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MODELLING URBAN SPACES WITH CUBES: BUILDING ANALOGUE SERIOUS GAMES FOR COLLABORATIVE PLANNING OVER MAPS

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Abstract

Games are popular as ever. Professionals from every field are trying to build their serious games, combining engaging playability with simulation and learning outcomes. Urban planning is no exception. However, materializing these games is no easy task. We propose a serious game development process to combine modern board game mechanisms with realistic urban maps, profiting from the simplicity, flexibility, and collaboration dynamics analogue games provide. For this, we tested two collaborative games with architecture students. Although different, the games have similar core mechanical and economic systems, modelling urban zones with hexagons and squares. The experience revealed some pitfalls to avoid in game-based planning practice and helped to define a development process for serious games for urban planning.

Keywords: Board games; Collaborative Planning; Game Design; Serious Games; Urban Planning.

1. Introduction

Serious games are a growing trend among urban planners (Dodig & Groat, 2019; Sousa et al., 2022b; Tan, 2017). The literature highlights the advantages of using games to support spatial and urban planning processes, mostly as a teaching and public engagement tool. However, no guides to help develop these games are available (Ampatzidou et al., 2018; Ampatzidou & Gugerell, 2019b, 2019a; Constantinescu et al., 2017, 2020). How to start? Analogue or digital games?

Both analogue and digital can deliver games to achieve purposes, depending on how the game is developed and simulates the "serious" issues (Dörner et al., 2016; Michael & Chen, 2005). The potential of digital games to provide massive and detailed simulation is well known (Wiggins, 2016). However, Analogue games have the advantage of being less expensive to develop (Sousa et al., 2022a) and support collaborative processes directly (Tan, 2016; Zagal et al., 2006). Using modern board game design elements can increase the potential of these serious games (Sousa, 2020a, 2021a, 2020b). Our goal is to test what game elements and design techniques planners can use in their games. Finding a simple process to support serious game development for urban planning would be a relevant first approach.

In this paper, we will explore a method of using grids to simulate spatial urban units (divisions) and cubes to represent land-uses and built densities, facilities, and infrastructures. For this purpose, we developed two games (G1 and G2) and tested them with different architecture master students (from two universities in Portugal). Each game simulated a distinct urban space. Both games were collaborative, where players should manage the game economy to achieve a sustainable urban system, proposing new land use and balances and transport systems. We tested two ways to model urban space (hexagons in G1 and squares in G2) (Adams, 2014). One game (G1) was more complex and demanded higher facilitation, while the other was simpler and playable by several simultaneous groups (G2). We tested if modern board game components and mechanisms, combined with urban maps, could deliver serious games for urban planning. By describing the development process, implementation, evaluation and changes from game to game, we hope our method can be replicable and contribute to the serious game research field.

The games delivered playable experiences, although we noticed that excessive focus on the game economy and progress can affect the simulation side (the serious side of the game) (Engelstein, 2019; Wouters et al., 2013). After discussing and analysing available data, we present a method to introduce a development process of serious games for urban planning.

2. Modern Board games and cities

In the last four years, several publications stated that board games were in their golden age (Konieczny, 2019), a worldwide hobby for millions of players (Booth, 2021). Even though the Covid 19 pandemic affected the boardgame industry and culture, the associated activities and enthusiasm are in recovery. *Essen Spiel* 2022 (www.spiel-messe.com) had 147.000 visitors, recovering since the 2020 cancellation. In 2021 the attendants were half of the 2019 edition (209.000). The 2022 edition had the same attendants as in 2011. This type of data is a mere example, as many other conventions, gatherings and fairs showed the same effects. In Portugal, a similar situation happened at the biggest national board game convention, *Leiriacon*. Despite this apparent success and popularity, we are talking about a niche activity. Modern board gaming is still an activity done by hobbyists (Rogerson & Gibbs, 2018; Woods, 2012).

These modern board games (MBGs) (including tabletop narrative, miniatures, card, and dice games) are different from mass-market games. MBGs try to deliver different experiences to players that wish to spend more time and money playing them than traditional board games. Defining MBGs is no easy task, but we can state that they are characterized by their mechanical and graphical design, aiming for gamers assuming a hobby (Sousa & Bernardo, 2019; Woods, 2012). MBGs foster player agency, narrative development and innovative game mechanisms (Sousa, Oliveira, & Zagalo, 2021). All these traits allow MBGs to deliver better simulations and deep experiences (e.g., strategic, challenging systems, interactive, immersive, and rich narratives, etc.). However, when players state what they enjoy the most in MBGs besides the material side (Rogerson et al., 2016), face-to-face social interactions are among the top reasons (Booth, 2020; Kosa & Spronck, 2019; Woods, 2012).

Another curiosity of MBGs is that a considerable number of successful games use the names of real cities. We consider the game successful among the hobby community if it ranks high on *Board Game Geek* (BGG) website (www.boardgamegeek.com). In the top 100 games, we find ten games related to cities (*Brass: Birmingham; Órleans; Maracaibo; Le Havre, Lisboa; Fields of Arle; Teotihuacan: City of Gods; Caylus; Troyes*), which is 10%. And, considering the same top 100, 12 are categorized in BGG with the city building (*7 Wonders Duel; Everdell; Puerto Rico; Underwater Cities; On Mars; Le Havre; Lisboa; 7 Wonders; Lords of Waterdeep; Architects of the West Kingdom; Keyflower; Caylus*) making it 12%, even higher than the names with real cities. These numbers mean that a relevant number of MBGs are approaching cities, in some way, trying to simulate some of their traits. We can speculate that players like cities and city-like themes fit the board game format.

3. Urban Planning and board games

There is a trend in spatial and urban planning to use games for several purposes as serious games (Sousa et al., 2022b). The majority of these games are digital, although there are some examples of analogue games (Dodig & Groat, 2019; Tan, 2017), some even depart from MBGs inspirations (Mewborne & Mitchell, 2019; Sousa, 2020a). Although digital games allow deep and interactive simulations and can reach enormous quantities of users, analogue games have considerable advantages for spatial and urban planning. These advantages became notorious when considering collaborative planning (Innes & Booher, 1999a, 1999b, 2018) and addressing planning as a co-creative process (Champlin et al., 2021; Constantinescu et al., 2017). Tan (2016) realized that the materiality of analogue games helped participants visualize and interact with each other in a collective decision-making urban planning process. These phenomena have been studied in detail for ortho games (Elias et al., 2012). Zagal et al. (2006) defined any analogue game as a collaborative experience due to the social contract of playing a multiplayer game and the constant requirements to activate the game system. Analogue games lack automation and ways to enforce the rules. Xu et al. (2011) found that the chores necessary to activate the game system can be engaging. Zhang et al. (2012) reinforced the collaborative dimension of board games, highlighting the need for the players to learn the game together.

One of the most evident strengths of using serious games for spatial and urban planning is the establishment of collaborative dynamics (Sousa et al., 2022b). Collaborative and co-creation approaches in spatial and urban planning are ways to address complexity. We define complexity as those problems where there are no clear or optimal solutions to all requirements (Portugali, 2016), which in the urban planning processes results from the conflicts of interests and the variety of urban functions. Using game-based planning processes where stakeholders can interact, learn, and test solutions that can support negotiation is something planners seek (Constantinescu et al., 2020; Eppler & Pfister, 2010; Hollmann et al., 2015; Legacy, 2017).

