIS simulations. Interface, representing how players interact with games, also has a clear parallel to the role of technological interfaces used in GIS to manipulate and view spatial data. However, the authors also recognize areas where further exploration is needed, particularly with concepts like Game mechanics and Contexts, which do not directly correlate with existing geographic terms. By identifying overlaps and gaps between game components and geographic concepts, they propose new terms—Rules, Agents, Interface, and Simulation—as additions to the traditional geographic lexicon. Thus, Ahlqvist and Schlieder (2018) offer a unified vocabulary, which we present as UGDPs, that bridges the fields of geography and game design.

6. Comparative Synthesis of Geogame Patterns, Game Elements, and Game Model

Utilizing synthesis methodology like Ahlqvist and Schlieder (2018), we compare the UGDPs with the frameworks that informed the efargo design (Poplin's game elements and Harteveld's TGD model). We first identify and discuss the overlapping patterns and elements and bring them into correspondence with the Reality, Meaning, and Play principles of Harteveld's TGD model (Figure 6a). We then identify the UGDPs that do not correspond to Poplin's elements and Harteveld's TGD model. We continue to include the two

game design frameworks, Holopainen (2011) and Järvinen (2008), to illustrate the game design perspective and the user-oriented perspective. Based on the comparative analysis illustrated by the efargo case study implementation, we propose expansions of the TGD model (Figure 6b), for community-focused serious pervasive geogame design. This model integrates the following additions: Representation (at the intersection of Reality and Meaning), Resources (at the intersection of Reality and Play), and Networks (at the intersection of Meaning and Play). These proposed expansions bridge pervasive games that focus on the individual player to pervasive geogames that address aligned player and contextual community goals.

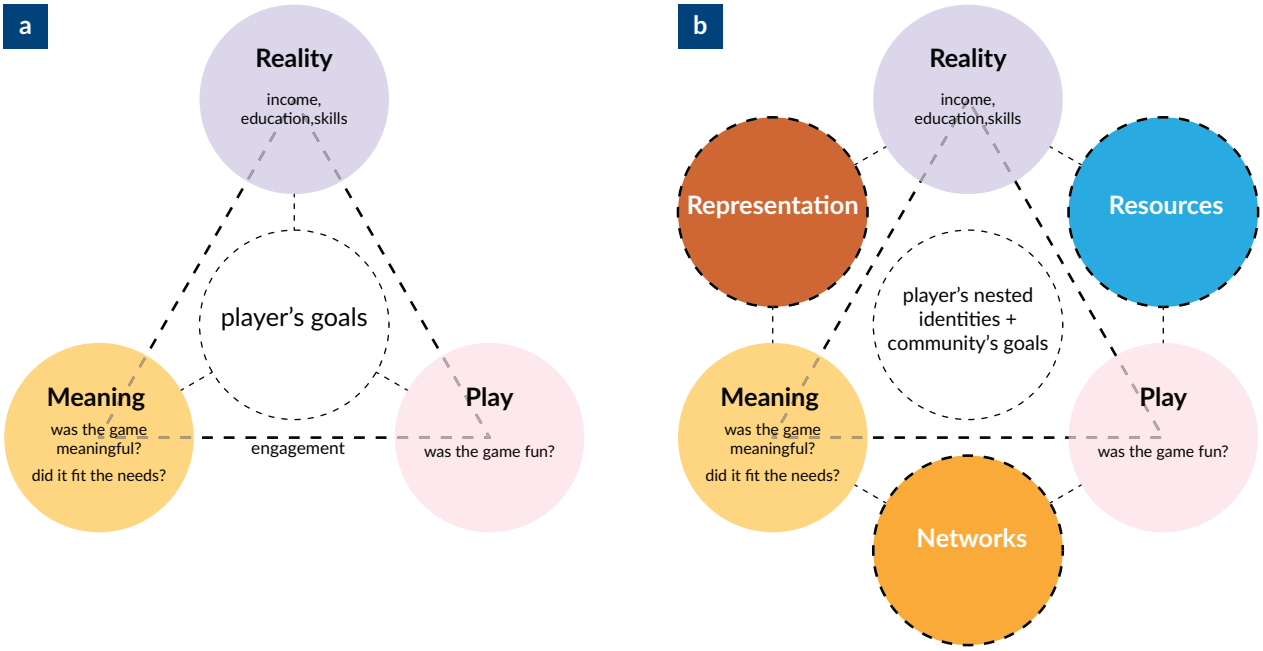


Figure 6. Extending Harteveld's model for pervasive game design for GeoSPEGs: (a) Harteveld's TGD model for pervasive games; (b) proposed expansions of the TGD for GeoSPEGs.

6.1. Synthesizing UGDPs With the Reality Component From the TGD Model

Reality (Harteveld) or Environment (Poplin) elements and attributes allow the game to connect to the real world. We propose that Ahlqvist and Schlieder's (2018) UGDPs Location, Distance, Neighborhood, and Field describe real-world geography as game space with the potential for play (Table 1). In this case, Location is understood as the method of specifying "where," Distance allows an understanding of the relationships between locations, Field is the understanding of continuous attributes or phenomena, and Neighborhood identifies areas or regions that have common attributes of Distance, Location, and Field. The game Environment, which for Poplin (2012) means a geographical location, was the City of Fargo for the efargo game. The efargo game Locations included all home typologies (single-family homes, duplexes, townhomes, and apartments) and reflected the reality of the City of Fargo's housing stock, which was 57% rental at the time of the efargo game. Including the Distance, Neighborhood, and Field patterns in the Reality principle of the game model allowed us to expand the game environment beyond a single player's reality, acknowledging the complex context of the city to which players could respond.

Table 1. Correspondence between Ahlqvist and Schleicher's UGDPs, Poplin's game elements, and Harteveld's TGD model.

UGDPs (based on Ahlqvist & Schlieder, 2018)	Components (Holopainen, 2011)	Key Game Elements (Järvinen, 2008)	Game Elements (Poplin, 2011, 2012; Srivastava, 2016)	TGD Model (Harteveld, 2011)
Location		Information	Environment	Reality
Distance		Information	Environment	
Neighborhood		Information	Environment	
Field	Game elements	Environment (Information)	Environment	
Meaning		Theme	Narrative	Meaning
Value		Contexts		
	Goals and sub-goals		Goals	
Event	Action (Events)	Game mechanics (Information)	Event	Play
New Rules	Rules (Modes of play, Evaluation functions, Closures, End conditions)	Rule set	Rules	
New Simulation	(Game session, Play session, Set-up and set-down, Game instance, Extra activities, Game time)	Information	Rules	

6.2. Synthesizing UGDPs With the Meaning Component From the TGD Model

Within serious games, the TGD model allows Meaning to be understood from the players' point of view and gleaned from the game's suitability to players' circumstances. We propose that Ahlqvist and Schlieder's (2018) UGDPs, Meaning and Value, correspond to Holopainen's and Poplin's Goals and sub-goals, allowing us to connect player context and community to the development of meaning and value (Table 1). In Poplin's framework, game Goals include finding satisfactory real-life solutions and educating players (Poplin, 2012) and thus can be understood to refer to the purposes behind creating games as well as to players' objectives. Meaning in a serious game comes from the achievement of value in the game at the individual scale (such as knowledge acquisition, skills development, and attitude or behavior shifts), and at the community scale (such as building social relationships, exerting social influence, and benefiting the community). In pervasive play, it becomes essential to derive value for individual players as well as for the community to maximize and achieve aligned rewards. For Ahlqvist and Schlieder's (2018) UGDPs, Value derived from the role played by spatial information is understood as Context in Järvinen's (2008) game elements. Meaning, therefore, may be understood as an emergent property of interaction, context, and alignment within a community. In the efargo game, creating value and achieving the goal of energy savings created alignment at the various scales (home, neighborhood, and city). For efargo, actions and mechanisms of winning the game were aligned towards the goal of energy savings as contextualized by the GUEP, thus creating shared goals, values, and meaningfulness. Further, we align Ahlqvist and Schneider's Meaning to Järvinen's game Theme (Järvinen, 2008), and extend it to the game Narrative (Srivastava, 2016), allowing players to interpret and draw meaning from representational storytelling. The Waste-a-Watt character provided a representation,

narrative, and theme linking the Environment, Objects, Goals, Rules, and Players across multiple games and events for Fargo's participation in the GUEP competition.

6.3. Synthesizing UGDPs With the Play Component From the TGD Model

Games are defined by game structures that simultaneously allow engagement, fun, and competition, governed by rules that create an immersive magic circle (Montola et al., 2009; Nieuwdorp, 2005). These form the Play component in Harteveld's model. Play is an important aspect in a pervasive game with a serious purpose: Where play is placed in ordinary reality, it spans between the game board and the real world, requiring players to move between them, which can be disruptive to the game's immersive qualities. Similarly, Play is a crucial aspect of distinguishing geogames from GIS-based artifacts that are not games, such as interactive maps. We include the following components, elements, and concepts into Harteveld's world of Play (Table 1). Ahlqvist and Schlieder (2018) incorporated Holopainen's (2011) modes of Play, Goals and sub-goals, Events, Evaluation functions, Closures, and End conditions in the category of New Rules. Rules or rulesets are procedures governing gameplay and are ubiquitous to the frameworks under consideration. Similarly, Poplin's game Rules define how games are played and how activity is rewarded, to meet the game Goals (Poplin, 2012). Further, Ahlqvist and Schlieder (2018) describe Simulation as a dynamic enactment drawing parallels between Game sessions, Play sessions, Set-up and set-down, Game instance, and Activities in Game time as the Objects, Agents, and Rules as in a GIS. An individual portion of the process bound in time is characterized as an Event and is related to Holopainen's Action and Järvinen's Game mechanics. All these elements come together to create a game's magic circle, i.e., the boundary separating the game from ordinary life (Montola et al., 2009). In the case of efargo, creating the magic circle started with engaging the community in a co-design process that developed the narratives and game characters. This aimed for the development of a community identity for the national competition, positioning ordinary life actions of energy-efficiency behaviors to be perceived as playful activity, defeating the hidden energy waste monster, Waste-a-Watt. Rulesets that establish weekly game session rhythms, cycles of cooperative and competitive actions and events, and weekly community and individual rewards are described above in Section 4 of this article. The Evaluation functions of the efargo game were based on two key aspects: engagement and energy use reduction. The engagement activities (how many efficiency activities, learning quizzes, and community events and dialogues were completed by players) determined the weekly engagement points and the resultant weekly block and individual winners. The energy function was tracked by the utilities, who were partners in the efargo effort, and provided energy use data to the design team at the city-wide scale and individual players' energy use. Players who reduced the greatest amount of energy were declared winners at the end of the nine-week efargo game implementation. The city-wide residential energy use was reported to the efargo community on a quarterly basis during the entire two-year duration of the GUEP competition, thus continuing to incentivize the use of the efargo game beyond the initial nine-week city-wide synchronous play period. This informed the community about their performance as a whole in reducing energy use across the city for the GUEP competition.

6.4. Representation: Proposed Addition to TGD at the Intersection of Reality and Meaning

In pervasive games, where life's ordinary spaces, time, and resources are cast into the magic circle (Montola et al., 2009), the idea of reality and its representation take on new meaning. Representations are filters or lenses that cause a shift in perception, which allows reality to be perceived as a game, and through which

immersion can be instantiated, even through ordinary life actions (Montola et al., 2009). Harteveld (2011) frames games as selective models of reality where representations are not neutral; they shape the player's perception and influence what is interpreted as relevant and meaningful. We propose Representation as depicting reality selectively to communicate meaning in the game (Table 2). From the UGDPs, we include Interface, Accuracy, Granularity/Scale within Representation. New interfaces (Ahlqvist & Schlieder, 2018), Interfaces (Holopainen, 2011; Järvinen, 2008), or Game tools (Srivastava, 2016) are representations by which players access the game (Figures 2 and 5). The interfaces determine how reality is selectively depicted and how the game is played, while also becoming the mechanism of creating immersive flow. The interface plays a crucial role in the dynamic of players making meaning. Accuracy (Ahlqvist & Schlieder, 2018) allows the spatial layering of information, and Granularity/Scale (Ahlqvist & Schlieder, 2018), i.e., the amount of information and the scale of representation, are important considerations aligning with meaning formulation in geogames.

The efargo game provided various game board components that represented meaningful aspects of the aligned individual, household, and community game incentives. In efargo's case, the city map (with blocks delineated based on census block boundaries) was the meaningful Granularity or Scale of aligned performance between the individual or household player and the neighbors identified with census blocks. A map of the city that showed each block's comparative performance through a color scale (Figure 5) was updated daily on the game board. The color-coding allowed players to compare their block's performance with others. The lightest green blocks were the lowest-performing, and the darkest green blocks were the highest-performing. The "greening" of the entire map based on higher community engagement and performance could lead to (and indeed, *did* lead to) energy savings that resulted in carbon savings for all Fargoans. Thus, the city map with neighborhood blocks was the daily and weekly representation of game goals (energy saving actions) and resulting performance, providing incentive and eco-feedback to game players.

Table 2. Comparing Ahlqvist and Schleicher's UGDPs to Harteveld's TGD model to include Representation, Resources, Community, and Networks.

UGDPs (Ahlqvist & Schlieder, 2018)	Components (Holopainen, 2011)	Key Game Elements (Järvinen, 2008)	Game Elements (Poplin, 2011, 2012; Srivastava, 2016)	Proposed Expansions of the TGD Model
Granularity /Scale		Information	Implied in Environment	Representation
Accuracy		Information	Implied in Environment	
New interface	Interface	Interface	Tools	
Spatial heterogeneity		Information		Resources
Overlays		Information	Implied in Environment	Networks
Spatial dependence		Information		
	Game elements	Environment (Information)	Implied in Environment	
New Agents	Players, Game facilitators	Players (Information, Components, Environment)	Player	Community
Object	Game elements	Components (Information)	Object	

We propose that Ahlqvist and Schlieder's (2018) UGDPs New interface, Tools (Srivastava, 2016), Information, and Interfaces (Järvinen, 2008), correspond to representations such as visuals and eco-feedback systems, and that they allow players to infer the meaning of geographic and spatial structures as representing the player context. These visual and interactive layers are where meaning is negotiated, based on how players perceive and respond to cues presented by the game environment.

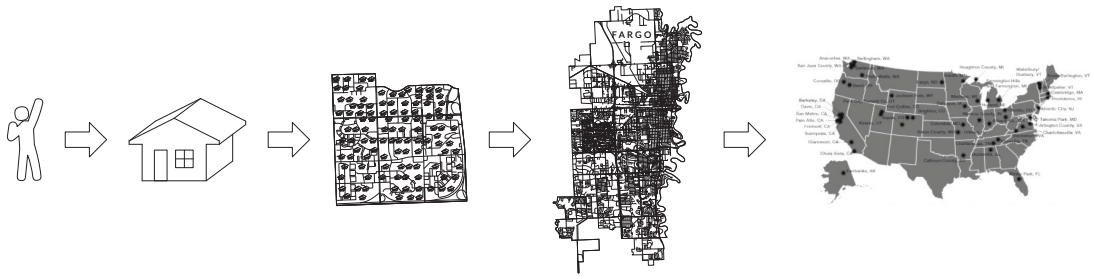
6.5. Resources: Proposed Addition to TGD at the Intersection of Reality and Play

Real-world differences in how players perceive the game are based on the reality of their physical, social, and economic circumstances, reflecting Spatial heterogeneity (Ahlqvist & Schlieder, 2018). In a GeoSPEG like efargo, the spatial component of pervasive games introduces a layer of complexity, as gameplay occurs within real-world settings where access and agency can vary significantly across players. For instance, renters may face structural or contractual barriers that limit the available energy-saving actions, whereas homeowners often have more autonomy to implement changes. Resources at the intersection of Reality and Play can address variability in player agency. These resources may take on the form of scaffolds (Reigeluth & Myers, 2013) such as in-game informational resources, game mechanics' flexibility and customization to suit player needs, and lastly, coaching that provides players with social, physical, and knowledge support. In the case of efargo, these scaffolds were made available through multiple instructional resources (for example, Figures 2e, 2f, and 2g), and players were able to select from a range of energy-saving actions (tokens, levels, and action cubes all provided multiple potential actions to choose from)—or to propose their own (Token 7, the Player's Choice token)—based on their individual circumstances. In addition to these scaffolds, providing resources that understand and recognize the resource gaps within the player community is crucial. For example, to address the lack of electronic devices in some households, an efargo station was set up for public use in the local library. Additionally, efargo gameplay was incentivized to have the block score inform the weekly champion (winner), thus encouraging assistance in the gameplay from neighbors and others.

6.6. Networks: Proposed Addition to TGD at the Intersection of Meaning and Play

Per the TGD model, players bring their own identities, contexts, networks, and expectations into the gameplay space. However, Spatial Dependency can manifest as individuals or groups in proximity, such as individuals living in the same neighborhood, who might be more likely to interact or share similar characteristics and form social connections and therefore exhibit similar behaviors or attitudes (Weijs-Perrée et al., 2017). In geogames, social cohesion develops through Spatial dependencies, and Networks of relationships between game Objects (individuals that have shared identity, or spatial, temporal, and thematic properties) can be realized through Overlays that can infer spatial associations by comparing mapped variables by locations (Ahlqvist & Schlieder, 2018). The efargo game used census block boundaries as game neighborhood blocks where such overlays and spatial associations occur, given that census blocks are bounded by visible features (e.g., roads), and nonvisible boundaries (e.g., property lines), and may share population characteristics such as economic status and living conditions. Additionally, in efargo, Spatial Dependency was conceptualized through the nested urban scales concept that intersected players' social and spatial identities held simultaneously across urban scales: the home, the neighborhood block, and the city (Figure 7). As the game progressed, the game structure allowed players to participate in game actions at increasingly large scales. Allegiances related to the multiple identities were further reinforced through aligned incentive structures. Methods of winning the game were based on completing energy-saving actions

and adopting energy-saving behaviors. For example, players cooperated within the household to earn points and with neighbors for the block-scale incentives. While the neighborhood blocks competed against each other for weekly incentives, they were simultaneously in a cooperative relationship as Fargoans for the national GUEP competition incentives.



temporal	week 1	week 2	weeks 3–7	weeks 8–9	1 year pre-competition 2 years competition 1 year post-competition
social	player	household	neighbor	community member	collective
spatial	home	home	block	city	GUEP

Figure 7. efargo social, spatial, and temporal expansions across nested urban scales.

7. Conclusion

In Harteveld's TGD model, the individual player is implicitly at the center of the Reality, Meaning, and Play attributes. In our expanded model (Figure 8), we continue to center players, but also explicitly add players' simultaneously-held identities across nested geographic urban scales. Intended for GeoSPEGs, the community is positioned as the audience and participant, in addition to the individual players. Thus, this expansion centralizes Ahlqvist and Schlieder's (2018) Agents (entities that act towards the goals) and Objects (individuals that have identities and spatial, temporal, and thematic properties; Figure 7) by expanding the focus from Player to Community goals. The community here includes other players, facilitators, cheerleaders, bystanders/onlookers, designers, stakeholders, and implementers, all related through shared geographic context.

While continuing to consider the balance between Harteveld's original attributes (Reality, Meaning, and Play), the expanded model addresses the potential for shared understandings. Thus, it situates Networks at the intersection of shared meaning and play, Representations at the intersection of emergent meaning shared between players and community, and Resources addressing diverse needs at the intersection of heterogeneous reality of the players and immersive gameplay. This aims to maximize player participation, shared community benefits, and aligned goals.

