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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.

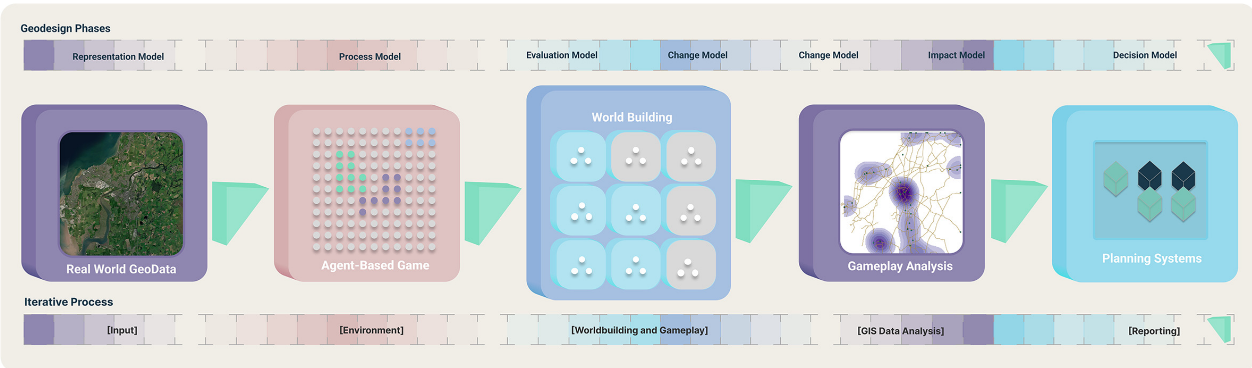

Figure 1. Geodesign framework and phases for research (top row); applied to the geogame CSI&II by Paradox Interactive and Colossal Order (middle row), an agent-based game connected to participatory planning, and exported gameplay results analysed in GIS and Rhino to formulate a report for real-world 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.