4. Methodology

To support our development process proposal, we tested games with architecture master students and collected quantitative and qualitative data about the players' experiences and perceptions. Two groups of students (from different universities) played two distinct urban planning game-based approaches. The games were created with similar game design principles and approached the theme of urban renewal. Both games defined a grid over a real urban map, allowing users to move coloured cubes representing the built environment and activities. The First game (G1) helped to set new characteristics and improve the second game (G2).

The next section explains the methodology for developing the games, collecting data and conducting the facilitation and debriefing of the serious game sessions.

4.1 Game design principles

Both games (G1 & G2) aimed to explore how to represent an urban reality in a serious game for urban planning purposes and how the players' decisions affected urban sustainability for a given territory. The objective was to achieve the best result possible (score), being a collaborative game experience based on choices.

G1 had a simplistic representation of the urban zone at stake, based on a hexagonal grid over a satellite map view. The G1 economy was complex, with automatic and chaining effects resulting from players' decisions. The scoring was also dense, considering the sustainability level of the urban zones based on the land uses and transport system. G1 is a turn-based game.

G2 had a detailed representation of the urban zone. Players could model it, adding pieces (urban elements) over an orthogonal grid. The G2 scoring system was simpler than G1, representing the balancing of the land uses and buildings for purposes of the score and representing urban sustainability. G2 has no specific order or defined turns.

4.2 Data collection instruments

In the two game sessions, the participants filled out a questionnaire, a new instrument created for the research purpose but based on previous similar experiments (Sousa, 2021b, 2020b; Sousa & Dias, 2020). Players selected answers through Likert scales from 1 (low) to 7 (high) before and after the play session and debriefing. We followed Mayer et al. (2014) recommendations to evaluate serious games, considering the players' experiences, knowledge and changes occurring during gameplay. Questions appearing in the pre-tests and post-test for direct comparison, organized by groups of questions (Q#):

- Games and collaboration (Q1):
  - What's the importance of collaborative urban planning?
  - The potential of innovation and ludic approaches for urban planning?
  - Can games be urban planning tools?
  - Can analogue games be better than digital games?
- How do you feel right now? (Q2):
  - Motivation/excitement
  - Anxiety/stress
  - Energy
  - Attention/focus
  - Empathy with the group
  - Knowledge about the zone at stake
  - Urban planning knowledge

Q1 aims to measure the students' perceptions of serious games and their uses for urban planning. Q2 collects data about the student's self-awareness and relates to the *Big Five Personality Traits*, as tested in other serious and ortho games (Heckman & Kautz, 2012; Sousa, 2021b; Sousa, Oliveira, Cardoso, et al., 2021). Q2 also considers the individual perception players had about the knowledge of urban planning and the urban territory at stake.

To evaluate the playability, engagement, and ability of the games to simulate an urban regeneration process, we introduce the following question in the post-test:

- Games experience (Q3):
    - Game complexity
    - Simulation detail?
    - Level of collaboration?

In the post-test, participants could write free comments. This data can highlight specific information players wished to share about the sessions that might be included in the defined questions.

All participants signed a declaration that they authorized data collection for research purposes.

4.3 Game facilitation

The sessions were conducted by the game designer, acting as the session facilitator. The facilitator explained the rules to the players, conducted a debriefing with students and collected data through observation and questionnaires. Interacting with students allowed the facilitator to do the debriefing stage, highlighting the connection between gameplay and the simulation issues (Crookall, 2010). As in any serious game, facilitators must teach the games and provoke participants to reflect on the experiences after the games. This requirement is even more important in analogue experiences due to the need to enforce the rules and analyse emergent behaviour (Sousa & Dias, 2020).

5. The case studies

This section presents the urban zones at stake, the game development, and the play sessions. First, we introduce the urban background of each case study and then how the developed game approaches it. Finally, the section presents the gameplay results per session.

5.1 Brief presentation of the two urban zones

The game sessions' purpose was to test ways to model an urban reality into a serious board game that could be a tool for learning about urban planning and testing planning ideas for realistic cases. Both games were played with architecture students (from two different schools) and simulated two different urban zones for urban renewal. However, each game modelled each urban zone differently and implemented some distinct game mechanisms but maintained the cost to add/remove pieces mechanics (resulting from combinations of game mechanisms). Game structure and complexity, the scale of each urban zone, and the length of each game were different. Still, both games were collaborative. Teams of players tried to achieve high scores during challenging urban simulations, balancing land uses and urban functions to achieve sustainability.

G1 was set for the Barreiro municipality riverside, an industrial city near Lisbon in the south River Tagus Bay. G2 was the zone of Paranhos, part of Oporto city, near the inner ring road and the Universities and Hospital facilities. Both zones have mixed land uses, requiring intervention to balance the demand for housing, transport, and facilities for daily uses. G1 zone was the Barreiro and Lavrario freguesias, with a population of 21.877 inhabitants, according to the census of 2011, and 7,74 km2. G2 was set in a part of the freguesia of Paranhos, in Oporto. In 2011, the total population of Paranhos was 44.298 inhabitants, living in an area of 7,17 km2. Freguesia(s) is the smallest political territorial administrative area in Portugal, a subdivision of a municipality.

5.2 Game development

5.2.1 Barreiro Case Study – Game 1

The following subsections describe the games' development and design options. These are standard game pieces common among modern board games, mostly in eurogames (Woods, 2012). They are available in various colours and can be acquired on websites like *Spiel Material* (www.spielematerial.de). The only exception is the *Agricola* (Rosenberg, 2007) forest tile which was taken from a popular modern board game. Using pieces from other games is common in game development and prototyping, reducing the time and resources to have functional, symbolic and playable game pieces for playtesting (Engelstein, 2020). The pieces represent urban buildings and the transport system, but also parts to track game progression, resources, income, and scoring (on the maps and the support tables).

5.2.2 Barreiro e Lavrario Case Study – Game 1 (G1)

In the first game (G1), we modelled the urban spatial units by using transparent paper with a printed hexagonal grid over a map (Figure 1). Each hexagon centre was 300 meters distant from each other to approach a map on the scale of 1:5.000 and form a playable area to place game pieces. These proportions represent a medium-scale planning process, fit, for example, for zoning of an urban master plan (Portuguese planning system).

Table 1
Sets of game pieces used in G1 and G2

Game pieces	Name	Base dimensions	Game where it was used and purpose	
			G1	G2
	Big House	20x20 mm	-	Buildings /Land uses
	Small house	10x15 mm	-	Buildings /Land uses
	City	10x20 mm	-	Buildings /Land uses
	Big Cube	20x20 mm	Buildings /Land uses	Buildings /Land uses
	Small cube	10x10mm	Tracking/Scoring	Buildings /Land uses
	Slab	20x20mm	-	Buildings /Land uses
	Stick	5x20mm	Transport system	Buildings /Land uses
	Cylinder	8x12mm	-	Tracking/Scoring
	Dice	16x16 mm	Tracking/Scoring	-
	Agricola forest tile	30x30mm	Buildings /Land uses	-

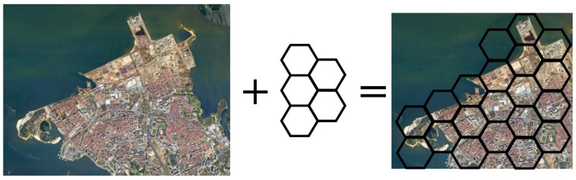


Fig. 1
Generating process of a playable grid by overlaying a transparent hexagonal grid over a standard urban map.