Ahlqvist and Schlieder (2018) identify three spatially-driven patterns in geogame design: (a) fundamental spatial patterns (locality, proximity); (b) spatial activity patterns (navigation, race-to-finish, collection); and (c) spatial interaction patterns (gaining ownership). They emphasize the incompleteness of these patterns and the need for more pattern identification. In recognition of the fundamental nature of nested urban scales, we propose this concept as a fundamental spatial pattern for geogames (Figure 7). This concept

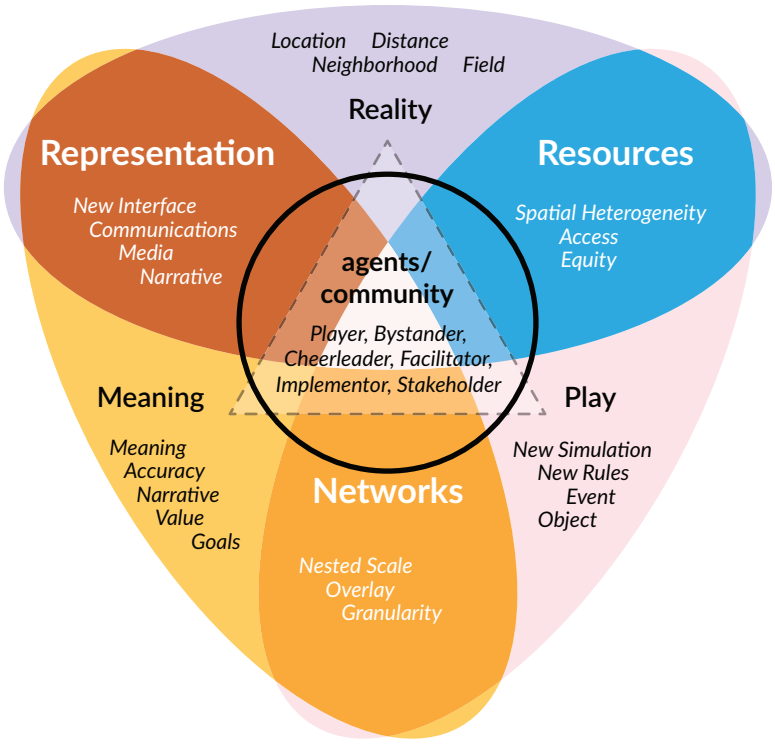


Figure 8. Proposed expanded model for the design of GeoSPEGs.

allows players to hold multiple simultaneous identities and makes available goal-aligned actions based on their geographic location and across multiple scales of agency.

While the proposed GeoSPEG design model builds on previous work (Ahlqvist & Schlieder 2018; Harteveld, 2011; Poplin, 2011, 2012; Srivastava, 2016, 2020) with the addition of a fundamental spatial pattern, both the expanded model and the spatial pattern need to be validated through application, data collection, and controlled analysis of other serious pervasive geogames. Additionally, the efargo game implementation existed within a national competition that provided the opportunity for shared identity, meaning, and goals for all Fargoans, which would be difficult to replicate in future studies.

Nevertheless, careful selection of games that incorporate aligned player and community goals, multiple locations (desks, parks, buildings, neighborhoods, and cities) with geographic interfaces, could be utilized to test the proposed concepts. For example, Greenmate, a single-player web-based game, incorporates typology-based mini-games across locations (home, school, and farm) to perform tasks leading to awareness of carbon footprint and energy consumption in daily tasks (Bhattacharya et al., 2025). The authors of the current article are designing a serious pervasive energy game that expands gameplay from competing schools to student homes and neighborhoods, which may provide data to test this model.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Google Gemini was used to format the reference list according to the APA citation style. The authors subsequently proofread the formatting.

References

$5 million Georgetown Energy Prize to reward community sustainability. (2014, April 23). *Georgetown University*. https://web.archive.org/web/20160112003935/http://www.georgetown.edu/news/georgetown-university-energy-prize-launch.html

Abrahamse, W. (2019). *Encouraging pro-environmental behaviour: What works, what doesn't, and why*. Academic Press.

Abrahamse, W., & Steg, L. (2013). Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change*, *23*(6), 1773–1785. https://doi.org/10.1016/j.gloenvcha.2013.07.029

Agusdinata, D. B., Hanif, M., Shwom, R., Watkins, D., Floress, K., Cuite, C., & Halvorsen, K. E. (2024). Effectiveness of conservation messages to reduce households' GHG emissions: A serious-gaming

experiment. *Journal of Environmental Management*, *351*, Article 119948. https://doi.org/10.1016/j.jenvman.2023.119948

Ahlqvist, O., Joshi, S., Benkar, R., Vatev, K., Ramnath, R., Heckler, A., & Soundarajan, N. (2019). Defining a geogame genre using core concepts of games, play, and geographic information and thinking. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 19–36). Springer. https://doi.org/10.1007/978-3-319-22774-0_2

Ahlqvist, O., & Schlieder, C. (2018). Introducing geogames and geoplay: Characterizing an emerging research field. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 1–10). Springer. https://doi.org/10.1007/978-3-319-22774-0_1

Ahmadov, T., Karimov, A., Durst, S., Saarela, M., Gerstlberger, W., Wahl, M. F., & Karkkainen, T. (2025). A two-phase systematic literature review on the use of serious games for sustainable environmental education. *Interactive Learning Environments*, *33*(3), 1945–1966. https://doi.org/10.1080/10494820.2024.2414429

Allcott, H., & Mullainathan, S. (2010). Behavior and energy policy. *Science*, *327*(5970), 1204–1205. https://doi.org/10.1126/science.1180775

Allcott, H., & Rogers, T. (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review*, *104*(10), 3003–3037. https://doi.org/10.1257/aer.104.10.3003

Andor, M. A., & Fels, K. M. (2018). Behavioral economics and energy conservation—A systematic review of non-price interventions and their causal effects. *Ecological Economics*, *148*, 178–210. https://doi.org/10.1016/j.ecolecon.2018.01.018

Aydin, E., Brounen, D., & Kok, N. (2018). Information provision and energy consumption: Evidence from a field experiment. *Energy Economics*, *71*, 403–410. https://doi.org/10.1016/j.eneco.2018.03.008

Barbosa, A., Iria, J., Cassola, F., Coelho, A., Portela, J., Küçük, Ü., Madureira, A. G., Zehir, M. A., Özdemir, A., & Soares, F. J. (2017). GReSBAS project: A gamified approach to promote more energy efficient behaviours in buildings. In *2017 10th International Conference on Electrical and Electronics Engineering (ELECO)* (pp. 1258–1261). IEEE.

Bartoschek, T., Schwering, A., Li, R., Münzer, S., & Carlos, V. (2017). OriGami: A mobile geogame for spatial literacy. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 37–62). Springer. https://doi.org/10.1007/978-3-319-22774-0_3

Benford, S., Magerkurth, C., & Ljungstrand, P. (2005). Bridging the physical and digital in pervasive gaming. *Communications of the ACM*, *48*(3), 54–57. https://doi.org/10.1145/1047671.1047704

Bhattacharya, S., De Feo, V., & Bourazeri, A. (2025). GreenMate: A serious game educating children about energy efficiency. *IEEE Transactions on Games*, *17*(1), 196–209. https://doi.org/10.1109/TG.2024.3415393

Boncu, Ș., Candel, O. S., & Popa, N. L. (2022). Gameful green: A systematic review on the use of serious computer games and gamified mobile apps to foster pro-environmental information, attitudes and behaviors. *Sustainability*, *14*(16), Article 10400. https://doi.org/10.3390/su141610400

Brandes, U., Nelson, C., & Smith, A. (2018). *Advancing energy efficiency in small cities. A summary report of the Advancing Energy Efficiency in Small Cities Workshop*. Georgetown University.

Chen, L., Chen, G., & Benford, S. (2013). Your way your missions: A location-aware pervasive game exploiting the routes of players. *International Journal of Human–Computer Interaction*, *29*(2), 110–128. https://doi.org/10.1080/10447318.2012.694790

Composto, J. W., & Weber, E. U. (2022). Effectiveness of behavioural interventions to reduce household energy

demand: A scoping review. *Environmental Research Letters*, *17*(6), Article 063005. https://doi.org/10.1088/1748-9326/ac71b8

Csoknyai, T., Legardeur, J., Abi Akle, A., & Horváth, M. (2019). Analysis of energy consumption profiles in residential buildings and impact assessment of a serious game on occupants' behavior. *Energy and Buildings*, *196*, 1–20. https://doi.org/10.1016/j.enbuild.2019.05.009

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." In A. Lugmayr, H. Franssila, C. Safran, & I. Hammouda (Eds.), *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9–15). Association for Computing Machinery. https://doi.org/10.1145/2181037.2181040

Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Vandenbergh, M. P. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *Proceedings of the National Academy of Sciences*, *106*(44), 18452–18456. https://doi.org/10.1073/pnas.0908738106

Fijnheer, J. D. (2022). *Household energy conservation with reality-enhanced serious games: Studies on effects in the real-world* [Unpublished doctoral dissertation]. Utrecht University.

Fijnheer, J. D., & van Oostendorp, H. (2015). Steps to design a household energy game. In A. De Gloria & R. Veltkamp (Eds.), *Games and Learning Alliance: 4th International Conference, GALA 2015, Rome, Italy, December 9-11, 2015, Revised Selected Papers* (pp. 12–22). Springer.

Fijnheer, J. D., van Oostendorp, H., Giezeman, G. J., & Veltkamp, R. C. (2021). Competition in a household energy conservation game. *Sustainability*, *13*(21), Article 11991. https://doi.org/10.3390/su132111991

Geelen, D., Keyson, D., Boess, S., & Brezet, H. (2012). Exploring the use of a game to stimulate energy saving in households. *Journal of Design Research*, *10*(1/2), 102–120.

Georgetown University Energy Prize. (2018). *About the prize*. https://web.archive.org/web/20180201031314/https://guep.org/about-the-prize

Granade, H. C., Creyts, J., Derkach, A., Farese, P., Nyquist, S., & Ostrowski, K. (2009). *Unlocking energy efficiency in the U.S. economy*. McKinsey & Company. https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/Sustainability/PDFs/US_energy_efficiency_full_report.pdf

Grilli, G., & Curtis, J. (2021). Encouraging pro-environmental behaviours: A review of methods and approaches. *Renewable and Sustainable Energy Reviews*, *135*, Article 110039. https://doi.org/10.1016/j.rser.2020.110039

Gustafsson, A., Bång, M., & Svahn, M. (2009). Power Explorer: A casual game style for encouraging long term behavior change among teenagers. In *Proceedings of the International Conference on Advances in Computer Entertainment Technology* (pp. 182–189). Association for Computing Machinery. https://doi.org/10.1145/1690388.1690419

Gustafsson, A., Katzeff, C., & Bång, M. (2010). Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment*, *7*(4), Article 54. https://doi.org/10.1145/1658866.1658873

Harteveld, C. (2011). *Triadic game design: Balancing reality, meaning and play*. Springer.

Head, L. A., & Hunt, P. (2014). Motivating utility customers to adopt multiple energy-efficient measures. In P. Hughes & S. Kiliccote (Eds.), *ACEEE Summer Study on Energy Efficiency in Buildings* (pp. 5.172–5.184). https://aceee.org/files/proceedings/2014/data/papers/5-857.pdf

Heinz, T., & Schlieder, C. (2019). Addressing spatio-temporal geogame relocation issues using design evaluation heuristics and agent-based simulation. In *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)* (pp. 1–4). IEEE. https://doi.org/10.1109/VS-Games.2019.8864532

Hirst, E., & Brown, M. (1990). Closing the efficiency gap: Barriers to the efficient use of energy. *Resources, Conservation and Recycling*, *3*(4), 267–281. https://doi.org/10.1016/0921-3449(90)90023-W

Holopainen, J. (2011). *Foundations of gameplay* [Unpublished doctoral dissertation]. Blekinge Institute of Technology. https://urn.kb.se/resolve?urn=urn:nbn:se:bth-00484

Huizinga, J. (1949). *Homo ludens: A study of the play-element in culture*. Routledge; Kegan Paul.

Inman, M. (2011). Removing the baseline. *Nature Climate Change*, *1*(9), 430–432. https://doi.org/10.1038/nclimate1296

Janelle, D. G., & Goodchild, M. F. (2011). Concepts, principles, tools, and challenges in spatially integrated social science. In T. L. Nyerges, H. Couclelis, & R. McMaster (Eds.), *The Sage handbook of GIS and society* (pp. 27–45). Sage. https://doi.org/10.4135/9781446201046.n2

Järvinen, A. (2008). *Games without frontiers: Theories and methods for game studies and design* [Unpublished doctoral dissertation]. Tampere University. https://web.archive.org/web/20200716134618/https://trepo.tuni.fi/bitstream/handle/10024/67820/978-951-44-7252-7.pdf

Kamal, A., Al-Ghamdi, S. G., & Koc, M. (2019). Revaluing the costs and benefits of energy efficiency: A systematic review. *Energy Research & Social Science*, *54*, 68–84. https://doi.org/10.1016/j.erss.2019.03.012

Karlin, B., Zinger, J. F., & Ford, R. (2015). The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin*, *141*(6), 1205–1227. https://doi.org/10.1037/a0039650

Kasapakis, V., & Gavalas, D. (2015). Pervasive gaming: Status, trends and design principles. *Journal of Network and Computer Applications*, *55*, 213–236. https://doi.org/10.1016/j.jnca.2015.05.009

Kasapakis, V., & Gavalas, D. (2017a). Revisiting design guidelines for pervasive games. *International Journal of Pervasive Computing and Communications*, *13*(4), 386–407. https://doi.org/10.1108/IJPCC-D-17-00007

Kasapakis, V., & Gavalas, D. (2017b). User-generated content in pervasive games. *Computers in Entertainment*, *16*(1), Article 3. https://doi.org/10.1145/3161570

Khanna, T. M., Baiocchi, G., Callaghan, M., Creutzig, F., Guias, H., Haddaway, N. R., Hirth, L., Javaid, A., Koch, N., Laukemper, S., Löschel, A., del Mar Zamora Dominguez, M., & Minx, J. C. (2021). A multi-country meta-analysis on the role of behavioural change in reducing energy consumption and CO_2 emissions in residential buildings. *Nature Energy*, *6*(9), 925–932. https://doi.org/10.1038/s41560-021-00866-x

Kordyaka, B., Laato, S., Weber, S., Hamari, J., & Niehaves, B. (2024). Exploring the association between engagement with location-based game features and getting inspired about environmental issues and nature. In F. F. Mueller, P. Kyburz, J. R. Williamson, C. Sas, M. L. Wilson, P. T. Dugas, & I. Shklovski (Eds.), *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Article 755). Association for Computing Machinery. https://doi.org/10.1145/3613904.3642786

Kuhn, W. (2012). Core concepts of spatial information for transdisciplinary research. *International Journal of Geographical Information Science*, *26*(12), 2267–2276. https://doi.org/10.1080/13658816.2012.722637

Kuhn, W., & Ballatore, A. (2015). Designing a language for spatial computing. In F. Bacao, M. Y. Santos, & M. Painho (Eds.), *AGILE 2015: Geographic Information Science as an Enabler of Smarter Cities and Communities* (pp. 309–326). Springer. https://doi.org/10.1007/978-3-319-16787-9_18

Laato, S., Kordyaka, B., Rauti, S., Hyrynsalmi, S. M., Hoikkala, M., Pietarinen, T., Laajala, T. D., Paloheimo, M., Inaba, N., & Hyrynsalmi, S. (2020). Do primal instincts explain engagement in location-based games? A hypothesis-forming focus group study on territorial behavior. In J. Koivisto, M. Bujić, & J. Hamari (Eds.), *Proceedings of the 4th GamiFIN Conference* (pp. 115–125). CEUR-WS. https://trepo.tuni.fi/handle/10024/216772

Lamb, R. L., Annetta, L., Firestone, J., & Etopio, E. (2018). A meta-analysis with examination of moderators

of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations. *Computers in Human Behavior*, *80*, 158–167. https://doi.org/10.1016/j.chb.2017.10.040

McGonigal, J. (2006). *This might be a game: Ubiquitous play and performance at the turn of the twenty-first century* [Unpublished doctoral dissertation]. University of California – Berkeley.

Méndez, J. I., Ponce, P., Peffer, T., Meier, A., & Molina, A. (2021). A gamified HMI as a response for implementing a smart-sustainable university campus. In L. M. Camarinha-Matos, X. Boucher, & H. Afsarmanesh (Eds.), *Smart and Sustainable Collaborative Networks 4.0 (PRO-VE 2021)* (pp. 683–691). Springer. https://doi.org/10.1007/978-3-030-85969-5_64

Michael, D., & Chen, S. (2006). *Serious games: Games that educate, train and inform*. Thomson Course Technology.

Montola, M., Stenros, J., & Waern, A. (2009). *Pervasive games: Theory and design*. Morgan Kaufmann Publishers.

mySidewalk. (n.d.). *Utilities*. https://dashboards.mysidewalk.com/fargo-neighborhood-affordability/utilities

Nasrollahi, H., Lampropoulos, I., Werning, S., Belinskiy, A., Fijnheer, J. D., Veltkamp, R. C., & van Sark, W. (2023). Review of serious energy games: Objectives, approaches, applications, data integration, and performance assessment. *Energies*, *16*(19), Article 6948. https://doi.org/10.3390/en16196948

Nieuwdorp, E. (2005). The pervasive interface: Tracing the magic circle. In *Proceedings of DiGRA 2005 Conference: Changing Views: Worlds in Play*. Digital Games Research Association. https://dl.digra.org/index.php/dl/article/view/188

Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative social influence is underdetected. *Personality and Social Psychology Bulletin*, *34*(7), 913–923. https://doi.org/10.1177/0146167208316691

Orland, B., Ram, N., Lang, D., Houser, K., Kling, N., & Coccia, M. (2014). Saving energy in an office environment: A serious game intervention. *Energy and Buildings*, *74*, 43–52. https://doi.org/10.1016/j.enbuild.2014.01.036

Poplin, A. (2011). Games and serious games in urban planning: Study cases. In B. Murgante, O. Gervasi, A. Iglesias, D. Taniar, & B. O. Apduhan (Eds.), *Computational Science and Its Applications—ICCSA 2011* (pp. 1–14). Springer. https://doi.org/10.1007/978-3-642-21887-3_1

Poplin, A. (2012). Playful public participation in urban planning: A case study for online serious games. *Computers, Environment and Urban Systems*, *36*(3), 195–206. https://doi.org/10.1016/j.compenvurbsys.2011.10.003

Poplin, A. (2024). Serious digital geogames and their implementations enhanced by artificial intelligence, mixed- and augmented-reality. In O. Gervasi, B. Murgante, C. Garau, D. Taniar, A. M. A. C. Rocha, M. N. F. Lago (Eds.), *Computational Science and Its Applications—ICCSA 2024* (pp. 189–201). Springer. https://doi.org/10.1007/978-3-031-65238-7_13

Rau, H., Nicolai, S., & Stoll-Kleemann, S. (2022). A systematic review to assess the evidence-based effectiveness, content, and success factors of behavior change interventions for enhancing pro-environmental behavior in individuals. *Frontiers in Psychology*, *13*, Article 901927. https://doi.org/10.3389/fpsyg.2022.901927

Reigeluth, C. M., & Myers, R. D. (2013). *Serious game design* report (prepared for the U.S. Air Force Research Laboratory). Unpublished manuscript.

Schlieder, C., Kiefer, P., & Matyas, S. (2006). Geogames: Designing location-based games from classic board games. *IEEE Intelligent Systems*, *21*(5), 40–46. https://doi.org/10.1109/MIS.2006.93

Schneider, J., & Schaal, S. (2018). Location-based smartphone games in the context of environmental education and education for sustainable development: Fostering connectedness to nature with

geogames. *Environmental Education Research*, *24*(11), 1597–1610. https://doi.org/10.1080/13504622.2017.1383360

Schneider, J., Schaal, S., & Schlieder, C. (2017). Geogames in education for sustainable development: Transferring a simulation game in outdoor settings. In *2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)* (pp. 79–86). IEEE. https://doi.org/10.1109/VS-GAMES.2017.8056574

Srivastava, M. (2016). The efargo game: A playful way to achieve city-wide energy efficiency. In W. Livingood & N. Zhou (Eds.), *2016 ACEEE Summer Study on Energy Efficiency in Buildings: From Components to Systems, From Buildings to Communities* (pp. 8.1–8.12). ACEEE. https://aceee.org/files/proceedings/2016/data/papers/8_1197.pdf

Srivastava, M. (2019). efargo energy challenge: Architecture as a gaming board in pervasive energy games. In M. B. Dodig & L. N. Groat (Eds.), *The Routledge companion to games in architecture and urban planning* (pp. 109–125). Routledge. https://doi.org/10.4324/9780429441325-8

Srivastava, M. (2020). *Purposeful play: Serious, pervasive, energy games as a way to bridge the energy-efficiency gap* [Unpublished doctoral dissertation]. Carnegie Mellon University.