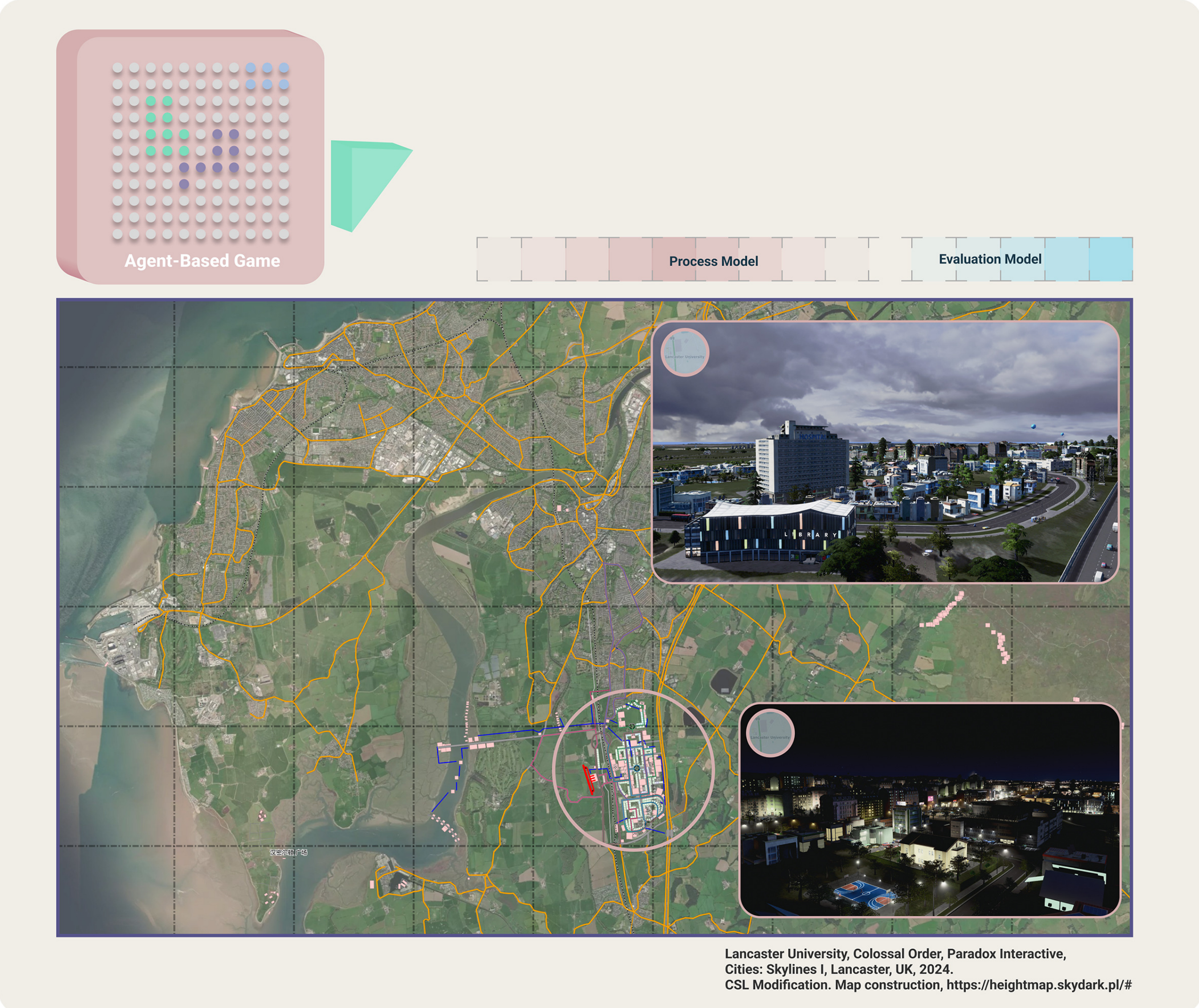

Figure 2. Example produced by the authors with CSL map modification (Lancaster University). Note: CSI map construction using the Heightmap tool and perspective images of gameplay and worldbuilding (https://heightmap.skydark.pl/)

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).

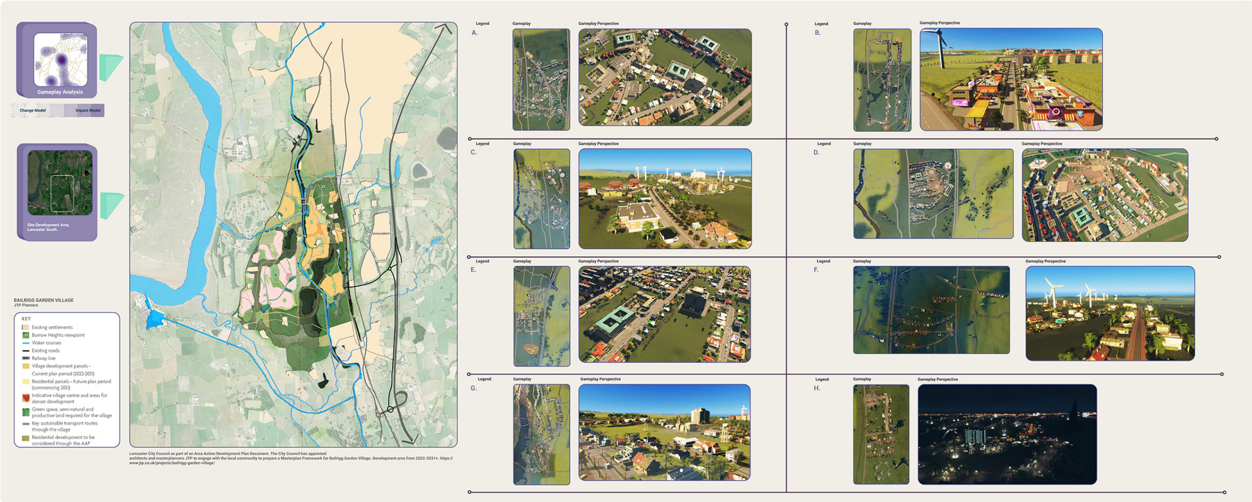

Figure 3. Juxtaposition of LCC, Local Development Plan, Bailrigg Garden Village, 5,000 mixed-tenure homes alongside green spaces and a mixed-use local centre. Notes: SPD Scheme by JTP Masterplanning Architects; Lancaster South Area Action Plan, UK, and Sample Study Game Images (A-H).

