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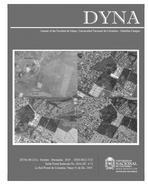

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Metropolis: an emerging serious game for the smart city

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Received: July 4th, 2019. Received in revised form: September 16th, 2019. Accepted: November 11th, 2019

Abstract
Emerging serious games mark the beginning of a new era in video games. Emerging serious games introduce advances in distributed artificial intelligence into their design in order to guide the player's manipulation of a specific subject in an adaptive way. In this article, we present a city simulator game, called *Metropolis*, which generates emergent properties. *Metropolis* can be used by a smart city for city planning, to make collective decisions, and for other purposes. This paper describes why *Metropolis* can be classified as a serious game. It also analyzes how its emergent properties can be used for managing a smart city, and especially how it promotes e-participation as an e-decision-making tool within the context of urban planning. In addition, this paper explores how *Metropolis* can be used to analyze a smart city's emergent citizen and urban patterns (urban spatial distribution) based on strong e-participation.

Keywords: emerging serious games; e-participation; smart city; urban planning.

Metropolis: un juego serio emergente en una ciudad inteligente

Resumen
Los juegos serios emergentes son el comienzo de una nueva era en los videojuegos: la introducción de avances en inteligencia artificial distribuida en sus diseños, para guiar la comprensión de un tema específico de forma adaptativa. En este trabajo, proponemos un juego de simulador de ciudad con propiedades emergentes, llamado *Metropolis*, que puede ser utilizado por una ciudad inteligente para planificar la ciudad, tomar decisiones colectivas, etc. Este artículo presenta las características de *Metrópolis* como un juego serio, así como un análisis de sus propiedades emergentes en la gestión de una ciudad inteligente, en particular, para promover la participación electrónica, como una herramienta de toma de decisiones electrónicas, en el contexto de la planificación urbana. Además, este artículo explora el uso de *Metropolis* para analizar la emergencia en una ciudad inteligente del patrón de sus ciudadanos y su patrón urbano (distribución espacial urbana) debido a la participación electrónica.

Palabras clave: juegos serios emergentes; participación electrónica; ciudades inteligentes; planificación urbana.

1. Introduction

The concept of the emergent game marks the beginning of a new era in video games [1, 3]. Emergent games represent the evolution of games that adapt to the player while maintaining the central thread of the game. E-participation in a smart city supports the participation of citizens in governance through the use of Information and Communications Technologies (ICTs) [13]. In a smart city, citizen participation is especially important; smart cities should be planned according to the needs of its citizens [19, 21, 23]. In general, e-participation encompasses different purposes: administration, policy making, service delivery, and decision-making.

In this paper, we analyze e-participation in the context of decision-making in a smart city. We define the tools that allow citizens to interact in decision-making processes that affect city life. We also define environments in which

How to cite: Aguilar-Castro, J. L, Altamiranda-Pérez, J. A, Díaz-Villarreal, F. J, Cordero, J, Chávez, D. and Gutiérrez de Mesa, J.A, Metropolis: an Emerging Serious Game for the Smart City. DYNA, 86(211), pp. 215-224, October - December, 2019.

DYNA, 86(211), pp. 215-224, October - December, 2019, ISSN 0012-7353
DOI: http://doi.org/10.15446/dyna.v86n211.80864

citizens learn how to participate, and specifically, to learn about the complexities of e-participation in decision-making processes in a smart city.

Introducing emerging serious games into a smart city allows for the transparent integration of technology into city dynamics. Emerging serious games can be used in different contexts in a smart city. Considering that one of the main characteristics of a smart city is the application of e-participation to facilitate collective decision-making about citizens' services and needs, we analyze how *emerging serious games* can be used in this context. In this paper, we explore the technology needed to construct a vision of urban development in a smart city and in a collective and secure fashion in order to manage the city's assets (schools, hospitals, etc.). Specifically, we are interested in serious games that promote e-participation in the context of urban planning.

Ahmed et al. [27] have developed a Technology Acceptance Model (TAM) and Trustworthiness Model (TM) that facilitate the use of serious games in e-government services, and empower citizen engagement and participation. These models are based on serious games that assist governments in increasing citizens' engagement through their online services. Pflanzl et al. [28] discuss game design as a way to motivate, engage, and change citizens' behavior with respect to public service improvement. Thiel [29] reviews recent academic projects concerning gamified participation tools. The gamified participation tools are a novel approach to encourage citizens to make use of their democratic rights by using digital participation platforms. Thiel et al. [30] provide a review of gamification strategies on e-participation platforms, and give an overview of the state-of-the-art of gamified participation initiatives. Thiel [31] also provides an overview of current trends for applying gamification to public participation. Together, these authors offer relevant insights for the design of future e-participation platforms, and establish the terminology for e-participation game research.