Players add pieces to the map in turn order (player's move). After each move, the game state could change and trigger the automatic appearance of new pieces (automatic urban growth). Some combinations of pieces generate instant income, and others generate income after a round (after all players have done one move/turn). The game had a duration of five rounds. Figure 2 shows the support tables for the game, expressing the meaning of each game piece, costs, and combined effects (income, negative impact and reduction).

In a general summary, players placed cubes representing land uses/buildings (housing, commerce/services, and industry), deciding how to reformulate the spatial unit (hexagons) dividing the urban zone. The green pieces (housing) cost nothing. However, one commerce/services (white cubes) and industry (Yellow cubes) needed three housing pieces (Green cubes) to be available. From the income perspective, each time players connect a white cube to a green they receive 1M€. The money was collective, available for any player to use. Yellow cubes also generated instant income when connected to white cubes. Because each hexagon could only have a type of cube (and a maximum of three cubes), the game demanded the player to use transport infrastructures to connect the hexagons. Adjacent hexagons were automatically connected. Players could place transport pieces to connect other hexagons, forming a transport line (sticks of the same colour). We defined four available transport infrastructures (red, blue, yellow, and black stick

	Game Pieces & limits	Cost	Instant Income	Negative Impact	Negative impact reduction	Cycle Income	Cycle impact reduction
Housing	| no limit	0	0	1x =	0	1/3 =1M€	1/3x - =
Commerce/services	| 1/3=	0	1M€ x	½ x =	0	1/2 =1M€	
Industry	| 1/3=	0	1M€ x	1 x =	0	1 =1M€	
Transport infrastructures	Max. length = 6	1x = 1M€	0	0	1 x =	1 x = 1M€ (max 3)	
Green spaces /Heritage sites	Max. 12	3M€	0	0	3	0	
Schools/Education	1/3=	9M€	0	0	9	0	
Police / Fire station		9M€	0	0	9	0	
Cultural /Sport facilities		6M€	0	0	6	0	
Health		12M€	0	0	12	0	

Fig. 2
Game 1 support table for players and the facilitator.

pieces). Players placed the transport sticks, forming transport lines (different colours), by connecting the edges of the hexagons. Dice, with the same colours as the cubes, tracked the connections and income over the respective cubes. The income limit per hexagon was 6, related to the maximum number of dice pips (D6) and the number of edges of the hexagons. The number of pieces for G1 was irrelevant since the game economy restrained how many pieces players could use.

Figure 2 also shows the negative urban impacts resulting from players' decisions. Small grey cubes represent these impacts. Each time a player adds a building/infrastructure piece (instant effect) and after each round/income stage (game cycle/feedback loop): new grey cubes appear or disappear. For every three hexagons with pieces, new grey cubes appear. However, green/heritage sites reduce one of these cubes per cycle (round). Players could also acquire public facilities to reduce the grey cubes (schools, police and fire stations, cultural and sports facilities, or health infrastructures).

From a game mechanical perspective, we combined several board game mechanisms (Engelstein & Shalev, 2019). Tile placement, staking, and connections were the core ones because each piece changed the game state (map) and generated income according to the set collection and connection mechanisms (e.g., white and yellow cubes near green ones: adjacent or connected by sticks to form transport networks). The game also used indirect tech/tracks to unlock new pieces and sources of income to fund public facilities (abstract tracks representing the rules in figure 2). The turn order mechanisms and the income cycles are necessary to deliver a sense of progression and establish the chains of actions.

From the standpoint of metaphorical narrative representation, players were the urban planners, deciding where to densify housing (occupying land space and staking game components) and balancing it with commerce/services and industry, which generated income. When players added new constructions, they produced negative impacts as effects from over-densification (disasters, social inequality, crime, pollution, health issues and so on). The colours of the sticks represented the different transport modes of the transport system, which reduced the time to travel in the city, making distant places near. The limits of green/heritage sites represent the land limitations for these uses. After the five rounds, the urban zone generated money/income (M€) according to players' decisions. These flows represented the balance of costs and income of the adopted choices in the plan.

Because G1 was collaborative, players must negotiate their moves even more when spending collective money. Generating income and reducing the negative impacts depends upon previous decisions (instant and cycle/feedback effects). The complexity of the game economy in G1 demanded constant support from the facilitator. Players could easily forget to trigger income of negative effects, like respecting the limits to place pieces.

5.2.3Paranhos Case Study – Game 2

For the second game (G2), we adopted an orthogonal grid. We considered an approximation to the scale 1:1.500, where 1cm of a square (1cm edge cubes) represents edges of 15m in reality. This scale is suited for a small urbanization planning process (Detailed Urbanization plan according to the Portuguese planning system). The map of Paranhos urban zone was adapted and modified to fit the orthogonal model and divided into sub-zones (Z#). The existing road system defined the boundaries of the sub-zones (Figure 3), requiring considerable adaptation to fit the orthogonal model. The playable map represented (approximately) 10-20% of the total area and population of Paranhos.

Fig. 3
Satellite map adapted to an orthogonal grid and the road system (thick lines).

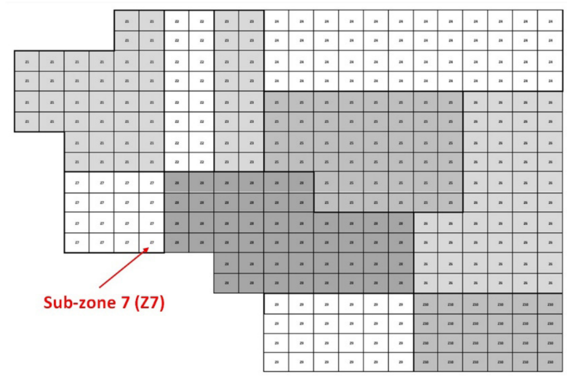


Fig. 4
Removing excessive graphical information for the game model (G1) and adding sub-zone information (numbers and shading different zones). Example of sub-zone 1 (red).

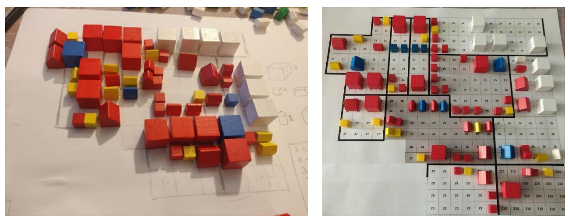


Fig. 5/ 6
First game (G1) development iteration (Left), and final possible model and available pieces for players to use (Right).