Srivastava, M., & Nelson, C. (2017). The energy efficiency prize: Simple design to overcome complex barriers. In R. Smith, K. D. Moore, & W. Zhao (Eds.), *Proceedings of the ARCC 2017 Conference: Architecture of Complexity* (pp. 344–351). Architectural Research Centers Consortium.

Staddon, S. C., Cycil, C., Goulden, M., Leygue, C., & Spence, A. (2016). Intervening to change behaviour and save energy in the workplace: A systematic review of available evidence. *Energy Research & Social Science*, *17*, 30–51. https://doi.org/10.1016/j.erss.2016.03.027

United Nations Environment Programme. (2024). *Annual report 2024*. https://www.unep.org/resources/annual-report-2024

Weijs-Perrée, M., van den Berg, P., Arentze, T., & Kemperman, A. (2017). Social networks, social satisfaction and place attachment in the neighborhood. *Region*, *4*(3), 133–151. https://doi.org/10.18335/region.v4i3.194

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Playful Reconfigurations: Learning, Making, and Playing Geogames for Urban Participation

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Abstract

Participatory engagements with digital tools and urban data have become a defining trend in smart city and digital twin projects. However, many platforms, interactive apps, and immersive media fall short compared to analog participation formats regarding open-ended collaborations and the inclusion of situated perspectives. In this article, we explore the potential of geogames to address these contextual and contingent aspects of urban participation. Drawing on Suchman's concept of "situated actions," we argue that gameplay and game making enable "reconfigurations" between structured game systems and open-ended play. We further propose that these "playful reconfigurations" bear the potential to attune digital media to contextual perspectives on urban planning issues and specific places. We illustrate this approach through three engagements with geogames conducted within the New European Bauhaus project Creating NEBourhoods Together, focusing on the co-creation of several mobility hubs. First, we introduce core geogame principles developed in three co-creation workshops with citizens in Neuperlach. These formats highlight the corporeal and performative dimensions invoked by digital media. Based on these insights, we discuss the making of participatory geogames as a reciprocal reframing of game systems and the urban issues at stake. Finally, we reflect on the resulting geogames by playing them on-site and observing how they co-constitute participatory engagements with the topic of mobility. In conclusion, we propose these "reconfigurations" as a resource to play with—a means of mediating between digital technologies and urban worlds, data and situated perspectives, presumed problems and contingent controversies.

Keywords

digital tools; co-creation; co-design; geogames; mixed reality; mobility; participation

1. Introduction

Alongside a growing critique of techno-centric urban digitization projects, many European and international cities put a focus on the potential of digital technologies for civic participation and co-creation. Playful media and geogames have emerged as prominent means of incorporating urban data and virtual models into participatory formats. A plethora of digital-city-twin teams began experimenting with game engines and playful prototypes, ranging from Minecraft models (Schrotter & Hürzeler, 2020, p. 109) to immersive experiences (Dembski et al., 2020, pp. 10–12) and narrative mapping applications (Kitchin & Dawkins, 2025, p. 5). Gamification is frequently discussed as a method to foster motivation and engagement, thus enhancing quantitative results of participatory processes (e.g., Heryanto et al., 2024, p. 149399; Lu et al., 2024, p. 4; Muehlhaus et al., 2023, p. 331). Other researchers focus on game-based approaches to support communication and cooperative deliberation (Kavouras et al., 2025) and to make participatory planning processes more effective (Kavouras et al., 2023, p. 22).

At the same time, gamification and platformization remain controversial approaches. Planning issues often resemble dynamic "wicked problems," requiring the contingent negotiation of multiple stakeholders (Rittel & Webber, 1973). In this regard, digital tools and online platforms may frame participation too narrowly, passively, and teleologically. Referring to "FixMyStreet," a map-based platform for gathering citizens' suggestions and reporting problems, Gabrys (2016) illustrates how digital media can exclude perspectives that deviate from their inscribed problem framing (p. 232). Thinking with Jacques Rancière, Rosemann (2013) suggests that genuine participation never follows a predefined structure but instead emerges in moments of conflict and contingency. Moreover, Loh (2019) remarks that gamification can lead to problematic paternalization or manipulation when conceived as a "psycho-motivational" optimization strategy (pp. 276–277). Additionally, digital media may introduce barriers related to digital literacy (Kavouras et al., 2025, p. 1).

Analog formats focusing on qualitative, dynamic negotiations (e.g., Nochta et al., 2021, pp. 269–270) appear more flexible in responding to unforeseen problematizations. There is a growing consensus among municipal institutions that digital tools and analog formats must go hand in hand (e.g., Connected Urban Twins, 2024) to bridge this gap. Yet, this relationship still requires closer investigation (Stelzle et al., 2017). This article revisits the perceived opposition between highly structured digital methods and more flexible and context-aware formats. As we argue, geogames bear the potential to bridge this gap, synthesizing geospatial technologies with serious gaming approaches. Gameplay always incorporates both a pre-defined structure (the game system) and open-ended play. We term this quality of games "playful reconfiguration" and explore it as a potential resource for shaping participation tools. Hence, we discuss how digital methods, such as data gathering, can be brought into a dialogue with analog and situated participation approaches.

We explore these questions in the context of a specific co-creation process conducted as part of the New European Bauhaus project Creating NEBourhoods Together. Through participatory engagements, two multifunctional mobility stations were placed, configured, and ultimately implemented to improve the mobility situation in Neuperlach—a late-modernist housing district on the outskirts of Munich. In parallel, the project developed a digital participation toolbox that incorporates insights from the mentioned co-creation process. The toolbox aims to support future participation for additional mobility stations or site-specific infrastructure, such as public furniture or local climate adaptation measures. It builds on data

and models from Munich's Digital City Twin initiative. While focusing on geogames was not a prerequisite for the NEBourhoods project, playful interactions and game concepts were a central resource for creating engaging co-creation tools.

This task revealed conceptual challenges concerning digital geogames and their role in participation processes. First, our team developed a concept for a gamified platform designed for longer asynchronous usage. Through a gamified application, citizens would propose locations and configurations for NEBourhood Hubs (see Figure 1, right side). This concept presumed the co-creation of mobility stations to be a relatively well-defined issue. Central questions, such as location-finding or functional configuration, would be framed as interactions of a game system. Moreover, this system would incorporate data on pathways, points of interest, or public furniture. Game patterns like a currency and a vote-based scoreboard would contribute to an engaging experience and foster relevant results.

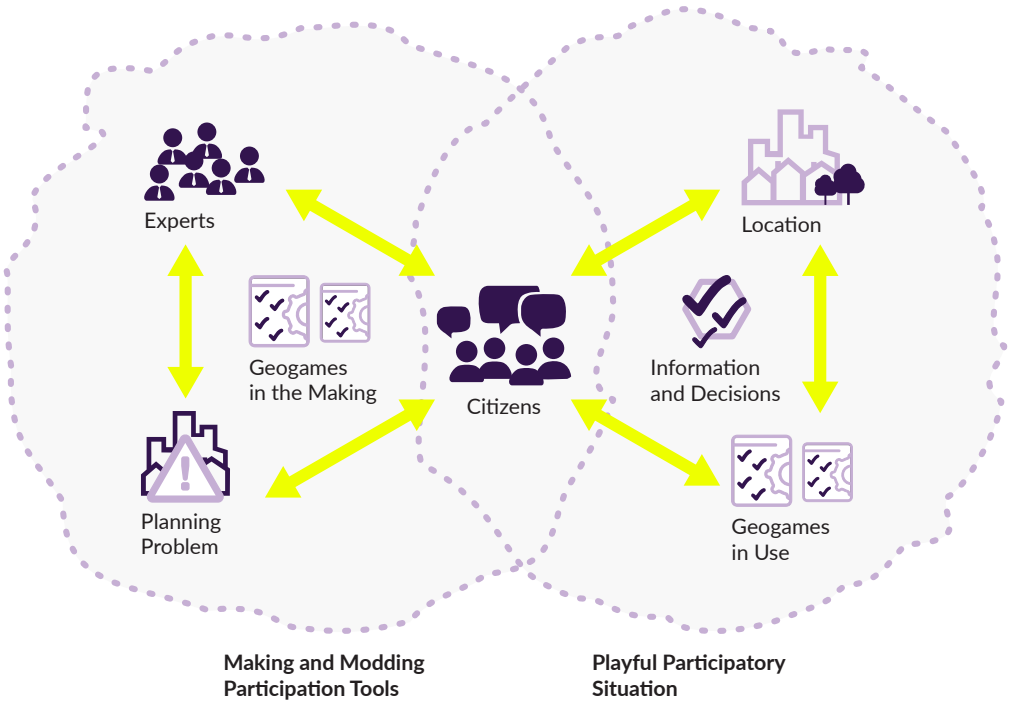

Figure 1. Extending participatory engagements with and through geogames.

However, experts from the TransitionHub team, conducting the overall co-creation of Creating NEBourhoods Together, argued for more open-ended participatory engagements. With a focus on social formats, stakeholder collaboration, and the local context, they were generally wary of developing digital tools and "doing" the participation thereafter. Arguably, a highly structured digital game would be less effective in including informal knowledge and would introduce biases regarding the player-citizens and their concerns. Furthermore, mobility issues in Neuperlach were complex and contextual. Understanding mobility required exploring extensive footpath systems, tunnels, and bridges. We became aware of "mobility hacks," such as subversively borrowed shopping carts and patterns of lost e-scooters. Experiencing access and barriers involved diverse social and material dimensions. Conversations with citizens revealed aspects such as collective grief for public furniture, which has been progressively removed since the 1990s. In cooperation with the TransitionHub team, we reconsidered the role of games: Instead of treating them as

merely a means to an end, we envision them as a broader field for co-creative activities, including making and adapting geogames, just like playing them (see Figure 1, left side). Each engagement with games addresses the framing of mobility issues, situated perspectives, and everyday knowledge.

In this article, we follow a series of experimental formats to bring digital technologies into an active dialogue with open-ended and context-centered approaches. As a theoretical foundation, we combine research on digital geogames with insights from critical game studies and game-inspired approaches in science and technology studies (STS). We discuss the playing and making of geogames as a contingent reconfiguration between a structuring game system and an open-ended situation. Thereafter, we introduce three distinct engagements with geogames involving "playful reconfigurations" and explore their participatory potential—learning from experimental and playful workshops, making and modding as a contextual attunement, and lastly, playing as a performative activity generative of unforeseeable situations. Through this, we propose "playful reconfigurations" as a crucial resource for participatory game making and playing.

2. Game/Play Reconfigurations

For our discussion of geogames, we have to revisit how the playing and making of games mediate between a predetermined system and a contingent situation in which a game unfolds. This juxtaposition resonates with the classical distinction between "game" and "play." The latter "is an open-ended territory in which make-believe and world-building are crucial factors" (Kampmann Walther, 2003). Conversely, games "are confined areas that challenge the interpretation and optimization of rules and tactics—not to mention time and space" (Kampmann Walther, 2003). Games appear as quasi-technological systems, which preconfigure the interactions between players and game elements. Thus, Flanagan (2009) highlights the central function of "rules in constructing games, with varying degrees of storytelling, conflict, and competition added into the (often, technology-driven) system" (p. 7).

Correspondingly, Ahlqvist and Schlieder (2018) characterize these game systems as structured by patterns representing "generic solutions to a specific class of design problems" (p. 3). Following this logic, a game can be described as a combination of interdependent, rule-based, or even algorithmic functions. The authors continue mapping relationships between geographical concepts and familiar game mechanics into "spatial game patterns" (Ahlqvist & Schlieder, 2018, p. 9). Concerning participatory geogames, these patterns allow for the involvement of geo-spatial data in the gameplay with instructions like "find a specific location" or "place this object." At the same time, the game-as-system introduces a framing of an urban planning problem, for instance, by directing the gameplay towards predefined questions, promoting particular interactions, and formatting the results that players may produce.

Against this background, games appear as rather deterministic systems. Yet playing a geogame involves a radically different experience based on corporeal interactions, improvisation, or the exploration of urban worlds. While game and play may appear as a paradox, Kampmann Walther (2003) argues for their necessary entwinement: "games *should* not be play; but that does not imply that they do not *require* play" (emphasis in original). A treasure hunt can be conceived as a technical system of GPS trackers, target coordinates, and a scoring mechanism. However, it also involves open-ended exploration of the surroundings, overcoming physical barriers, and unforeseen social encounters.

The anthropologist Lucy Suchman conceptualizes the enactment of technical scripts as "situated actions," involving a "reconfiguration" of both human and technology (Suchman, 2007)—or, in our example, player, game, and urban space. Playing as situated action is characterized by contingency, embodiment, and an open-ended engagement with the material environment (Suchman, 2007). While this situated aspect of digital technologies is often overseen, it represents a central aspect of gameplay. Flanagan (2009) points towards the subversive dimension of this reconfiguration: Play usually involves a creative reinterpretation or even the unmaking of the rules of the game (p. 8), thus shifting between normative compliance and destabilization of a predetermined system (p. 13). In this regard, enacting a digital geogame reconfigures geospatial information and digital media: Data overlap with material urban environments, and game mechanics are re-articulated as spatial performance and social encounters. Using the rudimentary example of hopscotch, Flanagan (2009) discusses how different rule sets invoke specific player relations and interactions with the surroundings (p. 8).

Reconfiguration through playful behavior bears the potential to mediate between distinct perspectives on urban issues and different framings of a planning problem. Loosely structured tools, which can be playfully adapted to a momentary setting, have a strong tradition in civic participation. Referring to the bottom-up process around the "Planbude" in Hamburg, Tribble et al. (2017) describe how participation tools are tailored to the context to facilitate a meaningful and creative collaboration between different stakeholders (p. 270). Playful devices, such as building kits or collaborative drawings, function very differently from the well-structured game systems discussed at the beginning of this section. Instead of imposing a discreet structure on the players' interactions, the tools appear as material to play with. Analogous to the concept of participatory "design things," playful interactions successively frame and reframe a controversial planning issue (Varga, 2018, pp. 37–41), blurring the distinction between a mere enactment of a game and its adaptation or remaking.

Hence, we extend the concept of "reconfiguration" to the creation of games. Making a geogame is an open-ended design practice that reframes planning problems and knowledge and bears the potential to involve diverse stakeholders' perspectives. Dumit (2017) discusses analog game design as an ethnographic research method that enables the exploration of complex socio-technical systems and the investigation of different actors' perspectives. Farías and Sánchez Criado (2023) likewise consider game making as the ongoing framing of a "para-ethnographic" field (p. 109). They describe how previous ethnographic observations are rearticulated as game rules, tokens, and materials. At the same time, playing the resulting game in public becomes a research site of its own, both through the gameplay and the conversations it provokes (Farías & Sánchez Criado, 2023, pp. 107–108). This methodological proposal underlines that game making and gameplay may be understood as reciprocally interconnected activities, which allow the successive bounding of urban issues, the mediation between different actors' perspectives, and the collaborative exploration of possible solutions.

These approaches are not limited to analog games: Ratto (2011) describes how the "critical making" of playful microcontroller flowers interweaves material collaboration with open-ended discussions (p. 255). Calvillo (2019) proposes data visualizations as a form of cooperative research and an attunement with complex urban issues such as air pollution. Visualization becomes a critical reassembly of available data, their interpretation, and their significance for citizens' everyday lives as well as the planners' strategies (Calvillo, 2019, p. 270).

With this excursus, we elaborated on the capacity of geogames to structure participatory interactions and to frame urban problems through game patterns and mechanics, which are often inscribed into digital media. Thus, digital games allow for the integration of urban data and the collection of structured information. Concurrently, we drew attention to game making and gameplay as open-ended activities, facilitating a reconfiguration of a game system to specific contexts and situated perspectives.

3. Methods: Learning, Making, Playing

To explore "playful reconfigurations" in practice, we turn to the co-creation process of Creating NEBourhoods Together, which defines the boundary conditions of this study. The geogames discussed in the following sections integrate qualitative insights from the co-creation process for two NEBourhood Hubs—multifunctional mobility stations in Neuperlach (see Figure 2). Hence, the emerging games should support future participation processes regarding mobility stations or site-specific infrastructure in public space.

A NEBourhood Hub is a modular pavilion offering free-to-use functions related to sustainable mobility, such as a shared cargo bike, a repair station, and mobility aids. Furthermore, the hubs are intended to enhance accessibility and quality of stay by offering benches, outdoor games, and tools to borrow. The co-creation process ensured that each hub met the needs of the local community by involving citizens in relevant design decisions (see Table 1; for more details, see Drechsel et al., 2024). Since Neuperlach is a large area, identifying general locations for intervention was crucial. These spots were then explored with particular attention to local features of urban space. Next, specific functions were configured for each site—for instance, should a large table or a bike repair station be included? Lastly, participants were involved in the design aspects. While

Figure 2. The installed NEBourhood Hubs are adapted to the urban surroundings and the neighborhood's needs.

technical aspects remained in the manufacturer's domain, the question was how a hub could contribute to the quality of the surrounding space. These fields of decision-making were addressed in three workshops, described in the following section. On this basis, hub proposals were refined in a scenario workshop with citizens, the manufacturer, local institutions, and public officials. Finally, two hubs were installed in Neuperlach.

This process provided requirements and insights for the design of geogames. The emerging prototypes should address relevant decision-making fields such as location finding and functional configuration (see Drechsel et al., 2024). Additionally, they should incorporate insights regarding qualitative aspects of mobility and participation methods from Neuperlach. As previously mentioned, many mobility problems turned out inherently "wicked" (Rittel & Webber, 1973), and relevant aspects emerged unexpectedly and anecdotally. This provided challenges for designing meaningful digital participation games—which we address through the concept of "playful reconfigurations."

Specifically, we introduce three ways of exploring a geogame's capacity to open up engagements with a particular urban context and situated perspectives on mobility (see Figure 3). Each reconfiguration described in the next sections involves a distinct methodological setup, through which a predetermined game system unfolds in a specific context. For the "Learning to Play" reconfiguration, we follow three co-creation workshops through which NEBourhood Hubs were designed. This allows us to explore how game concepts and interactions unfold in playful engagements in Neuperlach. "Making and Modding" describes the prototyping of several geogames and discusses how this process brings together insights on "situated play" with digital technologies and modular game components. Finally, we turn towards "Playing Geogames" to examine the resulting prototypes in action and investigate how they become co-constitutive of participatory situations. While we present these methods sequentially, we do not propose a fixed or teleological order of preparation, prototyping, and use. Each reconfiguration contributes specific interactions, encounters, and knowledge forms.

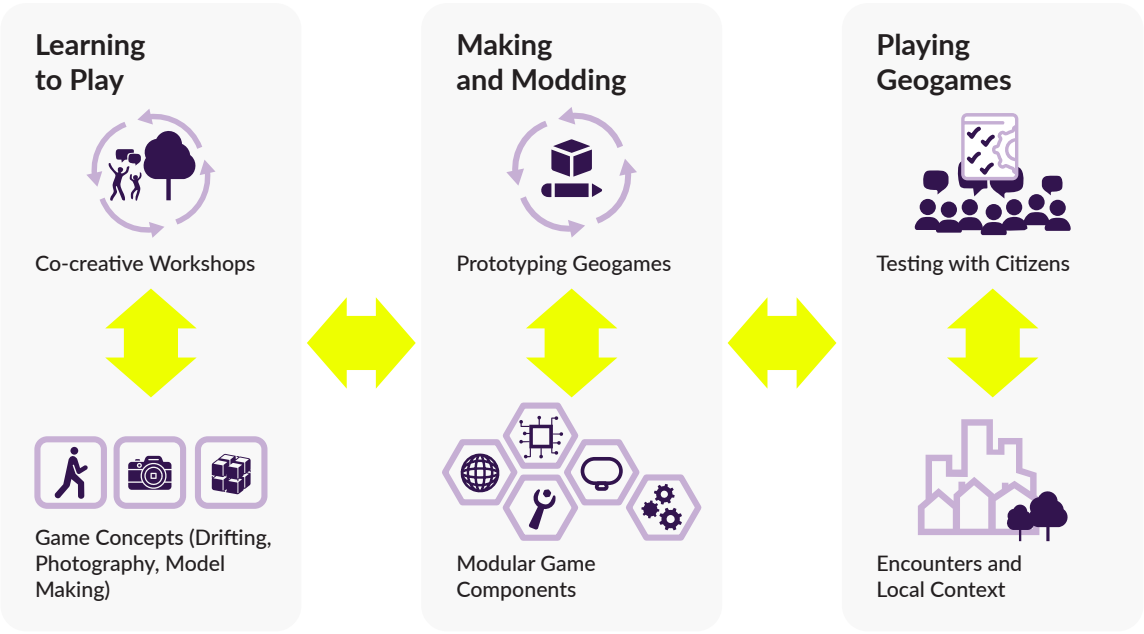

Figure 3. Methodology: Three reconfigurations are introduced for shaping and testing geogames.