In the domain of urban planning games, Poplin [32] focuses on online games and serious games for urban planning. The author overviews the urban planning games currently available online and give some examples of their game stories. Poplin also explores the potential of serious games in participatory public planning. Lundström et al. [33] address urban and regional planning as a wicked game. They explore the obstacles and opportunities for participatory methods in a wicked game called *The Citizens' Jury*. Martin el al. [34] present the research of architects and computer scientists on mobile, context-sensitive serious games for sports and health (also known as *exergames*). Recently, Madani et al. have proposed a serious environmental management game to improve understanding of environmental sustainability [26]. These game-based learning initiatives increase soft skills such as critical thinking, creative problem solving, and teamwork.

In this paper, we are interested in a gaming subtype called *construction and management,* often used in smart cities. Construction and management games are simulations in which players build, expand, or manage fictional communities or projects with a set of resource limits [5,7]. In these games, the player's objective is not to defeat an enemy, but rather to build something in the context of an ongoing process [9]. Examples of these include city construction games such as *SimCity* and *OpenCity* [4,5].

Specifically, we have proposed a game, called *Metropolis*, in which social dynamics emerge from the decisions that players take [9,15]. The game aims to collectively plan the successful growth of communities. The premise of *Metropolis* is that cities can be self-managed based on decisions taken collectively in an environment in which all players have roles of equal importance. In *Metropolis*, there is no local authority such as a mayor, governor, etc. This game can be used to plan a city, to manage a city's limited resources, to identify the collective interests of its citizen, as well as to meet other goals. It can be used to learn how to reach collective decisions. This learning aspect makes this game a serious game, since it offers this teaching capacity (learning how to reach collective decisions). At the same time, is fits the emergent system model, since the game generates results (city management).

Previous research focused on studying emergent behaviors of a city based on rules that govern the interactions between agents (players) that play social roles in this society. This paper uses a mechanism that reaches consensus opinions in Metropolis and establishes transparent forms of inclusion for e-participation. Additionally, *Metropolis* is designed to encourage the emergence of the collective urban vision of a city based on the interests of its citizens.

Hence, *Metropolis* can be viewed as an emerging serious game that teaches players about the complexity of e-participation in a smart city. Specifically, it teaches players how to do things together. As a result, *Metropolis* facilitates the emergence of smart city behaviors (urban patterns, city features, etc.) that are based on collective decisions.

This research contributes to three domains. It establishes the importance of e-participation in a smart city for democratic decision-making processes. It shows how emerging serious game can be used to teach e-participation. Finally, it confirms the emergence of smart city behaviors that are based on that e-participation.

2. Theoretical aspects

2.1. Emerging serious games

Emergence [2, 8, 16, 17] is "what happens when a relatively simple system of elements organizes itself spontaneously, without explicit laws, and thus gives rise to intelligent behavior." In the literature, there are several definitions of emergent games. For example, [1,3] indicate that games with emerging properties appear when a relatively simple set of rules leads to complex game strategies involving different levels.

Emergence in games is enabled by the definition of simple global rules for the behavior and properties of game objects, as well as by the interactions between the game world and players. Emergent forms can be expressed in different ways [1-3,8,15]. 1) Emergence occurs when, due to the decisions of the players, a pattern of collective behavior, shared social knowledge, or a common result appear in a game. 2) Emergence also occurs when the properties of game objects interact to create a completely new game. In this paper, we focus on the first type.

Taking into account the "serious" aspect, serious games are simulations of real-world events and processes for the purpose of engaging with serious topics or problem-solving [10-12]. Serious games train or educate users, introduce new topics, and deliver messages [11, 18, 25]. There are many different categories of serious games, including [10, 20] educational games, advergames, simulation games, political games, games oriented to religion, and health-oriented games.

2.2. Simulation of cities

City simulation is a type of game where the players build and manage a city using limited resources. An example of a city simulator is *SimCity*, a city-building game where the goal is to create, develop, and manage "SimCity" [4, 5]. The player starts the game with a blank map of a city, which she or he expands with budget purchases. The city must provide basic services to its citizens, such as water, electricity, urban waste management, etc. In addition, the citizens must create sites for health care, education, security, and entertainment, all represented by different buildings. The main sources of *SimCity* income are taxes, services, and specialized buildings located within the city (casinos, military bases, etc.). Similar city simulators include *LinCity* and *Opencity* [6].

Metropolis does not follow the same philosophy of games as SimCity, *LinCity* or *OpenCity*, which use a self-management model inspired by the *Prisoner's Dilemma* game. These games are clear examples of non-zero sum problems. In the *Prisoner's Dilemma* type game, the game assume that each player independently tries to maximize their own advantage regardless of other players' decisions [9]. In standard game theory analysis, to determine the Nash equilibrium, each player can betray the other (but interestingly, opposing players obtain better results if they cooperate) [2].