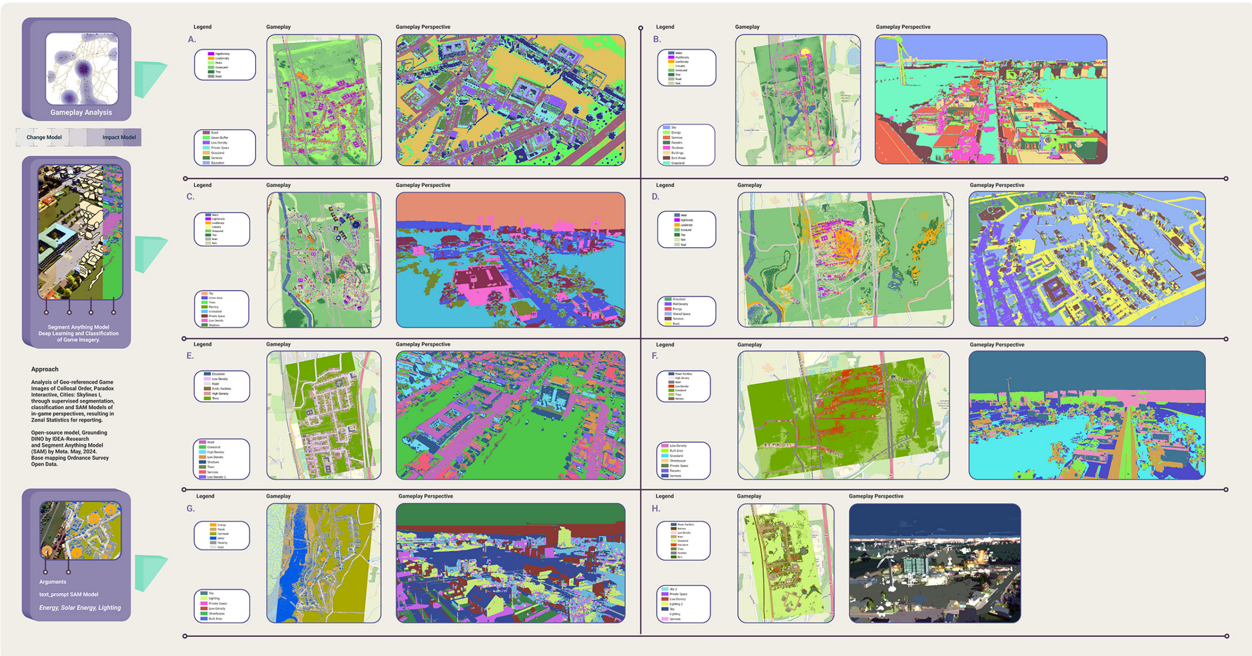

Figure 4. Game images generated using supervised (label A-F) and unsupervised classification (label G-H) and deep learning models (from CSI).