4. Learning to Play

First, we examine the unfolding of (digital) game concepts in specific playful situations in Neuperlach through three co-creation workshops. We have described digital geogames as quasi-technological systems whose elements and patterns configure interactions, present information, and determine possible feedback types. In this initial step, however, we shift the focus towards open-ended game play, namely, to how game mechanics are enacted in social situations and urban spaces. With reference to Suchman's (2007) concept of "situated actions," we explore dimensions of "situated play" that emerge from enactments with citizens in Neuperlach.

Table 1 provides an overview of the workshops developed and conducted in collaboration with the TransitionHub experts, who supported the project's co-creation activities. The events were publicly announced and conducted with citizens of Neuperlach in the autumn of 2023. Each workshop addressed relevant questions regarding NEBourhood Hubs, such as location finding or functional configuration (for more details, see Drechsel et al., 2024), and was conceived as a collaboration between stakeholders, creative practitioners, and experts. Citizens were invited via several media channels, such as a mailing list and direct contact at the project's pavilion (see Table 1). Given the demographics of Neuperlach, it was crucial to include older citizens. The Model Making format also targeted young locals and their parents. Each workshop was conceived and hosted with creative practitioners who had prior experience with the chosen participation methods. Furthermore, our team members participated in the workshops to gain an inside perspective on the emerging interactions.

Table 1. Overview of the methods and proceedings of the four workshops.

Method	Group Size	Age	Participants	Invitation	Duration	Results
Drifting	9	30–80	Citizens, team, creatives	Posters, mailing list, passersby (project pavilion, in public)	3 h	Locations on a small scale, qualitative aspects of mobility
Photography (workshop, competition)	7 + 6	30–60	Same as above	Same as above, adult education center	2 h + 2 weeks	Images with locations on a large scale, comments
Model Making	17	6–80	Same as above, students	Posters, mailing list, passersby (project pavilion, in public)	2 h	Models with functions and aesthetic aspects
Scenario workshop	30	30–80	Citizens, team, creatives, officials, institutions	Active invitation via email	3 h	Scenarios for hubs (location and functions)

Within the scope of this article, we discuss these workshops as an opportunity to learn about geogame interactions from a qualitative perspective, in specific social situations and urban contexts. Nonetheless, it was crucial that the workshop formats were contributing to the actual implementation of mobility hubs since participants may behave differently than in a playful situation without real-world consequences. Each

workshop followed a promising concept for a participatory geogame. Drifting focused on location-based interactions using GPS trackers. The Photography workshop investigated "camera-mediated" interactions, common in mobile games and augmented reality (AR) applications. Model Making explored tangible design interactions and collaboration. The fourth workshop, which is not discussed further here, aimed at combining the results (and some methods) from the three previous formats. Given our aim to learn about the situated unfolding of geogame concepts, this section focuses on playful social and material interactions. Digital technologies were used in ad-hoc and hacked ways, such as "manual" GPS tracking, smartphone cameras, and material models.

4.1. Drifting

Ralf Otto, a dance instructor who often works with elderly citizens, introduced us to Drifting, a collective urban-exploration exercise. He had developed the format inspired by the "dérives" of the Situationist International, a Marxist group of artists who practiced collective Drifting as a "playful-constructive behavior" and a phenomenological hijacking of the dominant (spatial) order (Debord, 1958). Situationist Drifting became a central reference for performative projects in urban space and many of today's digital geogames (Souza e Silva & Hjorth, 2009). At the beginning of our experiment, the participants were introduced to the format's goals and rules: They were to move slowly and stay close together. When a participant felt attracted to a specific direction, they carefully led the group in this direction until someone else took over. The group remained silent until everyone agreed on a potential site for a NEBourhood Hub. At this point, there was a short break to discuss this place and the participants' observations. After exploring an area, the group continued to another part of the district by bike to cover a larger portion of Neuperlach. This multimodal journey was documented using GPS tracking. Additionally, we took notes on the participants' comments and opinions. Thus, the workshop resulted in a travel chain, which included several suitable hub locations. Moreover, the stroll led to a psychogeographic re-reading of the explored spaces, corresponding to Debord's (1958) proposal. Gathering geo-locations for potential hubs likewise involved Drifting through the participants' memories and everyday anecdotes connected to these places.

4.2. Photography

Our second experiment was led by Sandra Singh, a photographer with experience in community work, and co-hosted by a local adult education center. Of course, smartphone cameras are a common feature in many participation apps and immersive games, allowing the capture of images or augmenting real-world representations on screen. However, we intended to treat the camera as an active agent rather than a passive sensor. Accordingly, we focus on camera-mediated interactions and the social and spatial dimensions they provoke. Favero (2017) discusses camera-based exploration practices as a powerful ethnographic inventory and an opportunity to assemble diverse mediated perspectives on urban space. Furthermore, we were inspired by discussions around participatory photography, which can enable specific co-creative formats and social encounters (e.g., Prins, 2010). Our Photography format followed a two-step approach: During an on-site session, Sandra introduced the participants to several exercises that encouraged them to engage photographically with the urban environment, for instance, by exploring visual features ("Search for lines!" "Play with background and foreground!") and by investigating the environment ("Find an interesting shot and wait until somebody passes by!"). These exercises involved a bodily exploration of urban spaces. After the initial session, the participants were invited to continue individually and submit their

results to a photo competition. The challenge involved capturing locations in Neuperlach central to their mobility practices and problems in a single picture, accompanied by a written explanation or voice recording. Finally, the photographs were placed on a map and assessed in a discussion with local planning experts.

4.3. Model Making

In collaboration with Enrica Ferrucci, an architect specializing in design pedagogy, we conducted a workshop on configuring and designing individual hubs. In this session, we introduced interactions with material models as a prominent playful approach in participatory design (e.g., Rambaldi, 2010) and as a method to allow tangible and intuitive interactions with digital media (see Memis et al., 2024). First, the participants covered cardboard cubes with images, collages, or symbols representing different functions. These cubes were then stacked and combined to create various configurations, prompting discussions about the interactions between different functions. At the end of this phase, participants used sticky dots to vote for proposed functions. Based on this voting, the most critical elements were constructed at a 1:20 scale. Wooden parts, plastic rings, and paper constructions were utilized to represent these functions and assess their feasibility. Moreover, participants shaped design ideas and discussed aesthetic preferences. As playful collaboration media, the models stimulated discussions around mobility. They allowed for materially grounded speculation about the role of NEBourhood Hubs in the neighborhood and in participants' everyday lives.

4.4. Situated Play

Through the described workshops, we explored how different game patterns and digital elements could be reconfigured to participatory situations in Neuperlach. These workshops provided insights into location-based exploration, camera-mediated investigation, and tangible design interaction. Whereas game patterns, such as location finding, movement rules, or competition, were integral to this experience, these engagements highlighted the "side effects" of these game systems. For instance, Drifting fostered a sense of community among participants and established an atmosphere in which personal anecdotes and memories were shared. Photography involved unexpected corporeal interactions with urban spaces, as well as encounters with interested inhabitants and sometimes suspicious pedestrians. The enactment of games in public involved several aspects of performativity. Fischer-Lichte (2015) identifies "unpredictability," "ambivalence," "perception as a performative process," and "transformative power" as central characteristics of performative actions (p. 31). These situations led to unexpected outcomes and blurred boundaries between participants and instructors. Data gathering became an active corporeal practice that affected the surrounding spaces. Building upon these principles, we specify five dimensions of "situated play" that we deem especially relevant for participatory geogames. This categorization draws on our discussion of design principles in previous articles (see Drechsel et al., 2024; Förster et al., 2025). The dimensions are as follows:

- Bodily Movement was a crucial aspect of both the Drifting and Photography formats. In particular, Drifting focused on the sensorial experience of moving with and responding to each other in a collective. This bodily engagement drew attention to obstacles, potential barriers, and material aspects of mobility.
- Collective Experiences emerged from group activities during the workshops and fostered a sense of community among the participants. Drifting together or collaborating on a model establishes trust and

open communication. Flanagan (2009) notes: "By playing together, people form close communities and develop a group identity and a sense of belonging" (p. 5).

- Interactions with the Environment emerged from camera-mediated explorations and Drifting exercises. Taking pictures encouraged people to take different positions or wait for something to happen. Drifting comprised an intimate phenomenological exploration of material and social spaces (for example, a drift might end up in a parking garage). Hence, these formats fostered a (re)exploration of everyday surroundings and led to new perspectives on the urban spaces under discussion.
- Material Making was most prominent in the Model Making workshop. Playing with material objects can serve as a speculative catalyst, open up associations, and ground participatory conversations (Guggenheim et al., 2017). In this way, resulting models, maps, and objects should not be regarded merely as "data," but also as active agents within the collaboration.
- Open-ended Storytelling provided the context for engagement with quantitative information, such as geo-coordinates or distinct suggestions for functions. While storytelling is also a classical element of gamification (Muehlhaus et al., 2023, p. 333), we refer not to predefined narratives but to the emerging narrations of participants—their memories, anecdotes, and affective responses.

These aspects of "situated play" were crucial to the workshops' outcomes and contributed to understanding mobility in Neuperlach. They led to diverse insights that did not directly derive from the introduced game mechanics. Whereas the initial goal of Drifting was to search for locations, or more technically, coordinates and comments, the workshop led to a deeper qualitative understanding of the visited urban spaces. This included the collective experience of visiting the spaces together, bodily engagement with the barriers of the pedestrian network, and historical anecdotes about a lost quality of public spaces. Although locations could be gathered with a GPS sensor and text comments, it would be difficult to collect this information solely through a standardized digital game.

5. Making and Modding

Based on our exploration of "situated play," we discuss how these insights can be incorporated into geogames—in our case, for co-creating NEBourhood Hubs. Our aim was not to create a single participation game, but to experiment with a toolbox that is configured to specific contexts and co-creation formats. With reference to our discussion on game making, we explore how the collaborative creation of different tools allows for critical engagement with the context, the integration of diverse perspectives, and the framing and reframing of mobility issues. Making and playing geogames should not be understood as two sequential steps but rather as intertwined collaborative knowledge-building activities (Farías & Sánchez Criado, 2023). As depicted in Figure 4, making games entwines game patterns and digital technologies on the one hand and integrates qualitative dimensions of "situated play" in Neuperlach on the other.

This approach involves two steps. First, we describe the preparation of technical game components, allowing for the relatively easy creation of geogames in collaboration with a group of students who, although untrained in programming games, contributed expertise in urban design and architecture. In the second step, we discuss how the making and modding of tools reconfigure these technical modules to different forms of "situated play" and enacted participation formats in Neuperlach. In this way, we present game making as a "situating" activity that contextualizes urban data and digital media within a specific participation project—in our case, the co-creation of mobility hubs.

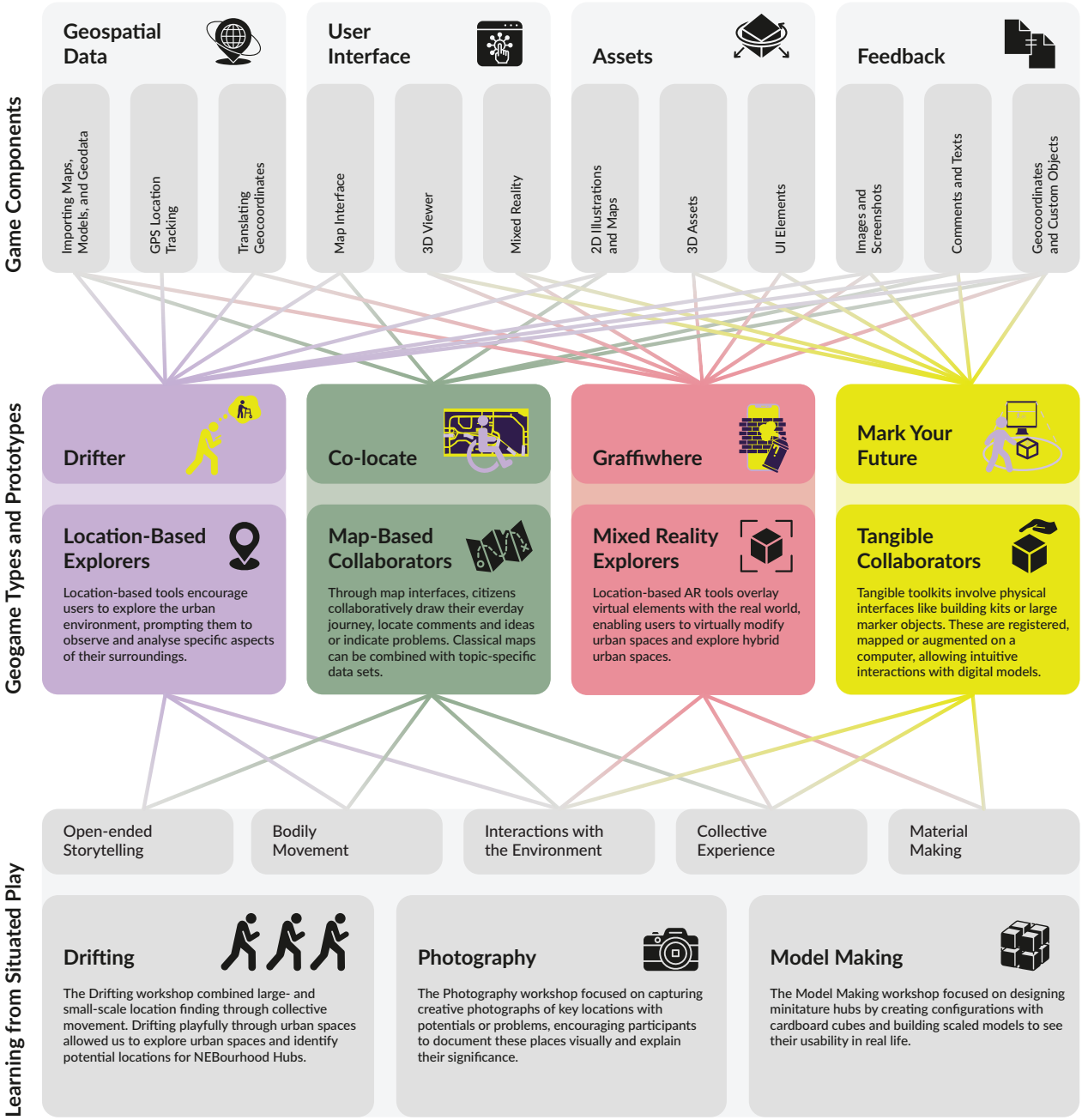

Figure 4. A map of game making: The prototyping process attunes geogame modules to dimensions of situated play and contextual understandings of mobility in Neuperlach.

5.1. Game Components

Our collection of game components is designed to enable the creation of digital geogames based on central interactions from our three workshop formats (see the upper section of Figure 4)—predominantly GPS location tracking, camera-mediated experiences, and design interactions. Additionally, these components integrate relevant functions for the co-creative design of NEBourhood Hubs, from location finding to configuration and design. Based on these requirements, we prepared game components for four relatively abstract geogame types (in the middle of Figure 4). "Location-Based Explorers" are built on GPS tracking and existing urban

data (for instance, maps), and focus on urban exploration and location finding. “Map-Based Collaborators” center on collaborative interactions with maps or models. “Mixed Reality Explorers” integrate AR and optional GPS tracking to investigate urban space and interact with physical and virtual elements. Finally, “Tangible Collaborators” emphasize haptic design interfaces, which could be integrated via AR marker tracking.

The game engine Unity was chosen as the foundation because it integrates several relevant functionalities and is relatively beginner-friendly. Additionally, this environment supports cross-platform deployment on smartphones, tablets, PCs, and virtual reality headsets. On this basis, the computer scientists in our team prepared scripts for accessing the device camera, GPS location tracking, and AR features. They also created custom scripts to support the integration of geodata and models from the digital city twin as well as from other sources. Further requirements, such as a library of 3D assets and visualization techniques, emerged during the prototyping process. The resulting toolbox of technical components comprised a set of custom scripts, assets, and adapted templates. To disseminate relevant skills, the computer scientists further prepared several live and video tutorials covering topics from basic programming to the adaptation of supplied scripts.

5.2. Assembling Prototypes

The prototyping process began in a collaborative design studio with 30 students on bachelor’s and master’s levels in architecture and urbanism during the winter term of 2023/2024. While we decided to produce the prototypes in an academic studio rather than, for example, with a school class in Neuperlach, we aimed to understand the making of geogames as a critical engagement with the local characteristics of Neuperlach and context-specific perspectives on mobility.

First, the group was introduced to the topic of mobility in Neuperlach and the process of co-creating NEBourhood Hubs. They partly observed the aforementioned workshops with citizens. Additionally, the creative practitioners responsible for these formats introduced the group to the specific methods of Drifting, Photography, and Model Making by reenacting them on-site. Hence, the group experienced “situated play” firsthand and gained insight into different aspects of mobility.

Through several ideation and concept-development formats, we explored how these insights could be rearticulated as participatory geogames—using performative exercises, storyboards, and paper prototypes. In parallel, the computer scientists on our team introduced the group to the game engine Unity and the prepared game components, thereby supporting participants with little prior programming experience in creating a set of working geogame prototypes. Furthermore, each group considered the social setting of its prototype, for instance, whether it would be played individually or collectively, synchronously or asynchronously. The prototypes were accompanied by a kit, including a short manual and any necessary additional material. Ultimately, nine exemplary geogames were developed as working prototypes, seven of which were further prepared for testing by a team member. The games were implemented as basic functional prototypes to showcase the key features of the participation format. Secondary features, such as automatic storage of results in a database or a dedicated user login, were omitted in favor of manual hacks.

Prototyping involved a second reconfiguration of game systems in response to different understandings of mobility in Neuperlach. While the experimental Drifting, Photography, and Model Making formats focused

on the unfolding of geogames through play, the making of games mediated between the assembly of game patterns, urban data, and digital media on one side, and the specific urban context on the other. This activity allowed for the reframing of planning issues and the incorporation of diverse stakeholders' perspectives. The process began with the predefined and necessary areas of decision-making for the co-creation of NEBourhood Hubs (location finding, configuration of functions, and design suggestions) and potential geogame types to address these questions.

However, game making also involved reframing, shifting, and contextualizing these decision-making fields, as we discuss using the example of the emerging prototypes. The games entangle issues such as location-finding with heterogeneous dimensions of mobility, ranging from the perceived quality of urban space to feelings of safety and experiences of barriers in Neuperlach's footpath system. As discussed in Section 2, prototyping geogames unfolded as the reciprocal framing and reframing of a "field" (Farías & Sánchez Criado, 2023) for participatory engagement, enabling an attunement between given geodata, different perspectives on mobility, structuring game systems, and "situated play." After articulating the basic interactions of a geogame prototype, filling this system with content and "modding" it to a specific situation added another layer of reconfiguration. Inserting and exchanging 3D models, texts, or urban datasets further adapted the game systems to a specific site, problem framing, and format. Thus, each of the geogame types shown in the center of Figure 4 was articulated in the form of specific prototypes and allowed a distinct recombination of digital technologies and open-ended engagements with mobility.

5.2.1. Location-Based Explorers: Drifter

Several games focused on urban exploration, mainly based on GPS location tracking and the presentation of geodata using a map interface on a mobile device. Players interact with this system by following paths, searching locations, or exploring specific areas, contributing geo-referenced feedback in combination with images, sound recordings, and text comments. Concerning the design of NEBourhood Hubs, such games supported large-scale location finding and a deeper understanding of mobility practices in Neuperlach. Additionally, different aspects of "situated play" were crucial for these projects. Drifting and Photography highlighted especially the relevance of bodily movement, interactions with the environment, and the possibility of relating geospatial data to open-ended storytelling.