Then the playable map was detailed, removing the satellite view to create a cleaner surface to place the game pieces, avoiding excessive graphical information. Figure 4 shows the map ready for the game (G2), introducing the names of the sub-urban zones (shaded differently).

In G2, we modelled the built fabric since we are working on a smaller scale than in G1. Game pieces from Table 1 allowed this modelling. The definition of the orthogonal map resulted from several experimentation steps, defining the available pieces and possible spaces to place them on the map. Figure 5 shows the hand-made draft of the game map, and Figure 6 shows the final map. Testing the number of pieces required us to build several possible models as part of game testing. Game pieces should be enough to model an approximation of reality (urban territory). But having fewer pieces demanded players decide what was more relevant to represent. This limitation is a common game design technique in MBGs (Woods, 2012).

In the first step of G2, players should distribute available game pieces according to the existing urban density and land uses (Figure 5). We set this quantity of available game pieces by experimenting with several possibilities (Figure 5 and 6). This first step ends by tracking the quantity of Housing, Commerce/services, Public facilities, and Green spaces in each sub-zone (Figure 4). We added coloured meeples for players to track this (each meeple had the colour of the land use over the black and with tables of Figure 7). Figure 8 details how the meeples track (registered) each land use in an urban sub-zone of the Sub-zones Tracking Board. During G1, it was

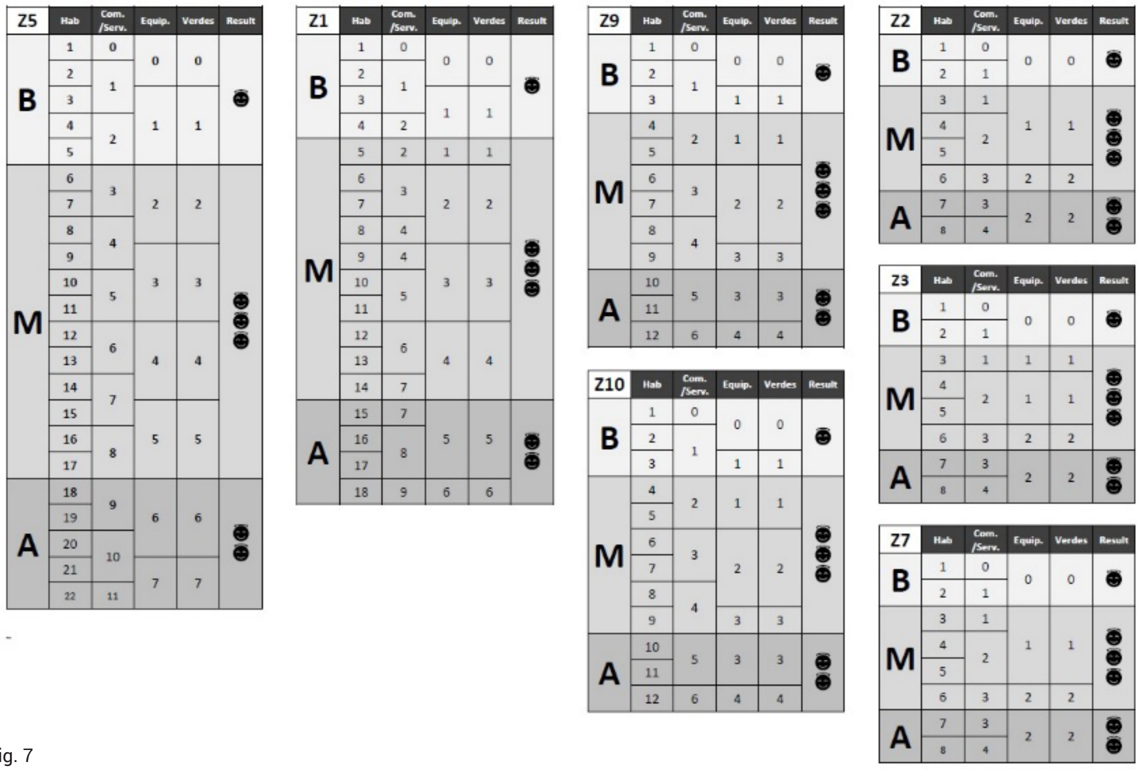


Fig. 7
Tracks to record the level of each land use for each sub urban zone in G2 (Sub Zones Tracking Board).

evident that having a formal tracking system would help the players make decisions and read the game state.

The second step of G2 was balancing the land uses according to the size of each sub-zone to obtain happy faces (scoring system in Figure 7). The purpose was to get the highest quantity of happy faces in the Figure 6 tracks while spending the least money. To move tracks, players could add buildings for a defined cost (Figure 8). This scoring system was an additional motivation for the game. While each group of players (team per table) were doing a collaborative dynamic, they competed with the other tables for the best score. In the second step of the game, together, players chose what pieces to remove or add to the map without a defined turn order.

Figure 8 shows the general rules for G2 step 2: the cost per piece (and equivalent cubes of each game piece) and several tracking tables to record the number of moves, total costs, scoring (green happy faces), and overall population the urban zone could maintain (total of tracks for housing in each sub-zone). The table on the left (Figure 8) records the model from step 1 (players write the number in the grey line), and the meeples allow players to have a general perspective of what changed in all sub-zones. Figure 9 exemplifies how the pieces are placed in the General Tracking Board (Figure 8) and how to do all these previous tracking processes. No Green spaces were available for players to use in step 1. This exception is why this track starts at 0.

Housing	Com/ services	Public Facilities	Green Spaces
+14	+14	+14	+24
+13	+13	+13	+23
+12	+12	+12	+22
+11	+11	+11	+21
+10	+10	+10	+20
+9	+9	+9	+19
+8	+8	+8	+18
+7	+7	+7	+17
+6	+6	+6	+16
+5	+5	+5	+15
+4	+4	+4	+14
+3	+3	+3	+13
+2	+2	+2	+12
+1	+1	+1	+11
0 =	0=	0=	+10
-1	-1	-1	+9
-2	-2	-2	+8
-3	-3	-3	+7
-4	-4	-4	+6
-5	-5	-5	+5
-6	-6	-6	+4
-7	-7	-7	+3
-8	-8	-8	+2
-9	-9	-9	+1
-10	-10	-10	0

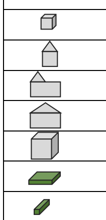
Costs			Moves					
0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9

Population		
0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9

General Information

Housing
Commerce / Services
Public Facilities
University Facilities

- **Pieces with triangular tops cannot support more pieces above**
- **Adding/removing one piece counts as a move**
- **Cost to add = cost to remove**
- Mazimum cubes por square **2 x**



Game Piece	Equivalent cubes	Cost (add/remove)
	1	1
	1	1
	2	2
	3	3
	4	4
	4	3
	2	2

Fig. 8
Tables to track the overall game stage for G2 and highlight the rules of play, The General Tracking Board for game G2.