This is the key point of these games. In our game, as in the *Prisoner's Dilemma*, cooperation is obtained as an equilibrium result. The game is played repeatedly, and as the game is repeated, each player has the option to punish the other players by not cooperating in previous games, or to cooperate. Thus, the incentive to cheat can be overcome by the threat of punishment, leading to the better result, which is cooperation.

2.3. E-participation and urban planning in the smart city

A smart city should be understood far beyond its application of ICT [13, 14, 19, 24]. For example, giving citizens the possibility to participate online in the city's management activities is an important component of what makes a city smart, not only from a technological point of view, but mainly because this type of city addresses and tries to satisfy the needs and requirements of its citizens [21, 22].

E-participation is considered an essential component of smart city functioning. It helps individuals get involved in the policy-making process through the use of electronic means. Classically, the three types of e-participation are [13, 14, 23]: i) e-decision-making; ii) e-information; and iii) e-consultation;

In general, e-participation helps develop the smart city, since it provides [13, 14] more focus on citizen needs, improved government responsiveness, greater government transparency, and increased citizen involvement. There are several mechanisms for e-participation: electronic voting (also known as e-voting), reputation systems, online communities, and online social networking. Our research analyzes how the use of e-decision-making in emerging serious games introduces, promotes, and lets users learn about e-participation.

We should also mention that urban planning is an interdisciplinary field that includes architecture, civil engineering, and public administration. It is a technical and political discipline related to the development and design of land use in an urban environment. Urban planning takes into account the physical layout of human settlements, the protection and use of the environment, as well as the repercussions of social and economic activities. It also encompasses the planning and development of water resources for common use, rural and agricultural land, parks, etc. In a smart city, urban planning is a collaborative process, in which citizens participate in the construction process using e-participation tools.

3. Game description

3.1. Game philosophy

The key strategy in *Metropolis* is that each player tries to enhance their individual advantage [9, 15]. However, inspired by the *Prisoner's Dilemma*, cooperation is crucial to our game. Cooperation balances the wishes of all, leading to collective happiness. Cities are punished when the people do not cooperate, since the quality of city life worsens. In *Metropolis*, a player's happiness is linked to construction activites based on the player's personal characteristics. For example, if a player has health problems, then the player should construct health care facilities. The percentage of health buildings in the city then determines the happiness of this player. Finally, the overall happiness of the city equals the average happiness of all the players. The incentive to cooperate can thus emerge, because the goal is to create a city in which all players feel better, i.e., reach consensus on community life.

The basic activity of the game is decision-making in the form of a council. On the council, each agent belonging to a group has the opportunity to vote for or against certain types of building constructions by making collective city budget allocations. There are two types of agents, one representing the players, and others that are randomly generated and controlled by the game. Personal characteristics are assigned to the agents, and these determine the types of construction agents will support. In other words, votes on the council represent construction choices. The city evolves as the agents decide to build or destroy facilities. Each player's actions directly affect the city.

In essence, each player represents a percentage of a city's population (a community). When someone wants to build in the city, a project is submitted to popular vote on the council. The game has a scoring system calculated for each year. The score is based on development rates in the city and on the happiness of its population, where the happiness of all agents determines the city's Happiness Index. Development rates in the city are calculated according to the balance between different development sectors (environmental, educational, etc.). They are individually calculated, then added together to determine the development rate of the city. The happiness of the people derives directly from the happiness of its agents.

3.1.1. Game rules

The game can be played with one or more players on one or more teams, where each team is represented by an agent. A time limit is set equal to the number of years needed to finish the game. Each agent may vote for or against the construction of a particular building in a particular area.

In order to simulate the percentage of citizens who cannot be controlled by the players, every city has 10 agents, of which at least five are artificial agents. Artificial agents are generated randomly and make decisions in the same way as other agents. Non-artificial agents have personalities, either generated randomly or defined by the user. (Refer to the explanation below.) Players request to build buildings that they want in their preferred areas by specifying site coordinates. The characteristics of a city used to calculate its development rate are health, education, environment, trade, industry and technology.

3.1.2. Characterizing constructions (Buildings)

Each type of construction in a map box (coordinate grid) is represented with a numeric value. Different types of construction have different effects on the game and on surrounding areas. [2, 9] present the details for each type of city construction, i.e., its effect: the radius of each building in the city (its coverage), the cost of the construction, the construction's group affiliation, and the bonus or penalty that it adds to the development rate. There are two types of buildings: primary buildings, which add/remove points to the development rate; and secondary buildings, which add/remove a percentage of points to the development rate. When the range of two identical buildings (primary/secondary) does not intersect, the buildings are combined for a total score. When ranges intersect, a positive bonus decreases by 50%, while a negative penalty remains unchanged.