The prototype Drifter by Wen-Shan Cui, Buket Göksen, and Justine Morin shows how these aspects intersect in a specific geogame (see Figure 5). The game follows a two-step approach of configuration and play. During the first phase, the game is configured through open-ended conversations with citizens of Neuperlach about their individual mobility experiences, for example, women feeling (un)safe walking at night, or the lack of public furniture for elderly citizens. In the second phase, these scenarios were encoded into a map-based exploration game that relates geodata on urban infrastructure to the discussed topic. The player re-enacts situations from the interviews, such as an older person walking to buy groceries. The game introduces a decreasing energy bar that prompts players to stop at bench locations. If no bench is found, they place a "joker" bench. The prototype demonstrates how a generic location-based game is reconfigured to different groups' mobility experiences by modding through interviews.

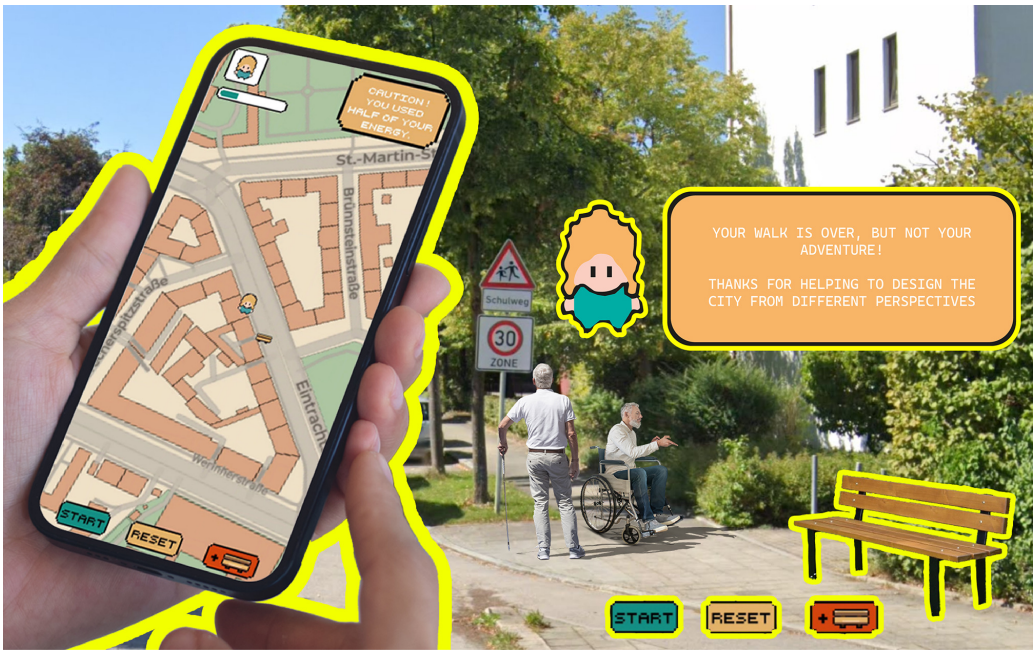

Figure 5. Drifter rearticulates situated mobility experiences as a location-based exploration game.

5.2.2. Map-Based Collaborators: Co-Locate

"Map-Based Collaborators" focus on large-scale patterns and potential sites for hubs. However, rather than emphasizing bodily movement, they draw inspiration from the design negotiations and the collective experience of the Model Making format. Accordingly, they support participatory discussion through cooperative map interfaces. For this purpose, they visualize urban datasets, models, and maps and allow for design interactions such as marking specific areas, adding items, or annotating ideas and opinions.

Co-locate by Yun Lou, Maximilian Schulte, Xiaochen Sun, and Yuan Zhang aimed to shed light on the experiences of citizens using mobility-aiding devices, such as wheelchairs, strollers, rollators, and walkers. Since the footpath system of Neuperlach suffers from diverse barriers, this perspective was crucial for the co-creation process and the installation of new mobility stations. The game prototype involves several phases during which users map their everyday routes and mobility challenges on a tablet or touchscreen (see Figure 6). Finally, the players configure and locate potential hubs based on this information. In an ongoing voting, each proposal receives points from the participants. Since the emphasis lies on the players' negotiation, the game elements are integrated more subtly than in the other prototypes and focus on structuring the discussion, incorporating the participants' narrations, and allowing for engaging interactions with the map.

5.2.3. Mixed Reality Explorers: Graffiwhere

"Mixed Reality Explorers" operate on a smaller scale than the previously mentioned game types and focus on visual and spatial interactions with urban spaces. Using mixed reality features on smartphones and tablets, they augment urban spaces with virtual elements and prompt players to respond to challenges positioned in urban spaces. Results can be saved as screenshots or database entries with GPS coordinates. By enticing the

Figure 6. Co-locate engages players in a playful map-based collaboration on accessibility.

players to move to specific locations of interest, these prototypes draw on the camera-mediated interactions of the Photography workshop, combining bodily movement and interactions with the urban environment. Also, they were influenced by the design interactions of the Model Making format.

The game Graffiwhere, by Mariam Suwwan, Taiane de Melo Nepomuceno, and Chenyuan Wang, was inspired by a strong graffiti culture in Neuperlach—a bodily activity that plays creatively with the material context (see Figure 7). The emerging geogame translates this practice to 3D-spraying in AR. This represents another form of modding, here with a focus on the interactions rather than on exchanging game assets. The gameplay consists of a collective spraying session in a public area. Different prompts invite players to create graffiti on themes such as "barriers" or "improvements for public spaces." Spatial drawing exercises encourage players

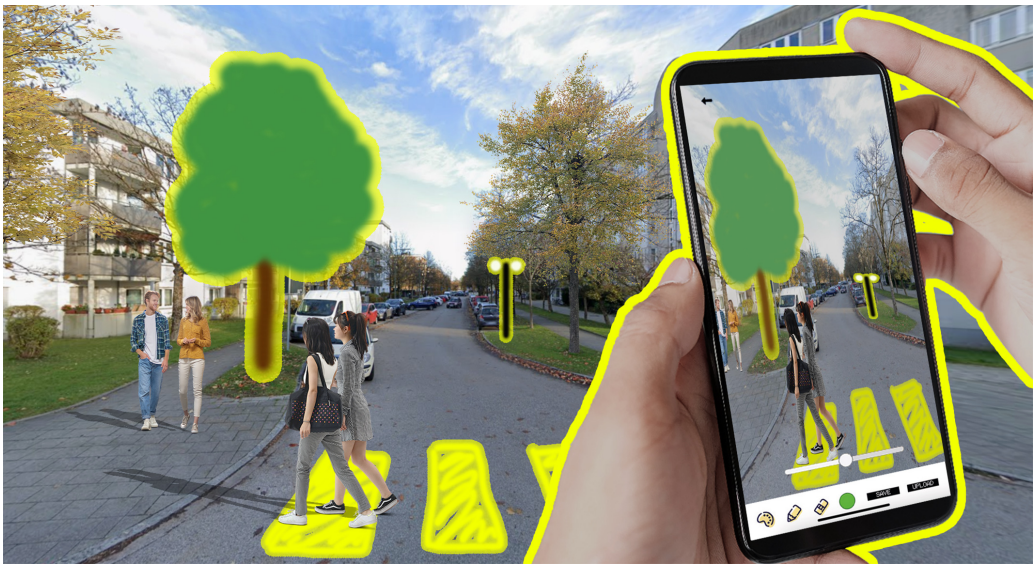

Figure 7. Graffiwhere introduces "virtual spraying" as a bodily engagement with urban space.

to move their smartphones like spray cans and interact performatively with the urban surroundings. Showing each other the resulting graffiti adds another layer to this playful engagement.

5.2.4. Tangible Collaborators: Mark Your Future

"Tangible Collaborators" link physical interactions with building blocks of physical items with an additional digital layer. In doing so, they enable explorative and playful engagement with digital models. While the two prototypes in this group tested different technical approaches for coupling physical items with a digital game system, an AR approach with marker objects proved to be a feasible way to achieve this result. The games aimed to incorporate tangible design interactions and collective collaboration, drawing on the Model Making format. In this way, they focus on the functional and spatial configurations of mobility hubs.

Mark Your Future by Lisa Ableitner, Alissa Schulteß, and Anna Zieziula consists of a physical installation at a potential location for a NEBourhood Hub (see Figure 8). This arrangement contains several large cubes recognized as markers by a camera. A large screen mirrors this camera's view but allows players to replace the cubes with diverse assets to construct a mobility station and redesign the location. Thus, the prototype entices playful, explorative, and collaborative interactions that unfold through the interplay between urban space, digital space, the marker cubes, and other participants. Hence, the prototype reconfigures a digital technology into a hybrid on-site interaction.

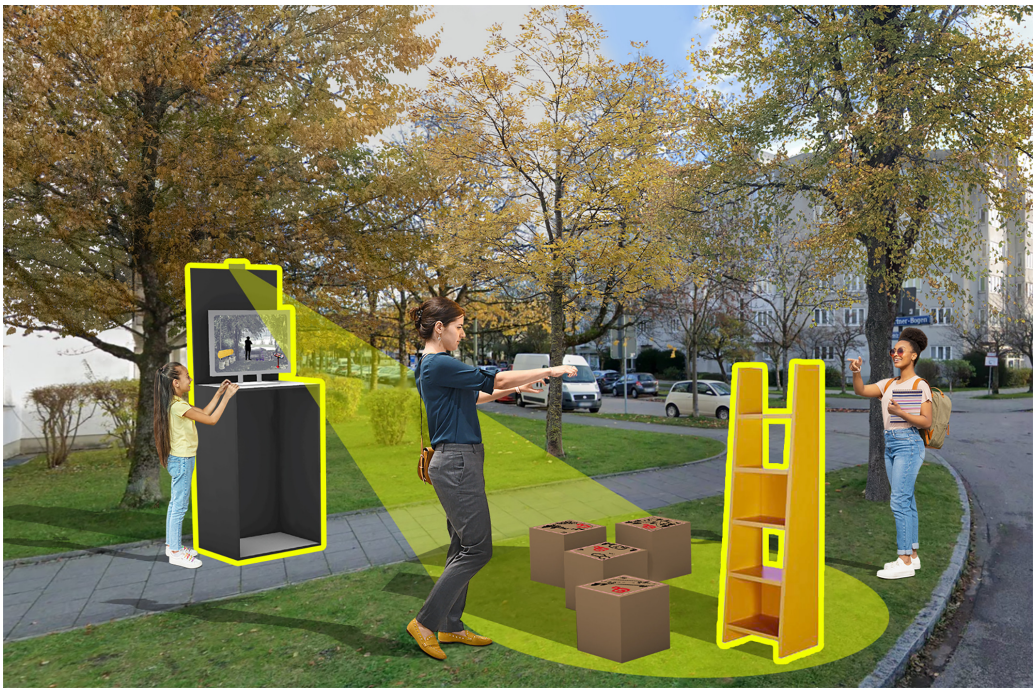

Figure 8. Mark Your Future supports discussions on mobility through playful material interactions.

6. Playing Geogames

Lastly, we discuss a third reconfiguration—the enactment of geogames in Neuperlach. While we consider game making and gameplay as reciprocally connected, this last section focuses on how the described geogame

prototypes were involved in playful on-site situations. We discuss two public "test play" events held in July and August 2024 in Neuperlach. Six games, four of which were described in the previous section, were prepared for gameplay next to an installed NEBourhood Hub (see Figure 9). The media column of Mark Your Future was set up on an adjacent lawn, while the collaborative mapping game Co-locate was presented on a screen on a table. The other prototypes were installed on smartphones and tablets. Each game was accompanied by a printed manual explaining its steps and activities. Test sessions lasted between 10 and 20 minutes and were supported by a member of our team, who took notes during the sessions. Furthermore, feedback generated through the prototypes was recorded (for instance, placed AR objects were documented via screenshots). Finally, players were asked to complete a survey about their experience and the games' potential for future participation processes.

Figure 9. Gameplay next to a NEBourhood Hub in Neuperlach.

We announced the events in advance through the project's mailing list, newsletter, and website, and also contacted interested stakeholders from earlier workshops. On the event days, we approached passersby to invite them to participate in a test play, which accounted for the majority of testers. In total, 46 players engaged with one or more prototypes and completed the complementary survey. Different age groups were represented, with a bias toward citizens below 35 (64%) and only 5% above the age of 68. This section focuses on gameplay observations and the players' qualitative feedback. In doing so, we trace emerging interactions between players, geogames, and their surroundings, and discuss the types of participatory situations the games generated.

6.1. Surrounding Formats

Exploring social constellations and participatory settings in which a game would be used was crucial to the prototyping process. Each game requires a specific process and social setting. Our test play highlighted this aspect, revealing its relevance for both the user experience and the outcomes of the participation games.

For instance, it was crucial to carefully introduce the players to the different prototypes and find a common understanding of what a game interaction means in the context of participation—e.g., is a virtual object placed in AR a suggestion or a marker for a problem? From the Drifting workshop, we learned to begin each format with a warm-up, while the Photography format introduced a longer asynchronous phase with an intensive workshop. Similarly, players engaging with the AR games in our test play required an introductory phase to explore the user interactions without considering the relevance of their contributions. Some people (especially older participants) had difficulties interacting with digital prototypes. In this case, it was particularly important to provide support and incorporate social formats that could compensate for these difficulties.

6.2. Unforeseen Multiplayer

Even games initially conceived as individual and asynchronous experiences evolved into collaborative gameplay. Our team members were supposed to behave passively by introducing the games and then observing, but in practice, they contributed much more actively to the gameplay. As mentioned previously, many older players struggled with digital interfaces such as AR features. Assistance and cooperation became so central that many testers attributed a high level of collaboration to the games in the survey, even to those designed as individual and asynchronous formats. While this aspect might be mitigated to a certain degree with improved user interactions or better tutorials, we view this "involuntary multiplayer-ness" as an intriguing dimension of "situated play" with digital media. The collaborative setup had a significant impact on how each geogame unfolded. Rather than functioning as streamlined media, smartphones and tablets became tokens passed among players, mediating social interactions—helping one another, discussing, and working together.

6.3. Conversation Catalysts

Some players were less interested in using the comment fields of our geogames as a feedback function than in verbally sharing their ideas with another person. Although Drifter was intended as a data-gathering game, the resulting coordinates were far less interesting than the conversations and shared stories triggered through gameplay. The tested AR games also elicited intriguing comments complementing the placed objects. One player casually explained that she had placed virtual lanterns so that trees would not occlude them—a significant problem for her sense of safety. The underlying reason for this thoughtful placement may have been lost in a screenshot, a saved geo-coordinate, or a brief comment. Talking about and "talking around" (see Calvillo, 2019, p. 67) the games were central to the testing session. At times, this aspect took over, and the geogames became mere conversation starters. Based on this observation, we highlight the importance of including open-ended formats in the gameplay to capture unexpected or easily missed responses.

6.4. Material Presence

The gameplay demonstrated the importance of the material presence and performative effects of geogames in public spaces. The prototype Mark Your Future combined a large screen-installation with several physical marker cubes that invited passersby to interact with it and gave the prototype a prominent appearance. Players arranging these cubes and checking the result on the screen manifested a performative activity. As a result, this prototype appeared the most appealing during the test sessions and attracted the highest number of players.

Other tools, like Co-locate, were presented on an inviting table for collaboration. In contrast, smartphone and tablet-based apps lacked this ostensive expression. Nonetheless, players moving through public spaces with their phones or interacting with an invisible reality also produced a particular effect on the environment and drew the attention of pedestrians.

6.5. Digital Minimalism

Several participants commented on imperfect and only partially implemented functions, such as a dummy multiplayer board or buggy navigation. Although we were transparent about the games' prototypical state, these obstacles confused the players and disturbed their interactions. A central lesson, therefore, was the value of creating minimalist games that focus on essential game mechanics. Other functionalities, such as multiplayer statistics, a shared map of results, or a user login, could be handled through social formats and ad hoc solutions. During our test gameplay, we added a notebook to the prototypes for additional comments and asked the players to take screenshots, which would later be collected. This reductive approach also opens up new opportunities to make and modify games with non-computer scientists and limited time resources. It leads us to the idea of a geogame as a minimalist medium accompanied by social practices, analog media, and hacks. Instead of an intricate system, the minimalist digital medium draws inspiration from games such as hopscotch (Flanagan, 2009) and is therefore robust enough to adapt to unforeseen situations. For instance, the game Graffiwhere consists of a relatively simple 3D drawing concept. However, these interactions enabled multiple playful expressions and engagements with the urban environment.

In conclusion, playing on-site added another layer of reconfiguration to our geogames. On the one hand, the games operated as media allowing for exploration of space and the contribution of opinions and ideas. On the other hand, they revealed themselves as active agents that co-constituted a playful situation, similar to the "speculative" devices described by Varga (2018). Rather than serving merely as a passive medium for gathering information, they manifested a material presence, operated as conversation catalysts, and became tokens mediating social situations.

7. Discussion

We have explored three "playful reconfigurations" of geogames—between digital game systems and open-ended play. Each of these reconfigurations allowed an opening towards situated perspectives and unexpected occurrences. Thus, they reframed both the participatory interactions and the issues at stake, combining necessary information for implementing mobility hubs with unforeseen issues and contextual knowledge. In this section, we revisit how each format allows for such reconfigurations and discuss challenges and potentials for future work. For this purpose, we introduce our reflections alongside some friendly yet critical remarks from collaborators of the Creating NEBourhoods Together project.

Through three workshops, we learned how game concepts unfold in formats with citizens in Neuperlach. The experiments revealed dimensions of "situated play" as a rich resource for further development. They allowed for low-cost experimentation with as-found digital media and exploration of the participatory situations such media would entail. However, these formats also faced significant challenges, such as finding a sufficient number of participants. Retrospectively, one member of the TransitionHub deemed the workshops too experimental, while another suggested they did not integrate well with the events of existing

institutions such as the local family café or youth centers. These issues raise interesting questions regarding the situations and contexts to learn from and point to possible connections to critical design discourses. For instance, Rosner (2018) documents how collaborating with a knitting circle reframed the role of digital tools and opened up space for situated exploration (p. 67). Or to put this differently: How could a GPS sensor be "reconfigured" through a workshop in a family café?

Making and modding geogames reconfigured digital technologies in relation to local mobility issues and the context in Neuperlach. The process involved collaboration among computer scientists, creative practitioners, and students from different backgrounds. On-site explorations and engagement with various stakeholders' perspectives were crucial for developing interactions and game concepts. As a result, the emerging prototypes linked digital participation tools to practices such as graffiti spraying and insights gained from interviews. Modding further adapted the games to contextual narratives and location-specific challenges. At the same time, the co-creative potential of these activities has to be explored in further research. The prototyping process described in this article remained within an academic context for practical reasons, such as the obligation to produce working prototypes. Yet there is considerable potential in opening these activities to local groups, school classes, or maker spaces, allowing for engagement of varying complexity and effort. Combining prepared modules in a game engine still requires technical support, whereas adapting game assets and the storytelling may be much easier. Such co-creative formats with geogames could be linked to "critical making" approaches, reassessing game making as a contingent material-semiotic deliberation (see Ratto, 2011).

Playing with the resulting prototypes produced specific performative and sociomaterial situations and provided crucial insights into the agency of the geogame prototypes. Rather than acting as passive media, the games emerged as active agents that contributed to social situations, manifested a material presence in urban space, and enticed performative effects. This reconfiguration links the playing of geogames to discussions of performative urbanism (Wolfrum & von Brandis, 2015). Nonetheless, the digital games were not equally accessible and attractive to all players, as noted by other researchers in this field (Kavouras et al., 2025, p. 3). Many participants required careful support during the gameplay. The testing session also highlighted the potential of these frictions to open up conversations and unexpected encounters. These insights challenge us to consider how digital and analog elements, structuring game elements, and open-ended play can be productively combined for an inclusive participatory format.

8. Conclusion

In this article, we began with a perceived gap between digital and analog methods. While the former provide innovative interaction types, integration of urban data, and new forms of communication, the latter appear more flexible in responding to unforeseen contexts and open-ended controversies. Through the concept of "playful reconfigurations," we propose that geogames have the inherent potential to bring these two sides into a productive dialogue.