Both boards (Figures 6 and 7) should provide information to support the game state during play. For step 2, players had the following quantity of game pieces (Figure 9): 4 big blue houses; 4 big yellow houses; 3 big red cubes; 4 small blue cubes; 4 small yellow cubes; 8 small red cubes; 6 green slabs; 6 green sticks. The equivalent cubes dimension associated with the pieces were: 20 housing (red); 10 commerce/services (yellow); 10 public facilities (blue); 18 equivalent cubes for green spaces. This relation between game pieces and equivalent cube values was the technique to control the game economy (costs and scoring) and the number of options associated with the available spaces on the map board (urban density and 3D volumes). In Figure 10, we present a view of the scoring board and the pieces to track each land use (with coloured meeples), the costs, moves (changes in the map) and happy faces with cylinders.

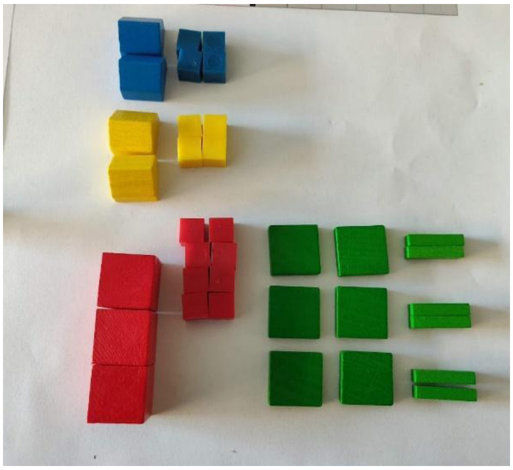


Fig. 9/ 10
Available pieces for step 2 and the game pieces used to track the board from Figure 7.

To obtain happy faces (Figure 10), players must balance the tracks in the Sub-zone Tracking Board (Figure 6). Each track, for each sub-zone, is divided into Low (L), Medium (M) and High (H) densities. However, players could only score the respective happy faces if all the meeples (the tracking pieces) were in the same density level (L, M or H). For example, one possible way for Z1 to score the three happy faces (Figure 11): housing at 11, Commerce/Services at 4, and Public Facilities and Green spaces at 3. Figure X exemplifies this, having the coloured meeples (same colours as for the game pieces on the map) to track each level for each zone.

As in G1, for G2, we combined several modern board game mechanisms (Engelstein & Shalev, 2019). Here the tile placement and pilling (staking) were fundamental to represent the built fabric and densities, but as an auxiliary mechanism to balance the tracks mechanisms for each sub-zone (Figure 7). Combining the levels of housing, commerce/services, public facilities, and green spaces was a set collection mechanism. To define the urban model in step 1, we used a combination of the action point mechanism and area control/majority adaptation. Players had a limited quantity of pieces to place in all the sub-zones. Each sub-zones could not have more equivalent cubes (Bottom right table for equivalent cubes in Figure 8) per sub-zone than the double of available small squares in the grid (each sub-zone has a different set of small squares, see Figure 4).

From a thematic and metaphorical perspective, the players should place pieces (step 1) to represent how they interpreted (modelled) the urban space, buildings, and land uses/densities. The zone has several universities and faculties buildings (white cubes). Setting the universities as different land uses for step 1 was a design choice to help players identify this particularity of the urban zone. Players could place blue/yellow cubes (public facilities or commerce/services) to manipulate the tracks. The spent money represented the public investment needed to implement the plan (the result of all players' decisions).

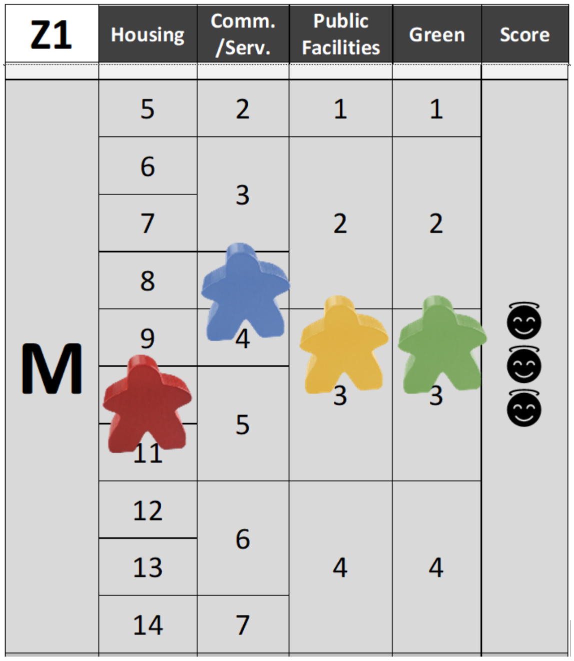


Fig. 11
An example of the maximum scoring (3 happy faces) for Z1 (extract from 6).

Each sub-zone of the play map is divided into small squares (spatial units), defining the maximum density, measured as the double of the equivalent cubes (Bottom right table for equivalent cubes in Figure 8). These equivalent cubes were necessary to set the game economy and represent game pieces of different volumes and shapes (using available pieces from Figure 5 and 6) for the students to express their architectural and aesthetic perceptions (3D). This design technique defined the urban density limits (e.g., Z1 has 36 squares, so the maximum equivalent cubes it can get is 72 for all urban and land uses). For scoring, we set the maximum score of three happy faces for the medium density (M in Figure 7). Housing was set to the maximum of half the quantity of squares (e.g., because Z2 had 16 squares, the housing maximum was 8), representing that half of the land could be used for habitational purposes. Commerce/services were set to be half of the housing, public facilities, and green spaces to be a third. We rounded these values and proportions, building progression scales in the sub-zone tracking boards (Figure 7). The aim was to represent the limits in urban plans. These relations were inspired by the G1 economy and a practical way to implement game rules that could simulate the urban planning zoning process (housing level demand a related level of commerce, services, public facilities, and green spaces, depending on the applicable legislation). We adopted the medium density as the preferable density (3 happy faces), high density to score the second best (two happy faces), and low density to score the worst (1 happy face). If players did not balance the tracks (all meeples in the same density level, see Figure 11), they would not score any happy face for that sub-zone, regardless of the density level of the land uses and urban functions. Failing to set the meeples in the same density level was the game challenge to simulate urban sustainability. This design option enforced the medium density (positive feedback) while allowing high density and avoiding low density (negative feedback) because it is an urban zone (part of the city of Oporto) with high demand for housing.

G2 was also collaborative, despite the competition between teams. Players discussed how to represent the urban zone in step 1, and then, in step 2, they discussed and decided how to score better. Because there was no rigid turn structure, players could define tasks to move pieces and track changes while discussing options.

5.3 Describing the play sessions

Next, we present some of the collected graphical data. In G1, the setup, endgame, and the results after each round. Because G1 and G2 were conducted differently (Table 2), the recording method has also different. For game G2 we only have pictures from step 1, step 2, and the endgame. G1 was played by two teams, one after another, with the permanent

Fig. 12
Table layout for G1.

support of the facilitator. G2 was played by three tables at the same time and same room. In G2, the facilitator passed by the tables regularly, answering questions and providing feedback according to the game state at each table.

5.3.1 Game session 1 (G1)

G1 required a table to keep the game pieces, the map, a computer showing the support costs and effects of the game pieces, and a small whiteboard to track the game state (Figure 12). The game pieces were coloured cubes (2cm). To create the facilities, we used tape to connect several cubes, forming the polyomino shapes of Figure 2.