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

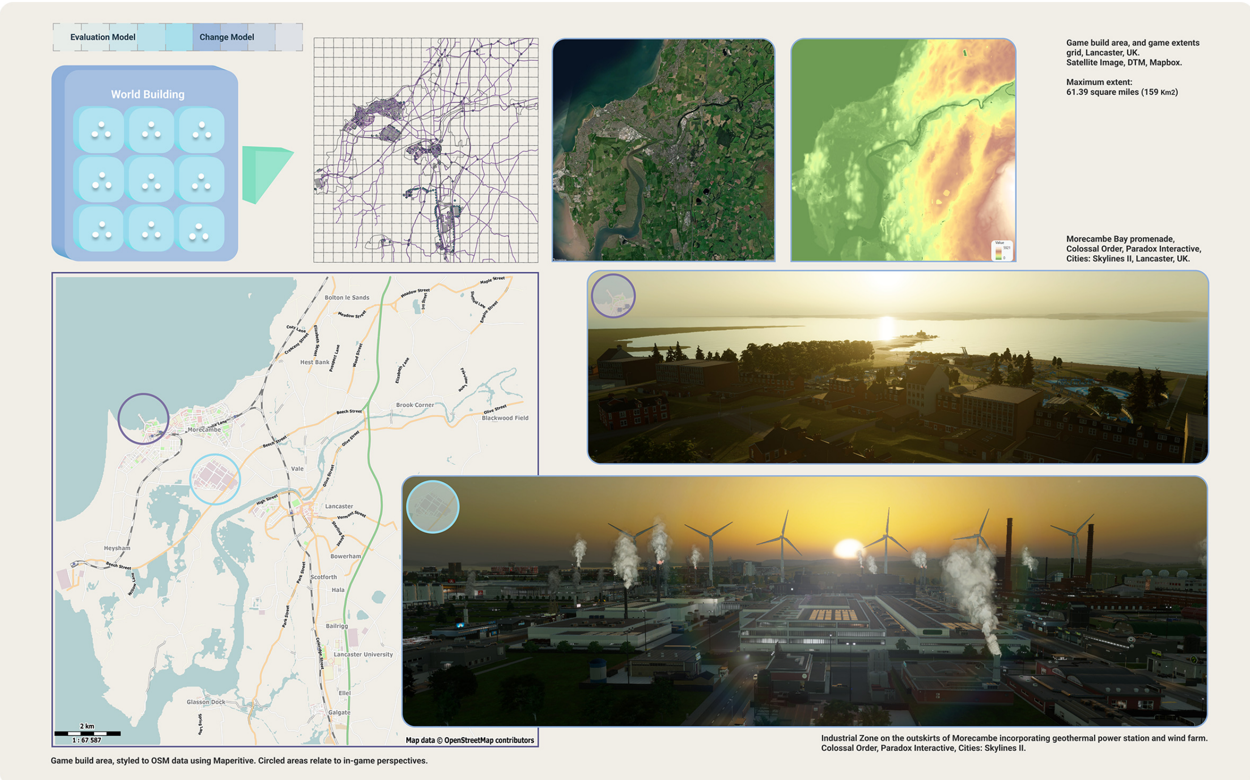

Figure 5. Example of transport, green space, commercial, residential, and industrial zones from a "worldbuild" of Morecambe Bay, Lancashire, North West UK. Notes: Map of gameplay created in CSII using the OSM Export mod, cartographically styled to an OSM layer via *Maperitive*; Includes in-game screenshots 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,

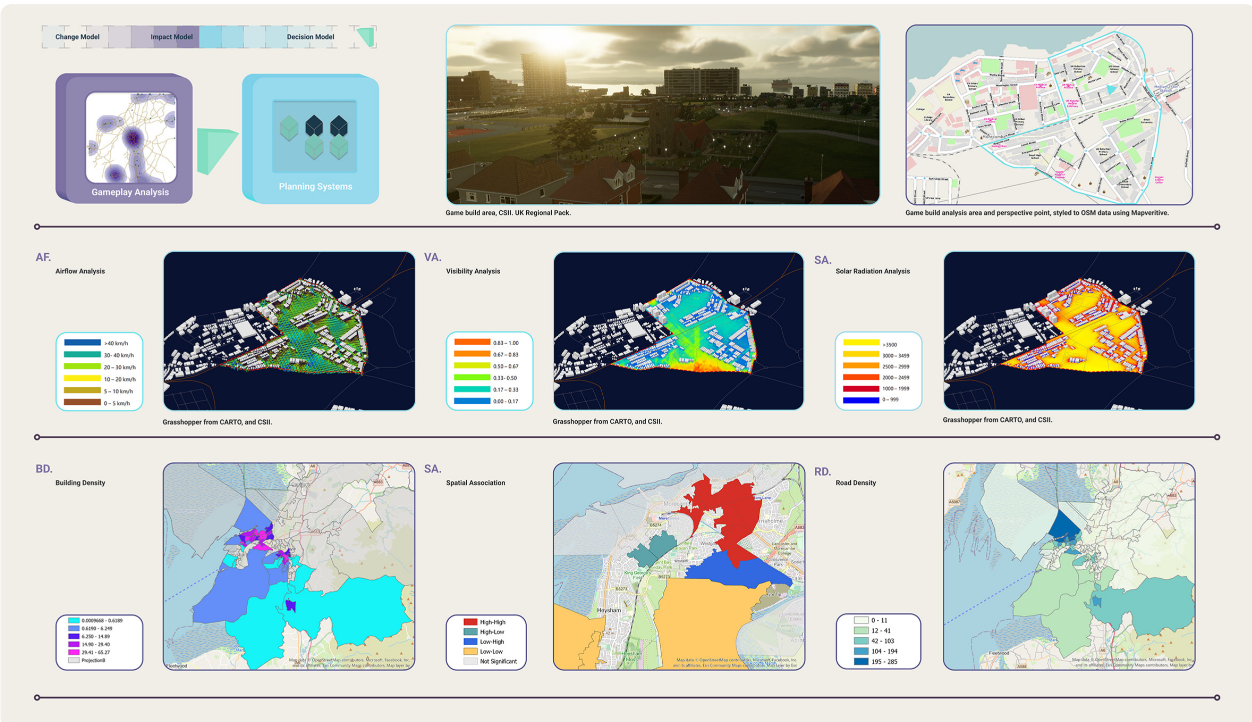

Figure 6. Analysis of gameplay using ArcGIS Pro, QGIS, and Rhino/Grasshopper.

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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Conflict of Interests

The authors declare no conflict of interests.

LLMs Disclosure

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).

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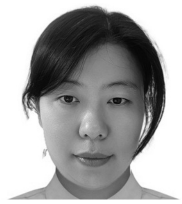

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