We explored these reconfigurations through three engagements with geogames. Each attuned a game system—workshop methods, game components, and digital prototypes—to a social and material urban context. Furthermore, we investigated how these engagements can be combined into a distributed cooperative learning process. Exploring "situated play" in a specific context allowed us to identify specific

qualities of play in Neuperlach. Making and modding prototypes incorporated these insights and approached game making as a successive process of shaping urban issues and participation formats. Finally, playing on-site highlighted the contingency and performativity of "playful reconfigurations," leading to unforeseen encounters and interactions.

This lack of control is precisely what makes geogames interesting for us. Instead of "improving" participation technologically or enhancing motivation, we discussed making and playing participatory games as experimental activities and opportunities for collaborative learning. This article aimed to bring different engagements with geogames into a productive dialogue. Nonetheless, these combinations deserve further exploration, intertwinement, and reconfiguration. This article does not conclude with a perfect game. Instead, it is an invitation to play and mod, to reassemble data, rules, planning issues, and urban media.

The game is on!

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Conflict of Interests

The authors declare no conflict of interests.

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Grammarly was used for spelling correction.

References

Ahlqvist, O., & Schlieder, C. (2018). Introducing geogames and geoplay: Characterizing an emerging research field. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 1–18). Springer. https://doi.org/10.1007/978-3-319-22774-0_1

Calvillo, N. (2019). Digital visualizations for thinking with the environment. In J. Vertesi, D. Ribes, L. Forlano, A. Camus, D. Vinck, N. Calvillo, D. K. Rosner, C. Dunbar-Hester, X. Kerasidou, L. Stark, S. Couture, S. J. Jackson, A. S. Chan, C. A. Hawthorne, C. Ilten, P.-B. McInerney, D. Nemer, P. Chirumamilla, W. R. Poster, . . . M. Jacomy (Eds.), *digitalSTS* (pp. 61–75). Princeton University Press.

Connected Urban Twins. (2024). *Unsere Vision*. https://www.connectedurbantwins.de/das-projekt-2/unsere-vision

Debord, G.-E. (1958). Theory of the dérive. *Internationale Situationniste*, *2*. http://library.nothingness.org/articles/SI/en/display/314

Dembski, F., Wössner, U., Letzgus, M., Ruddat, M., & Yamu, C. (2020). Urban digital twins for smart cities and citizens: The case study of Herrenberg, Germany. *Sustainability*, *12*(6), Article 2307. https://doi.org/10.3390/su12062307

Drechsel, M., Förster, N., Schubert, G., & Petzold, F. (2024). Situating digital participation: Incorporating material, contextual, and performative learnings into digital toolkits. In O. Kontovourkis, M. C. Phocas, & G. Wurzer (Eds.), *Proceedings of the 42nd International Conference on Education and Research in Computer Aided Architectural Design in Europe* (Vol. 2, pp. 465–474). eCAADe. https://doi.org/10.52842/conf.ecaade.2024.2.465

Dumit, J. (2017). Game design as STS research. *Engaging Science, Technology, and Society*, *3*, 603–612. https://doi.org/10.17351/ests2017.132

Farías, I., & Sánchez Criado, T. (2023). How to game ethnography. In T. Sánchez Criado & A. Estalella (Eds.), *An ethnographic inventory: Field devices for anthropological inquiry* (pp. 102–111). Routledge.

Favero, P. (2017). Curating and exhibiting ethnographic evidence: Reflections on teaching and displaying with the help of emerging technologies. In L. Hjorth, H. Horst, A. Galloway, & G. Bell (Eds.), *The Routledge companion to digital ethnography* (pp. 275–287). Routledge.

Fischer-Lichte, E. (2015). Performativity and space. In S. Wolfrum & N. F. von Brandis (Eds.), *Performative urbanism: Generating and designing urban space* (pp. 31–38). Jovis.

Flanagan, M. (2009). *Critical play: Radical game design*. MIT Press. https://doi.org/10.7551/mitpress/7678.001.0001

Förster, N., Drechsel, M., Meirelles Coutinho, C., & Schubert, G. (2025). Where digital meets analog: The future of urban co-creation. In N. Borgmann, C. Hellstern, & T. Zoch (Eds.), *NEBourhoods for tomorrow* (pp. 84–99). TUM School of Engineering and Design, Technical University of Munich.

Gabrys, J. (2016). *Program earth: Environmental sensing technology and the making of a computational planet*. University of Minnesota Press. https://directory.doabooks.org/handle/20.500.12854/115825

Guggenheim, M., Kräftner, B., & Kröll, J. (2017). Creating idiotic speculators: Disaster cosmopolitics in the sandbox. In A. Wilkie, M. Savransky, & M. Rosengarten (Eds.), *Speculative research: The lure of possible futures* (pp. 145–162). Routledge.

Heryanto, Firmansyah, F. H., & Rosmansyah, Y. (2024). Exploring collaboration in multiplayer gamification: A systematic literature review. *IEEE Access*, *12*, 149399–149431. https://doi.org/10.1109/ACCESS.2024.3477465

Kampmann Walther, B. (2003). Playing and gaming: Reflections and classifications. *The International Journal of Computer Game Research*, *3*(1). https://www.gamestudies.org/0301/walther

Kavouras, I., Rallis, I., Sardis, E., Protopapadakis, E., Doulamis, A., & Doulamis, N. (2025). Empowering communities through gamified urban design solutions. *Smart Cities*, *8*(2), Article 44. https://doi.org/10.3390/smartcities8020044

Kavouras, I., Sardis, E., Protopapadakis, E., Rallis, I., Doulamis, A., & Doulamis, N. (2023). A low-cost gamified urban planning methodology enhanced with co-creation and participatory approaches. *Sustainability*, *15*(3), Article 2297. https://doi.org/10.3390/su15032297

Kitchin, R., & Dawkins, O. (2025). Digital twins and deep maps. *Transactions of the Institute of British Geographers*, *50*(1), Article e12699. https://doi.org/10.1111/tran.12699

Loh, W. (2019). The gamification of political participation. *Moral Philosophy and Politics*, *6*(2), 261–280. https://doi.org/10.1515/mopp-2018-0037

Lu, X., Ren, F., Wang, X., & Meng, H. (2024). How gamified interactions drive users' green value co-creation behaviors: An empirical study from China. *Sustainability*, *16*(9), Article 3512. https://doi.org/10.3390/su16093512

Memis, I., Förster, N., & Petzold, F. (2024). Science fiction, software friction, spatial fantasies: Architectural speculations as a resource for digital design. In O. Kontovourkis, M. C. Phocas, & G. Wurzer (Eds.), *Proceedings of the 42nd International Conference on Education and Research in Computer Aided Architectural Design in Europe* (Vol. 2, pp. 517–526). eCAADe. https://doi.org/10.52842/conf.ecaade.2024.2.517

Muehlhaus, S. L., Eghtebas, C., Seifert, N., Schubert, G., Petzold, F., & Klinker, G. (2023). Game.UP: Gamified urban planning participation enhancing exploration, motivation, and interactions. *International Journal of Human–Computer Interaction*, *39*(2), 331–347. https://doi.org/10.1080/10447318.2021.2012379

Nochta, T., Wan, L., Schooling, J. M., & Parlikad, A. K. (2021). A socio-technical perspective on urban analytics: The case of city-scale digital twins. *Journal of Urban Technology*, *28*(1/2), 263–287. https://doi.org/10.1080/10630732.2020.1798177

Prins, E. (2010). Participatory photography: A tool for empowerment or surveillance? *Action Research*, *8*(4), 426–443. https://doi.org/10.1177/1476750310374502

Rambaldi, G. (2010). *Participatory three-dimensional modelling: Guiding principles and applications. 2010 edition*. Technical Centre for Agricultural and Rural Cooperation.

Ratto, M. (2011). Critical making: Conceptual and material studies in technology and social life. *The Information Society*, *27*(4), 252–260. https://doi.org/10.1080/01972243.2011.583819

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169. https://doi.org/10.1007/BF01405730

Rosemann, T. (2013). Planning in the face of democracy: Mit Jacques Rancière über Raumplanung und Demokratie nachdenken. *sub\urban. zeitschrift für kritische stadtforschung*, *1*(2), 41–60.

Rosner, D. K. (2018). *Critical fabulations: Reworking the methods and margins of design*. The MIT Press.

Schrotter, G., & Hürzeler, C. (2020). The digital twin of the City of Zurich for urban planning. *PFG – Journal of Photogrammetry, Remote Sensing and Geoinformation Science*, *88*(1), 99–112. https://doi.org/10.1007/s41064-020-00092-2

Souza e Silva, A. d., & Hjorth, L. (2009). Playful urban spaces: A historical approach to mobile games. *Simulation & Gaming*, *40*(5), 602–625. https://doi.org/10.1177/1046878109333723

Stelzle, B., Jannack, A., & Rainer Noennig, J. (2017). Co-design and co-decision: Decision making on collaborative design platforms. *Procedia Computer Science*, *112*, 2435–2444. https://doi.org/10.1016/j.procs.2017.08.095

Suchman, L. (2007). *Human-machine reconfigurations: Plans and situated actions* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511808418

Tribble, R., Wedler, P., & Katthagen, V. (2017). PlanBude Hamburg: Kollektives Wissen als Grundlage von Stadtgestaltung. *sub\urban. zeitschrift für kritische stadtforschung*, *5*(1), 267–276.

Varga, H. M. (2018). On design and making with STS. *Diseña*, *12*, 30–51. https://doi.org/10.7764/disena.12.30-51

Wolfrum, S., & von Brandis, N. F. (Eds.). (2015). *Performative urbanism: Generating and designing urban space*. Jovis. https://www.jovis.de/de/book/9783868593044

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ARTICLE

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Campus Changer: A Serious Geogame for Transforming the Main Campus of the Warsaw University of Technology

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Abstract

The goal of the article was to develop a serious geogame that allows for the activation of the Warsaw University of Technology's (WUT) academic community's involvement in the participatory planning process for campus revitalization and development. The Campus Changer geogame is implemented as a PC-based application that uses a detailed 3D model of the WUT campus and the players' real-time physical location. The geogame allows not only virtual exploration of a detailed, 3D model of the university campus but also raises awareness of the problems associated with the functioning of the members of the academic community in a jointly used space. The Campus Changer geogame, developed using the Unity engine with detailed WUT campus models (LoD [level of detail] 3), allows users to explore the campus and propose transformations. Guided by Genius Loci, the university's guardian spirit, players encounter challenges and interact with diverse campus stakeholders, such as academic staff, students, and local residents. Player decisions reshape the campus instantly, with changes visible in the 3D virtual world. The Campus Changer geogame allows users to manipulate detailed geospatial data (a 3D model of the WUT campus and its connection to GIS tools) and can be used as a powerful geoparticipation tool. The results of GIS analyses conducted by the authors of the article using data collected based on the results of a multi-player game provide insight into the opinions of different groups of the WUT academic community, who propose diverse changes in different parts of the campus. Compared to traditional planning consultations, the geogame

facilitates the collection of input from a significantly broader and more diverse audience, fostering inclusive and participatory decision-making. The most significant achievement of the project is the activation of the academic community and co-creation planning for the modernization and development of the university.

Keywords
co-creation; gamification; geogame; location-based game; participatory democracy; serious game

1. Introduction

Modern university campuses of leading universities not only play a crucial role in creating an environment for research and education at the highest level but also in supporting the formation of the academic community. Beginning with Plato's ancient school founded in the grove of Akademos, the Academy became a place for scientific discussion and social debate. Inspired by the ancient tradition, the development of the Academy can also be linked to Athenian democracy. As a place where participatory democracy evolved, the Athenian agora can be an inspiration for the creation of a contemporary digital agora (Olszewski & Wendland, 2021) which facilitates the participatory shaping of space through the use of modern geo-information technologies. The university campuses adhering to the tradition of the first Academy remain the heart of today's emerging so-called smart cities (Manville et al., 2014). At the same time, a modern campus can act as an urban living lab and provide a space for testing innovative technological and social solutions on a university scale before their implementation in large urban areas.

One of the key issues in the participatory shaping of development visions, both of smart cities and university campuses, is the problem of the local community's low involvement. This phenomenon has a high frequency of occurrence specifically in Eastern Europe as a consequence of long periods of passivity and lack of trust in institutions, which is typical for post-communist countries. One of the most effective ways of social activation, which is a prerequisite for shaping deliberative democracy at the local level and creating an open society (Popper, 1966), is the use of gamification methodologies and modern geo-information technologies. This approach may be implemented, for instance, through the development of so-called serious games (Abt, 1970; Djaouti et al., 2011; Duke, 1974), which provide users with the opportunity to entertain themselves, ensuring the transfer of attractively administered knowledge and players' activation. One development of this approach is the so-called geogames (Ahlqvist & Schlieder, 2018; Andrade et al., 2020; Poplin et al., 2017, 2020). These types of games are a combination of geospatial technologies, serious game methodologies, and participatory engagement of the local community. This provides city authorities and urban planners with the tools to engage a wide range of stakeholders, conduct a simulation analysis of multiple alternative scenarios, and increase the level of public involvement.

Skilful social activation facilitates the use of a mechanism referred to in the literature as volunteered geographic information (Goodchild, 2007; Haklay, 2010; Howe, 2006; Martella et al., 2015). Volunteered geographic information plays an important role in the approach proposed in this article. This concept, widely used, for example, in OpenStreetMap data collection, involves the social engagement of users in collecting, verifying the quality of, and updating spatially located data. Crowdsourcing develops under the influence of geo-information technologies and is an effective way to solve problems and create information by grouping participants (e.g., serious geogame users) around a collective idea. Initiatives like that shape (geo)informative

society as well. Serious geogames can be used in various fields such as smart city development, public transportation, energy efficiency, or climate change impacts (Olszewski & Wieszaczewska, 2016). The authors of this article developed and evaluated a serious geogame called Campus Changer to activate the academic community of the Warsaw University of Technology (WUT) and plan the participatory development of the university campus as a living lab of the capital city of Warsaw. In 2026, the WUT will celebrate its 200th anniversary. This milestone provides an opportunity to honour the legacy of Poland's best technical university while modernizing its campus. The revitalization of the campus requires engaging the academic community to propose changes in the spirit of participatory democracy, ensuring these changes will result from joint efforts. The use of gamification methodology in the developed serious geogame will promote social (geo)participation and facilitate the campus co-creation process.

The aim of the authors of the article is to develop the geogame Campus Changer, which allows the use of location-based game capabilities and detailed geospatial data (3D model of the WUT campus) as a powerful geoparticipation tool. In combination with GIS tools, this game also enables spatial data mining analyses useful in spatial planning.

The aim of the research is not only to develop a serious geogame, but also to analyze the possibilities of using this solution as a tool for social geoparticipation—both on the scale of the university campus and the entire city.

Specifically, we aimed to investigate whether such a tool can broaden community engagement, generate diverse proposals for spatial interventions, and provide structured input for campus development. To address these goals, the project combined a digital gameplay environment with the collection of participants' decisions, socio-demographic data, and qualitative feedback. The evaluation was carried out through the analysis of gameplay data using GIS methods and the integration of user opinions on selected campus areas. The results inform both the methodological value of serious geogames and the substantive vision for campus transformation.

2. Literature Review and Examples of Geogames

2.1. Serious Games

The key factor in the sustainable development and shaping of so-called smart cities by their residents is the ability to harvest and process available information (including spatial data), as well as the needs and expectations of the local community, and to extract and use the knowledge obtained. At the same time, this process supports the creation and development of an open (geo)information society. One of the most effective ways to implement this process is the use of gamification techniques and so-called serious games (Alfrink, 2014; Kapp, 2012; McGonigal, 2011; Uskov & Sekar, 2015; Zichermann, 2013).

Entertainment is not the only objective of creating serious games, although their entertainment potential is crucial as it influences motivation and involvement (Białous, 2024). The overriding objectives of serious games are to educate, train, simulate, and solve social problems. The intention of serious games is for players to acquire, develop, and consolidate specific skills and solve problems. They can also be used to raise awareness of the role of social responsibility and the consequences of taking economic and social action in the process

of shaping and using space. Serious games can contain elements of gamification, support active learning, and simulate real-life environments (Figure 1). Additionally, they can be a tool for provoking a measurable reaction or change in the player. Interactive games which integrate geographical data and GPS technologies or use real spatial data and geodesic systems for collecting information about space fit into the category of serious games as geogames. The terms location-based game, location-enabled game, and geolocation-based game also appear in the literature (Alavesa et al., 2017; Groundspeak, 2000; Montola et al., 2009; Pacmanhattan, 2004; Paelke et al., 2008).

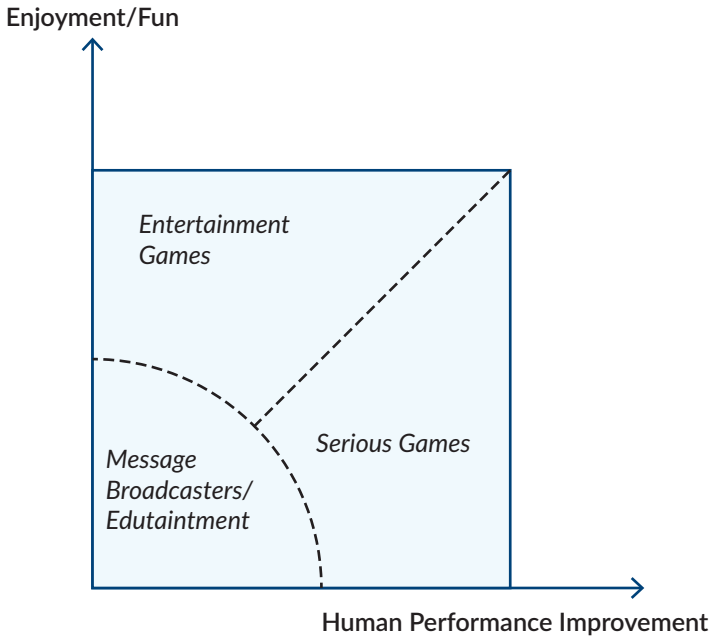

Figure 1. Differences among entertainment games, message broadcasters, and serious games. Source: Loh et al. (2015).

Computer games have been developed since the mid-20th century and have since then become part of mass culture. Electronic games are not only one of the main application areas of ICT but are also used in entertainment and education. Digital serious games can also be utilized in environmental protection, treatment, and rehabilitation, business development, etc. (Arnab et al., 2015; Breuer & Bente, 2010; Carvalho, 2017). Another application of such games is the visualization of spatial data, urban planning, or the optimization of urban transport (Canossa et al., 2013; Carvalho et al., 2015; Mat, 2014; Olszewski et al., 2018). With technological developments in geoinformation extraction and processing, computer games succeed in the increasing use of spatial data. Some of the earliest examples of this type of game were Ingress and Pokémon GO. However, it should be emphasized that these games were played on a map and not in a 3D urban space. The use of spatial data in serious geogames now demands a much higher level of detail and precision (LoD). A major impetus for the development of games that fully exploit the possibilities of 3D space models has been the use of game engines such as Unity or Unreal for the development of in-flight simulators. The 2020 edition of Flight Simulator, for example, uses around two petabytes of Bing map data, including aerial photographs and 3D scans.

2.2. Gamification in Social Participation

Social participation has long been seen as an essential element of democracy, ensuring that the public can affect the decisions of local authorities and public institutions. Traditional forms of consultation, such as open meetings, surveys, or referenda, do not always attract a wide range of stakeholders. For this reason, new tools are increasingly being used to encourage active participation. Gamification can effectively enhance the motivation of participants as it introduces an element of fun, challenge, and immediate feedback (Hamari et al., 2014). As a result, those taking part in consultations experience greater engagement and satisfaction with participation.

Recent years have seen a growing interest in the use of gamification mechanisms in various areas of social life, including civic participation processes. Gamification, defined as the use of game elements (e.g., scoring, levels, rewards) in non-game contexts, is gaining popularity in the areas of urban planning, education, and social consultation (Deterding et al., 2011). The core objective of these activities is to increase the engagement of different groups in decision-making and sensitivity to social issues.