Figures 13 (team 1) and 14 (team 2) show the state of the game after each round and the endgame (whiteboard), highlighting the following:

Fig. 13
Game (G1) progress in team 1.

Fig. 14
Game (G1) progress in team 2.

- The Number of occupied hexagons.
- Housing (green), commerce/services (white), Industries (yellow) and green/heritage spaces (tile from the board game *Agricola*).
- Negative impacts (Grey cubes on the map).
- The distance length of the transport lines (sticks from the *Catan* board game).
- Unspent money (coins from the *Villager's* board game).
- Final scoring (according to figure 1).

During the game (G1), it was necessary to find a solution to track the capacity of the facilities and green/heritage sites to absorb negative impacts (grey cubes). Players in both sessions piled them over the facilities' polyominos, green/heritage sites, and roads (the pieces that could remove the grey cubes).

5.3.2 Game session 2 (G2)

G2 was played in three tables simultaneously (demanding three copies of the game). Players could discuss among themselves and see what others were doing. The layout of the room affected the experience. The table layout (tables near each other) and the players' freedom of movement reinforced the collaboration of team members and the competition between teams (Figures 15 and 16).

The following figures represent the game result from step 1 (left): where players modelled the urban buildings of Paranhos. The challenge to represent the urban reality led to vivid discussions and sharing knowledge about those urban spaces: where to locate the higher densities (big cubes of 20mm per edge) and the respective land uses. Step 2 also appears side by side (right picture), showing the endgame in each


Fig. 15/ 16
Layout of the room, the three tables and players interacting with the game and themselves.

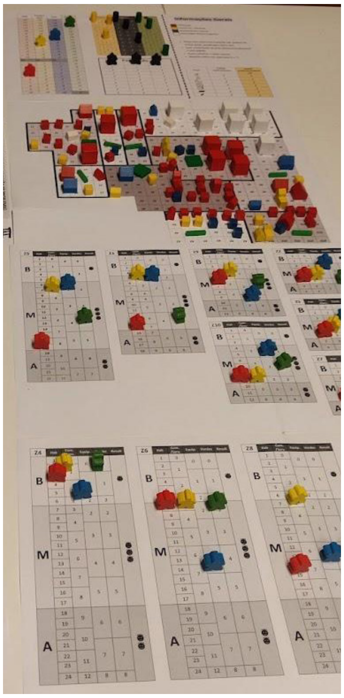



Fig. 17/ 18
Step 1(left) and Step 2 (right) for team 1 (G2).

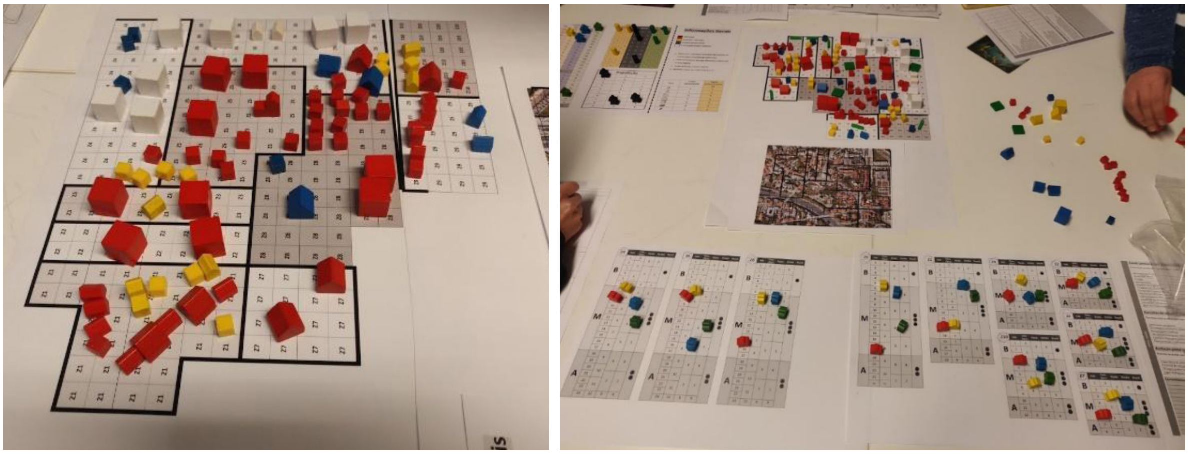


Fig. 19/ 20
Step 1(left) and Step 2 (right) for team 2 (G2).

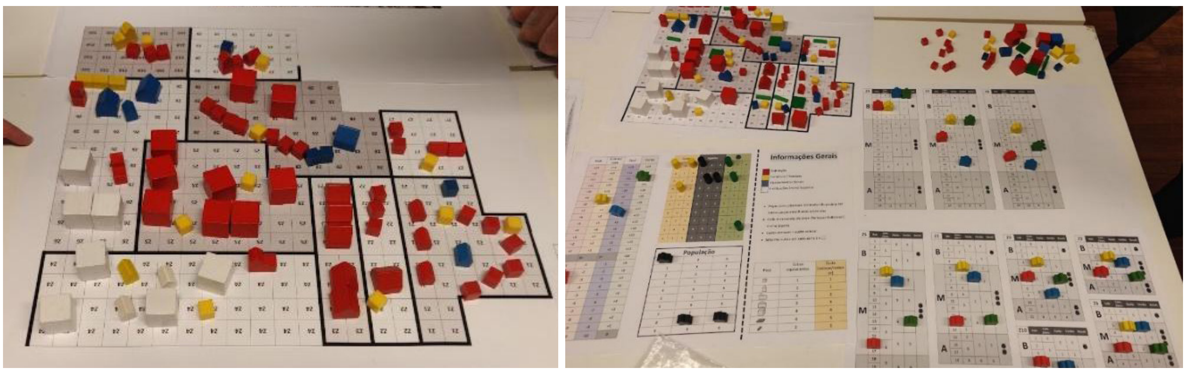


Fig. 21/ 22
Step 1(left) and Step 2 (right) for team 3 (G2).

table. Because G2 demanded managing the Sub Zones Tracking board (Figure 7) and the General Tracking Board (Figure 8), teams divided themselves to control each part of the game while discussing the overall strategy and necessary moves to achieve it. Because the boards were modular, players organized them as they preferred. This flexibility is why the following pictures show different perspectives (Figures 17 to 22).

6. Quantitative and qualitative data collection

This section presents the data collected through the questionnaires and facilitator observations. These qualitative and qualitative data collection methods were combined with the gameplay analysis in the paper discussion.

6.1 Available quantitative data

Table 2 presents the generic information about each session. Gender was balanced, and the ages varied from 21 to 48 years old. Table 2 shows the overall generic data for each session, the number of participants, and the duration and format of the game sessions.

Due to the low quantity of participants, no statistical tests were applied. For questions Q1, Q2 and Q3, we analysed the change in the results from the players' perceptions. Q4 related directly to the game, measuring the players' perceptions only in the post-test questionnaire. The median results (Likert scale of 1 to 7), related to the players' answers to the previous questions, appear in the following tables.