As a tool for social participation in spatial design, digital games support the development of a participatory culture in which citizens are actively involved in the planning and implementation of local spatial policy. This is exemplified by the game Minecraft, which is used in initiatives such as Block By Block to strengthen relationships in the community and revitalize neglected public spaces. The game serves as a collaborative platform and visualization tool to engage local communities in spatial policymaking. On the other hand, Cities: Skylines, as a city simulation, can be used to elicit ideas from residents in the spatial planning process, as shown by the example of the city of Hämeenlinna in Finland. One can also see the potential of games to diffuse causality, facilitating participation in the creation of spatial policy in the comfort of your home, which was particularly important in the era of the Covid-19 pandemic (Szot, 2021).

Gamification mechanisms in social participation can be divided into several main categories. Firstly, a system of points, badges, and rankings helps to clearly visualize participants' progress (Zeng et al., 2017). Secondly, narrative elements, such as a storyline or a guiding character, help to build an emotional connection with the project. Thirdly, collaboration or competition between participants plays an important role, which can increase commitment and encourage more frequent interaction with the system (Table 1).

Table 1. Categories of gamification mechanisms.

Category of gamification mechanism	Subcategory	Features	Examples of use
Reward systems	Points	Rewards for the completion of specific actions, progress monitoring possible	Points for voting in public consultations Rewards for activity on the platform
	Badges (rewards)	Distinction for specific achievements, building internal motivation	Xyz badge for the participation in numerous initiatives Medals for long-term commitment
	Rankings	Facilitating the comparison of participants' achievements, stimulating competition	List of the most committed participants Ranking of groups or districts in the civic budget

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	Rankings	Facilitating the comparison of participants' achievements, stimulating competition	List of the most committed participants Ranking of groups or districts in the civic budget
Narrative elements	Storyline	Creation of narrative context that emotionally involves participants	Story about the impact of civic decisions on urban development Simulation of consequences of various actions
	A guiding character	A character helping the user to get around the system	A virtual assistant explaining the decision-making process A hero guiding the user through the stages
Type of interaction between users	Collaboration	Engaging the users in collaborative project work	Creation of teams to implement public initiatives A system of common objectives to achieve
	Competition	Stimulating the activity through competition between the users	Competition for the best idea for public space development Challenges with rewards for the most active users

2.3. Examples of Games

Contemporary geogames are increasingly going beyond traditional educational and entertainment frameworks to become innovative tools supporting participatory urban design processes, especially in academic environments. Examples such as NextCampus or EquiCity Game (Nourian et al., 2023) show how games can simulate complex spatial decisions, engage different stakeholders, and present the consequences of alternative development scenarios. Initiatives such as Participatory Chinatown or Community PlanIt in turn focus on activating the residents and incorporating their voice into the planning process through gamification mechanisms as part of public consultations.

Geogames also adopt a form of spatial experiment, both physical, like Stroll Around Yesterday, and digital, like E-polis (Gazis & Katsiri, 2024) or Cities: Skylines – Campus, for example, allowing the participants to experience, test, and design space under simulated conditions. Their common denominator is the use of the game medium to increase engagement in real processes of shaping both urban and academic spaces.

Platforms such as Neighborland, Play the City, and Games for Cities operate on a different plane. Although they do not integrate advanced spatial data or GIS analyses, they are crucial in building the model of open inclusive participation. Neighborland allows the residents to submit ideas and run consultations through a user-friendly form of online communication. Play the City (2025) supports creative urban experiments based on cooperation between professionals and local communities, while Games for Cities uses gamification mechanisms to increase involvement in sustainable urban development. They have a common objective: the democratization of spatial planning and supporting the co-creation of a city as the common good.

Platforms such as Second Life can also be treated as both a tool and a universe for creating geogames. Second Life is a multiplayer virtual world that allows cooperating with other players in a virtual, 3D world. Developed for personal computers in 2003, in 2013 it had approximately one million regular users. The Second Life platform was used in education (universities create virtual campuses for lectures and seminars), art and creativity (artists and creators design immersive art installations and virtual galleries), research and experimentation, recreation and role-playing, and therapy and support groups.

The above examples greatly illustrate the potential of gamification in the broad activation of the participants and in building an inclusive decision-making environment. The immediate visualization of the consequences of decisions increases motivation and makes the voice of each participant visible in real time. Research shows that this type of interaction can enhance trust between stakeholders, as well as an understanding of the complexity of planning processes (Gordon & Walter, 2019; Hassan & Hamari, 2020).

On the other hand, achieving a high level of realism, by using LoD 3 or LoD 4 in building modelling, among other things, is time-consuming and requires substantial funding. Not all social groups have equal access to equipment and digital skills, which raises questions about digital exclusion (Faure et al., 2020). There is also a risk of part of players making decisions to merely score points or win a position in the ranking. For this reason, game designers must ensure transparent and substantive foundations of the process.

Gamification in public participation is a promising tool for increasing civic involvement and allowing the public to actively influence the decision-making process. Mechanisms like narratives, immediate visualization of changes, and complex analytical tools (GIS) considerably enhance the appeal of the entire process.

It should be emphasized that digital platforms enabling social geocivic participation are a special case of geogames. Solutions of this type can be considered not only as geogames, but also as serious games supporting social debate on the functioning of the city and its development. Digital platforms such as Participatory Chinatown, Better Reykjavik, or Community PlanIt involve interactive exploration, decision-making, and immediate visual feedback on player actions. These digital platforms show that gamification may find application in diverse social and urban contexts. With the growing popularity of immersive technologies (AR, VR) and tools for data analysis (GIS), one can expect even more advanced and engaging solutions supporting participation and collaborative decision-making.

Video games, in general, rely on players' engagement emerging spontaneously from the sheer opportunity to do something. While a player's acceptance of the game premise is a prerequisite for engaging with the game at all, once the player does engage, they tend to stay within the game even in the absence of an explicit prompt to act (Gee, 2007). This is most starkly evidenced by "walking simulator" games, where, in the most

extreme cases, the player is offered no explicit objectives and no corresponding explicit challenges (e.g., Key & Kanaga, 2013; The Fullbright Company, 2013). Arguably, it is more appropriate to discuss gameplay in terms of prompts or invitations rather than challenges, since demonstrating that a video game can maintain player engagement at least temporarily, without imposing any sort of difficulty, would be trivializing.

3. Problems and Methodology

3.1. WUT Campus and Its Problems

The WUT is one of the best technical universities in Poland, with almost 200 years of tradition and history. The university conducts advanced research in nearly all technical disciplines. For several years, WUT has also been one of the 10 research universities in Poland, which further stimulates its scientific development. However, the problem with the university is the low degree of interdisciplinarity in research and courses offered. The alienation of the individual faculties can also be seen in the physical space—even the area of the main campus is an unintegrated space dominated by car traffic and car parks. It needs to provide a sense of community of urban space and ideas. Despite its central location and historical significance, the WUT campus faces several challenges that hinder its functionality, accessibility, and integration with the surrounding urban environment. One of the primary issues is multi-level alienation, evident both in the spatial fragmentation of faculties and the lack of cohesion between the campus and the urban fabric. The area remains largely closed to the city, limiting its accessibility and interaction with the surrounding community. Additionally, the campus is predominantly car-centred, with excessive parking spaces and vehicles often occupying pedestrian zones, making mobility difficult, particularly for individuals with disabilities. The built environment is characterized by an overabundance of concrete surfaces, a lack of green recreational spaces, and a general absence of sustainable and pro-environmental design solutions. Despite the presence of distinctive architectural elements, such as historic buildings from the late 19th century and a protected natural monument, parts of the campus remain degraded and underutilized (Figure 2). The planned revitalization seeks to transform the campus into a model university space—one that is multifunctional, aesthetically cohesive, ecologically sustainable, and inclusive. Key objectives include improving accessibility, integrating green infrastructure that aligns with climate adaptation strategies, and reinforcing the campus's historical identity while positioning it as a modern, competitive academic centre.

Figure 2. Public spaces of the main campus of WUT.

3.2. The Game Concept and Gameplay Walkthrough

Campus Changer is a proprietary geogame designed and developed in the Unity engine and using accurate models of the WUT campus (LoD 3; Główny Urząd Geodezji i Kartografii, n.d.). The game allows the users of the game to explore the virtual space of the campus and suggest changes in its organization and appearance. The participant is guided by Genius Loci, who is the university's protective spirit, adding a narrative character and enhancing the sense of mission.

Campus Changer was designed not primarily for entertainment but to engage the academic community in participatory planning, stimulate reflection, and collect spatially explicit feedback. This geogame can also be treated as a digital platform enabling social geoparticipation. The use of GIS tools to analyze the collected data of game users also allows for the full utilization of the possibilities offered by spatial data mining in the decision-making process.

Decisions made by players have an immediate effect on the appearance of the virtual campus, which acts as a powerful incentive. Moreover, various stakeholder groups participate in this process, including academic staff, students, and residents of the nearby area. This facilitates understanding different perspectives and real co-creation of the campus space. Additionally, a geoinformation tool devised by the authors allows for the conversion of data about decisions made by users into gjson format, which is subsequently analyzed in GIS systems. This promotes drawing conclusions about the preferences of different groups within the academic community and planning specific urban solutions.

In comparison with traditional consultations, the Campus Changer geogame generated a wide range of opinions and ideas, including from groups frequently overlooked in participatory processes. Immediate visualisation of decision consequences, combined with narratives and elements of challenge, made participants feel responsible for shaping the common space.

Examples of changes anticipated by the participants of the game are shown in Figure 3. The left side depicts the current state, while the right side shows the target state. For instance, an outdoor gallery is expected in the square in front of one of the buildings. Players would like to see more greenery and benches around the fountain. A good example of the proposed changes is also the expected relocation of the rubbish bins to provide space for a café.

During the preliminary analyses, a series of site visits were conducted. Nine spots within the campus, which in the research team's opinion required changes in the spatial development the most, were identified. They included (Figure 4):

1. The area around the chimney and the road leading next to the Mechanics Building;
2. The square between the Faculty of Building Services, Hydro and Environmental Engineering, and the Mechanics Building;
3. The gates and inner courtyards of the Chemistry Building;
4. The area between the Faculty of Mathematics and Data Science and the Chemical Technology Building;
5. The fountain and the area surrounding it in front of the Physics Building;
6. The green space between the Physics Building and the residential building;

Figure 3. A current view (left) and an option of designed changes (right).

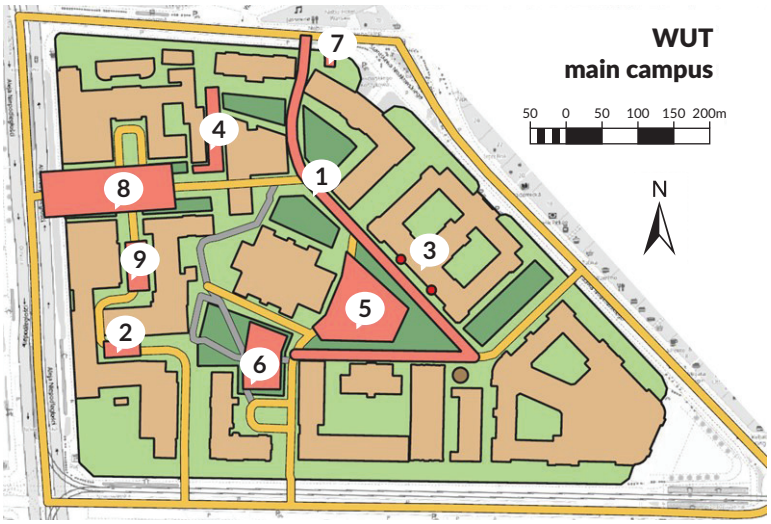

Figure 4. Location of selected areas.

7. The areas around the guardhouse at Koszykowa Street;
8. The area near the monument of Ignacy Mościcki;
9. The area between the Faculty of Electrical Engineering and the Institute of Aeronautics and Applied Mechanics.

A typical gameplay session in Campus Changer begins with the player entering the 3D model of the WUT main campus. Guided by Genius Loci, the guardian spirit of the university, the player is introduced to the objectives of the game and to the interactive characters representing different stakeholder groups (students, staff, residents). The player can freely navigate the campus, approach specific locations, and interact with these characters, who present diverse perspectives and challenges related to the use of campus spaces. At each of the nine selected areas, the player is asked to consider options for change—such as reducing parking to increase green areas, revitalizing a fountain, or adding social and cultural facilities—and to choose solutions. These decisions are immediately visualized in the 3D environment, allowing the player to see the transformation of the campus in real time.

The gameplay continues as the player explores additional areas, interacts with further characters, and gradually shapes a holistic vision of the campus. At the end of the session, the system records the player's decisions together with basic profile data, which are then analyzed using GIS tools and combined with feedback to inform the participatory planning process.

3.3. Game Design

The game design for Campus Changer had three main goals:

1. Maintain the user's engagement for longer than it takes to fill out a questionnaire, allowing us to collect more answers from each user;
2. Provide more detailed context for questions;
3. Present each question as a discussion between stakeholders, as opposed to relying solely on the user's pre-existing point of view.

While the Campus Changer platform is implemented as a PC-based serious game, it integrates a highly detailed 3D model of the real campus and engages players with spatially explicit decision-making tied to real locations. This duality—between a virtual gameplay environment and its grounding in real-world geography— allows Campus Changer to be treated as both a geogame and a serious game.

In Campus Changer, the first interaction between the user and the game is the initial conversation with Genius Loci, a fictional character. Superficially, this introduces a simple narrative, but functionally this is how we communicate to the player that characters in the game can be approached and talked to. The user is thus aware that any person they can see in the game represents a potential interaction, and seeing a character in the distance becomes a gameplay prompt. The player is free to ignore the prompts, but since they have already engaged with one, they are more likely to continue engaging. This would not necessarily be the case if prompts were not readily available and clearly presented to the user, for instance if questions were triggered by simply entering an otherwise unmarked area.

It would be incorrect to assume the user engages with the game in one specific way. Currently accepted understanding is that the same in-game events can be interpreted in widely different ways by different players, depending on each player's unique emotional needs and preferences (Hunicke et al., 2004). Video games leverage this by providing several parallel streams of stimuli. A simple example is a game where an arcade challenge such as performing an increasingly difficult series of timed jumps is accompanied by a story about searching for a kidnapped princess, which in turn is stacked on top of memorable visuals and music (Nintendo, 1985). In Campus Changer, the interaction can be seen as a series of tasks dispensed by Genius Loci, or even a series of debates between other characters, providing an alternative engagement method compared to the exploration of the campus. This approach is not because the creators believe they have crafted a great story or characters, but because some users find it easier to engage with the characters, while others prefer interacting with the in-game environment.

We hypothesize that this is a unique advantage of a (serious) game over a traditional survey, which only engages the user in a singular manner, and does not leave much room for customizing the experience. For instance, it is equally natural for the user to traverse the campus along any available path, whereas a simple body of text, such as a survey, implies just a single, linear way to read it, typically from top to bottom.

Responding to questions when "standing" in a corresponding spot within the virtual representation of the campus also means that a wider range of information is available to the user:

- They can examine the local spatial relationships.
- They can familiarize themselves with the overall function of the surroundings.
- They can more easily envision themselves using a given space.
- If they are already familiar with the campus, it is easier for them to recall specific memories and associations.

We decided to present questions as discussions between characters in order to further ground the interaction in reality. The university campus presented in the game is not an abstract or fictional place but can be and is actually visited by thousands of people on a daily basis. It has, in other words, its stakeholders. We distilled a number of plausible responses to our questions into a number of fictional personas that represent archetypes of campus users, such as a student, a teacher, an administrative employee, or a resident (since this particular campus also contains residential buildings). This is meant to help overcome the main disadvantage of a PC app, which is the absence of other users.

Some design objectives were pursued by omission. Campus Changer provides no method for keeping a score and no negative consequences for user decisions. For example, a character who represents a certain opinion will not express anger if the user chooses differently. The goal here was to discourage users from optimizing their experience according to an external metric. Anything that could be interpreted as a measure of success could lead users to modify their answers to fit the expectations of an implied judge.

4. Preparation and Testing of the Game

4.1. Development of the Game

The main goal of the application is to implement an innovative way of collecting the university community's opinions on the revitalization of the WUT campus. The necessary information is divided into two categories: the vision of the new campus and user data (so-called metrics). Information about the campus vision is gathered during the gameplay as the player completes tasks. User data are harvested at the beginning of the game, gathered almost imperceptibly for the user, as the collection is integrated into the game tutorial. This knowledge allows the authors and project teams to draw conclusions about which revitalization plan should be adopted.

The last part of the game design stage for Campus Changer was planning the structure of the application code. Productions based on the Unity engine are divided into scenes, where each scene contains a hierarchy of objects that fill it.

It was predicted that each of the planned functions of the application would require at least a few objects with individual classes overseeing their operation for implementation. For this reason, a structure based on "managers," which are objects that steer the operation of their subordinate subcontractor objects, was decided upon. Each "manager" is supposed to directly exchange data with the engine and send fragments of this information to specific "executor" objects when needed. Such a project structure allows for maintaining a high level of transparency in the application operation and facilitates the debugging process since an error in one section of the application does not affect the operation of another part.

Accurate representation of the main campus of the WUT as a 3D model with an adequate level of spatial information generalization and cartographic quality required obtaining 3D data of the buildings located in this area. Initially, it was planned to acquire the required models using the website geoportal.gov.pl, which provides a 3D representation of buildings from the BDOT10k database. However, the idea was abandoned. The decision was made due to the insufficient detail of the model visualizations and the way this information was recorded. Ultimately, the utilized 3D models of buildings were those designed as part of the project Warsaw University of Technology Ambassador of Innovation for Accessibility. The source data underwent an aggregation process, which facilitated the creation of models consisting of several larger fragments, enabling Unity to render them much more efficiently. Additionally, each object in the game world was required to have a designated collision with other objects. As part of the game project implementation, simplified representations of each obtained model were created to be used in the collision physics generation process.

The prepared data were exported to the .fbx format and imported into the Unity environment, where their integrity was later checked.

4.2. Technical Implementation and Testing of the Game

The authors intended the final version of the game Campus Changer to operate at an efficiency of around 60 frames per second for an NVIDIA GeForce GTX 1650 graphics card, Intel Core i7 ninth-generation processor, and 32 GB of RAM. During the project implementation, a series of prototypes were tested to

analyze the system performance. The game mechanics facilitate movement around the scene with the WASD keys and "looking around" using the mouse. Subsequent iterations of the game prototype focused on optimizing the method of generating objects and scene lighting.

The optimization process involved, among others, adjusting numerous variables in the engine regarding:

- The quality of the generated light and shadows;
- The compression of used textures and generated materials;
- The distance of shadow generation from the player;
- The distance of object generation from the player.

Additionally, for materials such as leaves and tree trunks, which were abundant in the scene, the GPU Instancing option was enabled. This option made objects covered with such prepared material be instantiated directly by the graphics card, bypassing calculations at the computer processor level. Furthermore, for all objects, the Occlusion Culling option was enabled, ensuring that objects the player does not view in a given frame are not generated. Subsequently, for vegetation models (tall and low greenery), the LoD Group function was added, which replaces models with less detailed ones when the player is sufficiently far away, significantly reducing the workload of the graphics card by eliminating unnecessary geometry calculations.

In most cases, such an optimized prototype allows for obtaining 60 frames per second with the mentioned equipment specification, with instances of reduction to 30 frames per second in spots in the scene most "cluttered" with objects.

The final version of the game was prepared both in Polish and English.

4.3. Evaluation Process

Information about the consultations on the campus revitalization project for the 200th anniversary of the WUT was sent to the entire academic community of the university. An email encouraging recipients to download the game and participate in the gameplay was also sent to community members: staff, doctoral students, and students. Due to the high hardware requirements, the 2.4 GB installation file was downloaded by only a portion of the respondents. A total of 92 participants, representing staff, doctoral students, and students at the WUT, took part in the Campus Changer game.

The game was tested for three different equipment specifications:

- Weaker than that for which the app was created;
- Similar to that for which the app was created;
- Stronger than that for which the app was created.

Each of the three machines used for testing operated using a Windows 10 system. The application launched in all cases, but the performance varied. On the weakest computer, the game ran at an average of 30 frames per second, with drops to 15 frames per second during more demanding moments. Tests on hardware with

computational power similar to that of the developer's computer yielded results of around 60 frames per second in most cases, with drops to 30 frames in demanding situations. The strongest configuration achieved a consistent result of 60 frames per second, with occasional drops to 50 frames per second.