Table 2
Generic data related to the game sessions (G1 and G2)

Game session	Number of participants	Duration per game (min)	Total duration (min.)	Format
G1	10	60	120	1 team of 5 players per game
G2	17	120	120	3 tables (teams of 5 to 6) playing simultaneously

Table 3
Question 1 (Q1): players' perceptions of games (as serious games) and the collaborative dynamics before (B) and after (A) playing the games (values).

Q1 (Games and collaboration)	Game 1 (G1)			Game 2 (G2)		
	B	A	B-A	B	A	B-A
What's the importance of collaborative urban planning?	7.0	7.0	0.0	6.0	6.0	0.0
The potential of innovation and ludic approaches for urban planning?	7.0	6.5	-0.5	6.0	7.0	+1.0
Can games be urban planning tools?	5.5	6.0	+0.5	5.0	7.0	+2.0
Can analogue games be better than digital games?	5.5	6.0	+0.5	6.0	7.0	+1.0

Table 4
Question 2 (Q2): players' perceptions of their feelings and awareness of urban planning subject before (B) and after (A) playing the games (values).

Q2 (Feeling of the players)	Game 1 (G1)			Game 2 (G2)		
	B	A	A-B	B	A	A-B
Motivation/excitement	6.5	7.0	+0.5	5.0	6.0	+1.0
Energy	3.5	3.0	-0.5	2.0	2.0	0.0
Anxiety/Stress	6.0	6.0	0.0	5.0	5.0	0.0
Attention/focus	6.0	6.0	0.0	6.0	6.0	0.0
Empathy with the group	6.0	7.0	+1.0	6.0	6.0	0.0
Knowledge about the zone	3.50	5.0	+1.5	5.0	6.0	+1.0
Urban planning knowledge	5.00	6.0	+1.0	6.0	6.0	0.0

Table 5
Question 3 (Q3): game experience evaluation (values).

Q3 (Game experience)	Game 1 (G1)	Game 2 (G2)
Game complexity	5.0	2.0
Quality of the simulation	6.0	6.0
Level of collaboration	7.0	7.0

6.2 Available qualitative data

We also analysed players' commentaries and the facilitator's notes. Three players in each session wrote commentaries about the sessions. These transcriptions are presented in Table 6.

The facilitator also made notes. They are organized in Table 7, considering what was noticed by the facilitator as positive (+), neutral (0), and negative (-) based on observation, player behaviour and direct player statements.

Table 6
Transcription of the players' (P) commentaries in G1 and G2.

Game Session	Player	Commentary
G1	P1	*"Enriching game that introduces a new perspective on urban planning"*
	P2	*"First the game seemed to be very complex, but as we started playing, we become more efficient, and was possible to think about urban planning and some of its key concepts of what to do to balance the urban zone"*
	P3	*"Loved it!"*
G2	P1	*"It is interesting how a creative abstraction can generate solutions to improve the urban zone"*
	P2	*"Very interesting to deal with multiple situations in a group dynamic. Congratulations! Very good!"*
	P3	*"I think it is very positive to do these ludic activities that make us question the existent proposals"*

Table 7
Facilitator notes systematized for G1 and G2 comparison.

Generic dimensions	Game 1 (G1)			Game 2 (G2)		
	+	0	-	+	0	-
Games a dynamic to initiate a formal planning process	●			●		
A somehow abstracted approach		●		●		
Immersive activity	●			●		
A collaborative activity	●				●	
Interactive activity	●				●	
Easiness to understand		●		●		
Players wanted more time to play			●			●

7. Discussing collected data

The general evaluations, according to players' perspectives, seem positive. Players were able to play the games and define urban planning solutions. Table 3 reveals that, in all games, the participants' perception that games can be tools for planning increased and that analogue games can be better than digital ones. Other dimensions were inconclusive.

Table 4 shows that the participants considered they had learned about the urban zones at stake. Learning about urban planning was less conclusive because it increased in G1 and stayed unchanged in G2 (Table 4). Although this seems like a positive outcome, players admitted they had little knowledge about each urban zone. The facilitator shared some information about the zones, realizing that a summary of the urban zones could help the players during the game. Similar effects were noticed in previous serious games. Wouters et al. (2013) state that serious games are more effective when combined with other learning approaches. Providing more information or challenging players to search for it outside the game could solve this.

During gameplay, G1 players admitted they are focusing excessively on the economic side of the game. Figures 12 and 13 show the building up of the economy as the game evolved, allowing players to buy expensive facilities that solved negative impacts. Again, during debriefing, two players (20%) admitted they just wanted to get more and more money and were the other players that restrained their impulses. These gameplay effects relate to the "Incan Gold Experience", conducted by Stephen Blessing, where the abstraction of games tends to overcome the narrative in repeated play (Engelstein, 2019). The excessive focus on scoring and less on the simulation side is problematic in a serious game. Fostering playability can affect the simulation and learning side of a serious game. In our case, these emergent players' behaviours were suited for the debriefing as an example for the facilitator to invoke, stating that the economic dimensions may dominate an urban planning process. Because economic principles affect urban planning, exploring, and debating these complex issues are possible outcomes of serious games.

Still, in the feelings dimension (Table 4), motivation/excitement increased in all games. Empathy with the group perception increased in G1 and stayed unchanged in G2. Energy only decreased in S1. Considering that the games were one of several workshops students attended on the same day, these results can be seen as even more positive. G2 was longer (120 minutes without a break), and the games were the last activity.

Table 5 reveals what was expected. G1 was perceived as complex (5.0), although the facilitator was always present. G2 was simpler (2.0). Adding direct tracking mechanisms to G2 helped reduce the complexity (Figure 6 and 7). Despite the different complexity levels, participants considered the games provided high collaborative experiences (7.0) and a considerable simulation quality (6.0). Overfocusing on the economic side of the game can affect the urban simulation accuracy. Also, the size of the hexagons, not matching a neighbourhood or any urban block, impacted the level of simulation perceived by G1 players. Adams (2014) recommends hexagonal grids to simulate terrain in general, allowing equal distances between adjacent hexagons (land units). For urban patterns, he prescribes squared grids. We used hexagons in the G1 to simulate transport connections because the distances between land units (hexagons) were relevant to the model: connected hexagons triggered income and negative impacts. Finding a new rationale to fit the hexagons to the urban morphology might solve this in future implementations. Even though G2 used a square grid, creating a board that tried to replicate the urban morphology of Paranhos demanded considerable distortions. Besides these differences, both games were highly collaborative, according to the players' perceptions.

The players' comments (Table 6) were very positive, showing contentment and surprise about the game effects to simulate a planning process and support collaborative decision-making and its learning effects. These were optional comments. While the majority decided not to comment, we received no negative comments. In G1, 33.33% commented. While in G2, only 17.65%. The late finish hour (7 p.m.), the last activity of the day, might explain the lack of commentaries. Though, the players that decided to comment were expressive, like G1P3: "*Loved it!*". Games demand high energy and cognitive skills (Hodent, 2017), more when they require strategic planning and multiplayer interactions from players. This might have tired the players, affecting energy and motivation.