During test gameplay, several minor bugs were found, such as materials and objects mismatched (incorrect texture), objects mispositioned on the scene, or text extending beyond the designed UI. However, a more serious issue was also discovered. The detected problem was that after exiting the game and rejoining it, there was an unplanned reset of already completed tasks. This bug was fixed before preparing the final version of the application.

As soon as the tests were complete, the preparation of the final version of Campus Changer began through the implementation of indispensable corrections. The game was prepared in two versions: Polish and English (see Figure 5 for the English version).

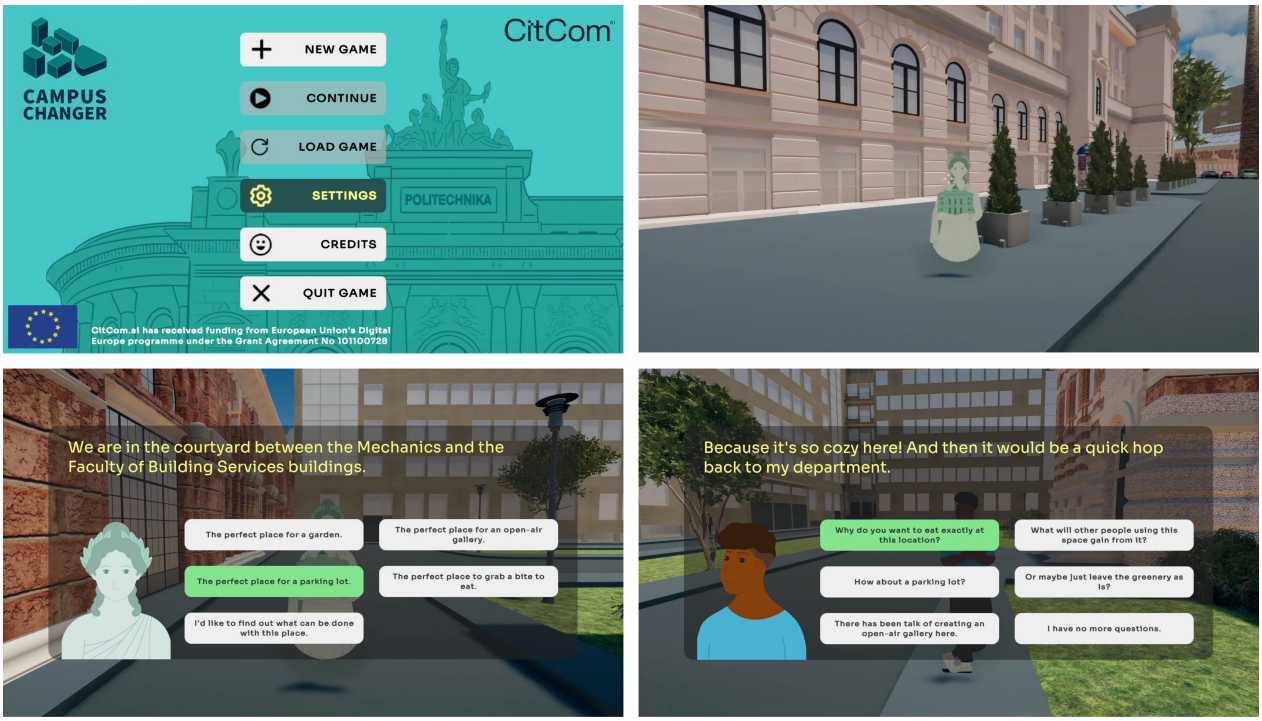

Figure 5. Dialogues in Campus Changer.

5. Results and Discussion

To analyze the results obtained through the use of the Campus Changer serious game, a proprietary geoinformatics tool was utilized. This tool facilitates the conversion of data stored on the Unity server in gjson format into a spatial database. This allowed for the automation of the data analysis process in a spatial context using GIS tools. Table 2 contains a summary of the tasks completed by the players and the dominant responses received. The results indicate that players, who are representatives of the university's academic community, would welcome changes in the way the campus space is utilized. The expected changes include a significant expansion of green areas and pavements used by pedestrians and bicycles at the expense of

reducing parking spaces. This concept, expressed as "human-oriented," reflects the idea of universal design and Society 5.0.

The analysis focused on nine selected areas of the campus identified as requiring revitalization or a change of use. Within the serious geogame, participants interacted with these areas, and the data generated by the game engine were automatically transformed into gjson and stored in a spatial relational database. This enabled us to conduct classical GIS spatial analyses and to visualize players' activities and trajectories on the campus map.

In addition to the spatial data, we collected user profiles and participants' opinions concerning each of the nine areas. These qualitative inputs were integrated with the spatial analysis results, which allowed us to interpret preferences and needs expressed during the game. The combination of both data sources provided the basis for developing a holistic revitalization concept for the campus, aligned with the expectations of the academic community.

Analysis of results also shows that the academic community expects the creation of food and drink spots like cafes with outdoor tables and folding chairs, aiming not only to quench your thirst and satisfy your hunger but also to help create an open community and support networking. The need to meet more than just physiological needs is exemplified by the desire to establish an outdoor gallery to present artwork as interactive multimedia exhibitions. It is also interesting that there is a proposal for mobile catering in the form of food trucks to be available in the central WUT campus. The area selected for food trucks is chosen so that these vehicles would not create any major disturbance for pedestrian or cyclist traffic.

The users of the game expect the revitalization of a heritage fountain, which is one of the oldest spots on the university campus, dating back to almost 200 years ago. This structure and the surrounding area are associated with historic events from World War II, especially the Warsaw Rising in 1944. The results of the serious game show that the academic community respects its history and expects the heritage site to be restored and surrounded by greenery rather than be replaced with a stage for outdoor performers or a car park.

Table 2. Most frequent responses from the players.

Problematic location	Location on the campus (map)	Most frequently proposed solution	Other solutions
The area around the chimney and the road leading next to the Mechanics Building		Widening the pavement at the expense of the road and the car park	Widening the road and enlarging the car park
The square between the Faculty of Building Services, Hydro and Environmental Engineering, and the Mechanics Building		Creation of an outdoor gallery allowing for interactive visualizations of artwork	Car park Food and drink facility

Table 2. (Cont.) Most frequent responses from the players.

Problematic location	Location on the campus (map)	Most frequently proposed solution	Other solutions
The gates and inner courtyards of the Chemistry Building		Opening the building's courtyard for the academic community	Closing the courtyard Limiting access to the courtyard
The area between the Faculty of Mathematics and Data Science and the Chemical Technology Building		Modern decorative exterior design	Enlargement of the car park Green area
The fountain and the area surrounding it in front of the Physics Building		Restoration of the heritage fountain and extension of the surrounding green area	A stage for outdoor performance
The green space between the Physics Building and the residential building		Cafe with outdoor tables	Bin shelter
The areas around the guardhouse at Koszykowa Street		Food and drink spot with outdoor tables	Security guard shelter Living Lab
The area near the monument of Ignacy Mościcki		Green area	Car park
The area between the Faculty of Electrical Engineering and the Institute of Aeronautics and Applied Mechanics		Food truck area	Utility facility for the building

6. Conclusions and Future Work

The preparation of Campus Changer required great effort and dedication associated with both the preparation of the game concept and the creation of detailed 3D models of the buildings, the design of the graphics of the game, and the optimization of functionality in the Unity engine. Effective communication with the academic community of the WUT and convincing them to participate in the serious geogame was another formidable challenge. Due to quite high equipment requirements, both in terms of the graphics card, the processor, RAM, and disk memory, approximately 100 people took part in the tests of the Campus Changer game. The number is equivalent to the number of participants in consultations on the WUT campus revitalization in 2024. The consultations were conducted by the university's authorities utilizing traditional methods. Participation in the game allows the players to familiarize themselves with the WUT campus by taking a virtual walk around a 3D model of the university. An indirect manner of learning about the campus is a value in itself, but the use of a geogame as an effective tool for public geoparticipation is equally crucial.

The conducted research shows that the serious geogame is an extremely effective tool for conducting social consultations and stimulating the activity of the academic community. It is also an attempt at the modern implementation of the idea of the digital agora by utilizing mechanisms of a serious geogame. The emotional involvement of the players proved to be much higher than during surveys, interviews, and consultations. The most engaging element of the game was the introduction of Genius Loci into the game. The guardian spirit of the university guided the participants of the serious game, facilitated learning about the virtual campus, and, first and foremost, guided and supported the users during decision-making. It was also justified to introduce avatars of other characters into the game, including employees, students, or residents of nearby houses. While talking to these characters, the players had an opportunity to familiarize themselves with different perspectives and needs. Users' opinions show that student-players considered virtual conversations with characters representing both academic and non-academic university staff to be of highly cognitive value. This was an opportunity to learn their views and better understand them. The result is the creation of commonality in the academic community and the realization of the idea of deliberative democracy. As noted by Nicholson (2012) and Kapp (2012), the effectiveness of gamification in the context of public participation depends not only on the introduced scoring mechanisms or rankings. The significance of social context and values that guide the whole process is key. In urban development or university campus projects, it is important to address the needs of different groups and to communicate objectives transparently. Introducing gamification mechanisms for the sole purpose of "fun" could trivialize the problem if participants lack a sense of real impact on reality.

The development of an in-house tool to automatically convert the decisions made by players in the virtual world of Campus Changer into a spatial database also plays a crucial role in the use of the serious geogame. The conversion and analysis of the data in the GIS tool environment allow for discourse on space development and revitalization of the WUT campus, not in the virtual world of the game but in the real-life space of the university campus. The obtained results will facilitate a more thorough debate on the changes in the way the university operates on the eve of its 200th anniversary.

The developed game is dedicated to the revitalization of the main campus of the WUT, but it can be altered to suit a different area. It is important to highlight that the concept of the game is universal since it can be adapted with relative ease for use in another public space, such as the campus of any university or city district.

The developed source code in the Unity game engine is generic in nature, although of course adapting the game for another area would require developing 3D models of that space and adjusting the narrative. One of the concepts of the planned development of the Campus Changer geogame is also to increase the level of player interaction. Engagement in a more heated debate or interaction with virtual characters in the game world could result in greater involvement and a better understanding of various attitudes. Another intriguing idea for the development of the game is to allow players to enter the buildings and explore them virtually. This version of the game could also be used to learn about the university by potential visitors at WUT or high school students planning to study at the university.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The data collected during the research are available upon request by email. The installation file of the Campus Changer game can be downloaded from the site: https://drive.cenagis.edu.pl/s/CampusChanger

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

References

Abt, C. (1970). *Serious games*. University Press of America.

Ahlqvist, O., & Schlieder, C. (2018). Introducing geogames and geoplay: Characterizing an emerging research field. In O. Ahlqvist & C. Schlieder (Eds.), *Geogames and geoplay: Game-based approaches to the analysis of geo-information* (pp. 1–18). Springer.

Alavesa, P., Pakanen, M., Kukka, H., Pouke, M., & Ojala, T. (2017). Anarchy or order on the streets: Review based characterization of location based mobile games. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI Play '17)* (pp. 101–113). Association for Computing Machinery.

Alfrink, K. (2014). *Gamification: The future of learning?* Springer.

Andrade, B., Poplin, A., & de Sena, Í. S. (2020). Minecraft as a tool for engaging children in urban planning: A case study in Tirol Town, Brazil. *ISPRS International Journal of Geo-Information*, *9*(3), Article 170.

Arnab, S., Lim, T., Carvalho, M. B., Bellotti, F., de Freitas, S., Louchart, S., Suttie, N., Berta, R., & De Gloria, A. (2015). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology*, *46*(2), 391–411. https://doi.org/10.1111/bjet.12113

Białous, M. (2024). Społeczne wyobrażenia przyszłości. Wykorzystanie gry narracyjnej The Quiet Year jako narzędzia badawczego. *Przegląd Socjologiczny*, *73*(3), 77–97. https://doi.org/10.26485/PS/2024/73.3/4

Breuer, J., & Bente, G. (2010). Why so serious? On the relation of serious games and learning. *Eludamos. Journal for Computer Game Culture*, *4*(1), 7–24.

Canossa, A., Seif El-Nasr, M., & Drachen, A. (2013). Benefits of game analytics: Stakeholders, contexts and domains. In M. Seif El-Nasr, A. Drachen, & A. Canossa (Eds.), *Game analytics: Maximizing the value of player data* (pp. 41–52). Springer. https://doi.org/10.1007/978-1-4471-4769-5

Carvalho, M. B. (2017). *Serious games for learning: A model and a reference architecture for efficient game development* [Unpublished doctoral dissertation]. Eindhoven University of Technology. https://research.tue.nl/en/publications/serious-games-for-learning-a-model-and-a-reference-architecture-f

Carvalho, M. B., Bellotti, F., Berta, R., de Gloria, A., Sedano, C. I., Baalsrud Hauge, J., Hu, J., & Rauterberg, M. (2015). An activity theory-based model for serious games analysis and conceptual design. *Computers and Education*, *87*, 166–181.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9–15). ACM Press.

Djaouti, D., Alvarez, J., & Jessel, J.-P. (2011). Classifying serious games: The G/P/S model. In P. Felicia (Ed.), *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches* (pp. 118–136). IGI Global.

Duke, R. D. (1974). *Gaming: The future's language*. Sage.

Faure, L., Vendramin, P., & Schurmans, D. (2020). A situated approach to digital exclusion based on life courses. *Internet Policy Review*, *9*(2). https://doi.org/10.14763/2020.2.1475

Gazis, A., & Katsiri, E. (2024). E-polis: An innovative and fun way to gamify sociological research with an educational serious game—Game development middleware approach. *International Journal of Education and Information Technologies*, *18*, 20–32. https://doi.org/10.46300/9109.2024.18.3

Gee, J. P. (2007). *Good video games + good learning: Collected essays on video games, learning, and literacy* (2nd ed.). Peter Lang.

Główny Urząd Geodezji i Kartografii. (n.d.). *Modele 3D budynków*. https://www.geoportal.gov.pl/pl/dane/inne-dane/modele-3d-budynkow

Goodchild, M. F. (2007). Citizens as sensors: The role of volunteered geographic information in the geospatial revolution. *Geojournal*, *69*(3), 211–221. https://doi.org/10.1007/s10708-007-9111-y

Gordon, E., & Walter, S. (2019). Meaningful inefficiencies: Resisting the logic of technological efficiency in the design of civic systems. In R. Glas, S. Lammes, M. de Lange, J. Raessens, & I. de Vries (Eds.), *The playful citizen: Civic engagement in a mediatized culture* (pp. 310–334). Amsterdam University Press. https://doi.org/10.1515/9789048535200-019

Groundspeak. (2000). *Join the world's largest treasure hunt*. Geocaching. https://www.geocaching.com

Haklay, M. (2010). How good is volunteered geographical information? A comparative study of OpenStreetMap and Ordnance Survey datasets. *Environment and Planning B: Planning and Design*, *37*(4), 682–703. https://doi.org/10.1068/b35097

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *Proceedings of the 47th Hawaii International Conference on System Sciences* (pp. 3025–3034). IEEE. https://doi.org/10.1109/HICSS.2014.377

Hassan, L., & Hamari, J. (2020). Gameful civic engagement: A review of the literature on gamification of e-participation. *Government Information Quarterly*, *37*(3), Article 101461. https://doi.org/10.1016/j.giq.2020.101461

Howe, J. (2006, June 1). The rise of crowdsourcing. *Wired*. https://www.wired.com/2006/06/crowds

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). MDA: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI. Nineteenth National Conference of Artificial Intelligence* (pp. 1–5). Association for the Advancement of Artificial Intelligence. https://cdn.aaai.org/Workshops/2004/WS-04-04/WS04-04-001.pdf

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. Pfeiffer.

Key, M., & Kanaga, K. (2013). Understanding gamification: The importance of game mechanics in learning environments. *Journal of Educational Technology Systems*, *41*(2), 163–178.

Loh, C. S., Sheng, Y., & Ifenthaler, D. (2015). Serious games analytics: Theoretical framework. In C. S. Loh, Y. Sheng, & D. Ifenthaler (Eds.), *Serious games analytics. Methodologies for performance measurement, assessment, and improvement* (pp. 3–29). Springer.

Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J. K., Thaarup, R. K., Liebe, A., Wissner, M., Massink, R., & Kotterink, B. (2014). *Mapping smart cities in the EU*. European Parliament. https://www.europarl.europa.eu/thinktank/pl/document/IPOL-ITRE_ET(2014)507480

Martella, C., De Gennaro, C., & Fasiello, R. (2015). Volunteered geographic information and local development: A case study in the context of the Italian urban development. *Journal of Urban Technology*, *22*(2), 125–140.

Mat, H. S. (2014). Gamification: A strategy for motivating the workforce. *Journal of Business and Management*, *3*(2), 15–22.

McGonigal, J. (2011). *Reality is broken: Why games make us better and how they can change the world*. Penguin Press.

Montola, M., Stenros, J., & Waern, A. (2009). *Pervasive games: Theory and design*. Morgan Kaufmann.

Nicholson, S. (2012). *A user-centered theoretical framework for meaningful gamification*. Scott Nicholson. https://scottnicholson.com/pubs/meaningfulframework.pdf

Nintendo. (1985). *Super Mario Bros* [Video game]. Nintendo.

Nourian, P., Azadi, S., Bai, N., de Andrade, B., Zaid, N., Rezvani, S., & Pereira Roders, A. (2023). EquiCity game: A mathematical serious game for participatory design of spatial configurations. *arXiv*. https://doi.org/10.48550/arXiv.2309.13396

Olszewski, R., Pałka, P., & Turek, A. (2018). Solving "smart city" transport problems by designing carpooling gamification schemes with multi-agent systems: The case of the so-called "Mordor of Warsaw." *Sensors*, 18(1), Article 141. https://doi.org/10.3390/s18010141

Olszewski, R., & Wendland, A. (2021). Digital Agora—Knowledge acquisition from spatial databases, geoinformation society VGI and social media data. *Land Use Policy*, *109*, Article 105614. https://doi.org/10.1016/j.landusepol.2021.105614

Olszewski, R., & Wieszaczewska, A. (2016). Zastosowanie nowoczesnych technologii geoinformacyjnych w społecznej geopartycypacji. In D. Gotlib & R. Olszewski (Eds.), *Smart city: Informacja przestrzenna w zarządzaniu inteligentnym miastem* (pp. 69–84). PWN.

Pacmanhattan. (2004). *Pacmanhattan*. http://www.pacmanhattan.com

Paelke, V., Oppermann, L., Reimann, C. (2008). Mobile location-based gaming. In L. Meng, A. Zipf, & S. Winter (Eds.), *Map-based mobile services* (pp. 310–334). Springer. https://doi.org/10.1007/978-3-540-37110-6_15

Play the City. (n.d.). *Projects*. https://www.playthecity.eu/projects

Poplin, A., Andrade, B., & de Sena, Í. S. (2020). Geogames for change: Cocreating the future of cities with games. In D. Leorke & M. Owens (Eds.), *Games and play in the creative, smart and ecological city* (pp. 64–93). Routledge.

Poplin, A., Kerkhove, T., Reasoner, M., Roy, A., & Brown, N. (2017). Serious geogames for civic engagement in urban planning: Discussion based on four game prototypes. In C. Yamu, A. Poplin, O. Devisch, & G. De Roo (Eds.), *The virtual and the real in planning and urban design* (pp. 189–213). Routledge.

Popper, K. R. (1966). *The open society and its enemies* (5th ed., revised). Princeton University Press.

Szot, J. (2021). Gry wideo jako narzędzie sprawcze w partycypacji społecznej przy projektowaniu przestrzennym. *Zeszyty Naukowe Politechniki Poznańskiej. Architektura, Urbanistyka, Architektura Wnętrz*, *7*, 233–242. https://doi.org/10.21008/j.2658-2619.2021.7.18

The Fullbright Company. (2013). *Gone Home* [Video game]. Steam.

Uskov, V. L., & Sekar, S. (2015). Serious games and gamification in education. *Computer Applications in Engineering Education*, *23*(3), 701–704.

Zeng, Z., Tang, J., & Wang, T. (2017). Motivation mechanism of gamification in crowdsourcing projects. *International Journal of Crowd Science*, *1*(1), 71–82. https://doi.org/10.1108/IJCS-12-2016-0001

Zichermann, G. (2013). *Gamification by design: Implementing game mechanics in web and mobile apps*. O'Reilly Media.

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