The facilitator notes provided auxiliary information to discuss the games' results. In G1, the facilitator noticed the effects of the over-focus on the economic side. The game lost some meaning (the relation to urban planning). Players wanted to progress and collect more and more money. They wished to continue playing more and more rounds. Although this is positive because it means engagement, forcing the players to stop playing is a negative experience. In G2, the facilitator observed disengagement from some players (two players in total, one in each different table). The game did not require formal turns for each player to move a piece, being prone to the "alpha player effect", when one player can replace others in the game, making the decisions and moving the pieces in their place. This effect can be problematic in a collaborative decision-making process. However, most players (more than half) were totally immersed in the game (based on observations and questionnaires).

8. Proposing a development method to design analogue serious games

The two game experiments revealed that similar game-based approaches can deliver serious games for urban planning. An urban map with a grid (hexagonal or orthogonal), the pieces players can move to change the urban model, and its effects (adjacency to simulate connectivity effects and staking/pilling up to simulate densities in tridimensionality) are key elements of our proposal (Figure 22). A tracking system is necessary to enforce and control the game economy, scarcity, and combination effects (connectivity and densities). If these tracking and combination effects demand complex processes and player agency, the games tend to be complex to learn and master. Figure 23 presents our proposal to develop serious games: using maps, cubes, tile placement and staking as core game mechanisms.

First, we define our planning case, the urban zone to address and the serious game purpose (1). Next step (2) is setting the game world, the type of map and grid system (quadrangular, hexagonal, or other variations), connecting the game space to the physical components (cubes of different colours and sizes is a simple solution) and their meaning (what urban elements they represent).

Considering that tile placement, staking, and connections/adjacency are the core mechanisms of our proposal, the mechanical system requires defining the game economy, meaning the values and flows for the mechanisms' activations. Because these activations change the game state, we need to use other auxiliary game mechanisms to track the changes (track bars work, but other small components like cubes are valid options). Dealing with the mechanical system is step 3.

In step 4, the game must be detailed, defining the game structure, if it is real-time, played by turns, competitive, collaborative or a mixed approach, and when it ends (e.g., time, achieving objectives, etc.).

Step 5 is likely to happen several times during the development process. The game must be playtested as many times as possible with different users. Then, the playtest results are evaluated according to the game's playability and potential to reach serious purposes because we are dealing with serious games. Only when the game achieves the OK state (playable and fit for serious purposes): the game is ready for use (6). We recommend defining in step 6 the facilitation and formal

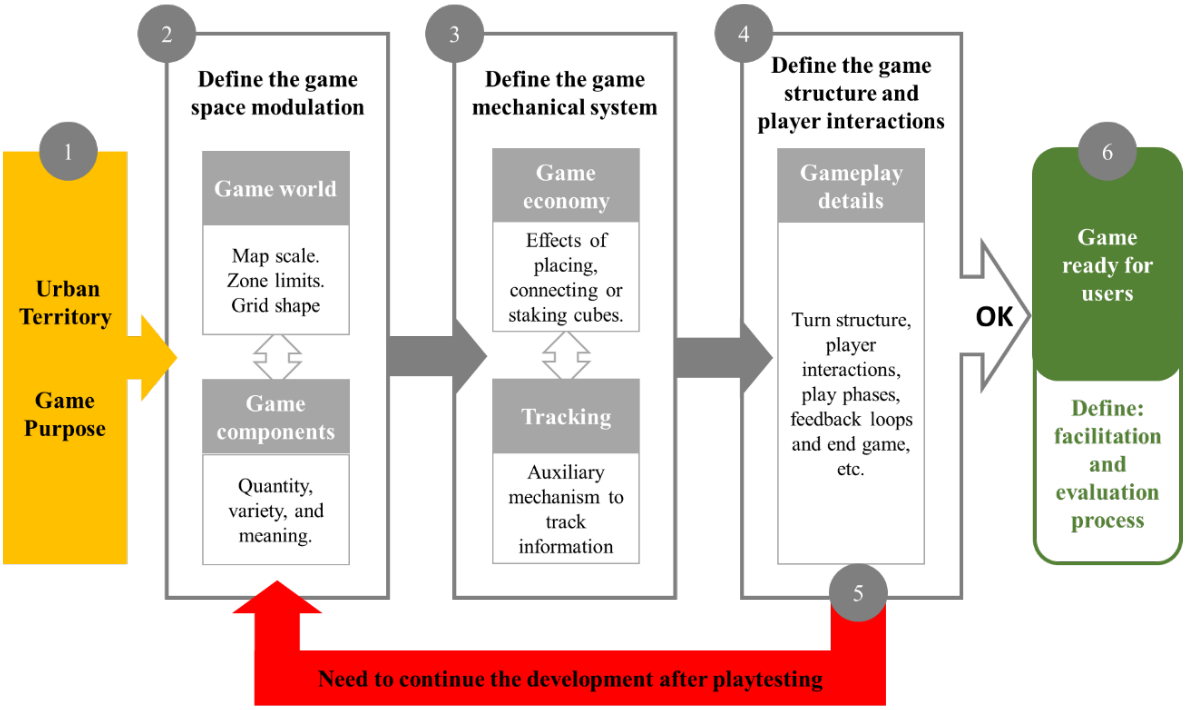


Fig. 23
Process to develop analogue serious games for urban planning: combining urban maps, cubes, tile placement, staking and connections/ adjacency effects.

evaluation process. These are requirements serious games demand, especially the evaluation of the game outcomes are project deliverables (e.g., according to research, project, or client requirements).

8. Conclusion

In each game, pre-tests and post-tests delivered quantitative data for direct comparison, completed with the graphical photography, players' comments, and the facilitator's notes. The analysis of this data allows us to conclude that both games could work as serious games for teaching and support a collaborative planning process. Combining MBG mechanisms, using existing game pieces and simple graphical adaptations to realistic urban maps, is viable. Yet, we must admit that the game objects are simple and inexpensive, and building this type of game demands considerable game design knowledge, more than initially expected. Besides this, other pitfalls should be stated and avoided. It is necessary to provide auxiliary information about the urban zones, adjust the playable models to the scale and the urban morphology (especially in hexagonal grids) and avoid excessive focus on the game economy that can disengage players from the overall urban system. Adding tracking visual systems and direct facilitation helps lower the game's complexity. Game facilitations should not be overlooked because games that demand higher complexity to deliver detailed simulation can fall into abstracted systems.

The place to play and the energy level of the participants can impact serious game experiences. These strategic games demand high cognitive skills and energy levels. Doing them after other exhausting activities is not recommended.

From a game system perspective, tile placement and pilling mechanisms simulated the urban changes over the maps. And the set collection mechanisms represented the combinations and generic relationships between buildings, land uses and transport systems. Tracking flows and resources is essential in urban simulations. Using coloured dice and tables with tracking bars fit this purpose, although direct track tables/bars are easier to handle. We believe these are core mechanisms that analogue serious games for urban planning can use extensively, while the way to model urban grids seems to be the biggest challenge. These findings are systemized in our game development process proposal for an analogue serious game for urban planning (Figure 22).

Future research could focus on the new game mechanisms. Experiment with detailed game pieces and evaluate if they are less prone to abstraction and disengagement from urban issues. Introducing narrative development can also be a way to improve meaning.

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