3.1.3. Agent personalities

At the beginning of the game, players must choose among four types of personalities. Artificial agent personality types can either be chosen randomly or selected by the player. Personality determines the behaviour of the agent during the game.

The performance of human players and artificial agents differ. Human players are used to calculate player happiness. Artificial agents determine their own happiness and behaviours during the game. For example, an artificial agent assigned the role of environmentalist always votes against proposals that harm the environment.

An agent's personality determines its basic needs and its concominant happiness. Other personality traits that are not activated for a given agent remain by default at normal levels (1000 points); for activated personalities, the range is 1250-750 points. [2, 9] describe the personality types (Saver, Healthy, etc.) their relationship with construction types, and how they are used to calculate player happiness. For example, a Healthy player's Index of Happiness for health care facilities is 750, meaning that this type does not require a lot of city health facilities.

3.1.4. The council

The council makes decisions based on what each player wants to build, and according to the personalities of the agents voting for or against a building project. The votes of 10 players are taken into account to make a decision. The decision is determined by majority vote.

3.1.5. Assessing building proximity

Details in [2, 9] specify the penalties or bonuses related to the proximity of certain types of buildings. Proximity is related to the distance between construction types. For example, the game awards a bonus for types of buildings that players prefer grouped together, otherwise it issues a penalty. That means, our game promotes or penalizes the clustering of certain types of construction projects in the city according to type. It allows cities to define zones (e.g., industrial zones, educational campuses) because buildings attract other buildings with similar functions. For example, the proximity of a hospital (primary health care) to an industrial building would result in a -6 point penalty applied to *both* buildings based on their proximity. In contrast, if a research center (technological institution) is built near a school or university (educational institution), both construction projects would receive a bonus of 3 points. The area that each type of building type covers, i.e., its coverage, determines its proximity. (See Section 3.1.2.)

3.1.6. Total score for the development index

In a city, each Development Index is linked to a type of personality and type of construction. For example, for a development in higher education, the city must already have a lot of primary and secondary educational facilities. The Development Index is determined by the impact and quantity of each construction on the city's development: It is derived from the bonus or penalty for each construction type and for each type of development. In general, the total score for each Development Index j is calculated as:

$$PT_j = \sum_l \sum_i (PC^l_{ij} + \sum_s CER_{si}) + \sum_m \sum_k (PC^m_{kj} + \sum_s CER_s \quad (1)$$

where l represents all primary buildings and m all secondary buildings in the city, respectively; CER_{ik} represents bonuses and penalties depending on building proximities i and s (or k and s, respectively). CER_{ik} determines the closeness between two buildings if not more than 3 boxes separate them, and PC_{ij} is the total score of building i for Development Index j to which it pertains. Thus, the total score of the index is calculated.

3.1.7. Calculation of city happiness

The game calculates the happiness of a city. For that, it determines the relationship between each of the city's Development Indexes (calculated previously) and the personality of each player. The overall relationship determines the Happiness Index of each player. The calculation for the score of the Happiness Index for each player p is:

$$VI_p = \sum_j \frac{1000 * PT_j}{TRJ_{pj}} \quad (2)$$

where TRJ_{pj} is the total required by player p for Index j, according to her or his personality. The general index of happiness in a city is the average of the Happiness Index of each agent.

4. Testing

This section defines several experiments undertaken with *Metropolis* within the context of e-participation in a smart city. Each scenario tests a different characteristic provided for *Metropolis* to facilitate e-participation and to support the development of the smart city. For the testing, we assumed that each player represents a specific community within the city.

The hypothesis states that emergence in a smart city is very important because it allows the smart city to adapt to the needs of its citizens. We tested two properties of *Metropolis*: whether the citizens (players) were able to learn about the importance of e-participation for democratic decision-making processes, and whether e-participation generated the emergent behaviors and characteristics of a smart city, specifically, whether urban patterns emerge due to collaborative urban planning. With these experiments, we wanted to prove whether e-participation contributes to the emergence of urban planning in a smart city, and whether *Metropolis* can be used to teach e-participation skills that support decision-making.

4.1. Case 1: emergence of urban patterns

In this first test, we set the playing time to 3 years and the number of real players to 2 (the rest of the players were artificial agents managed by the game—see Section II.B for more details. Most player personalities were randomly generated. In the upper right of Fig. 1 below, in the turn (shift) button (*Proximo Turno, Next Turn*), the game displays information about the current turn (*Turn 1 of 36*) and the current player (*Jugador/Player 1 de/of 2*).

Each turn in the game represents one month for each player. In this case, because we have selected 3 years of play, the game will take 36 turns to finish. Every 12 months a

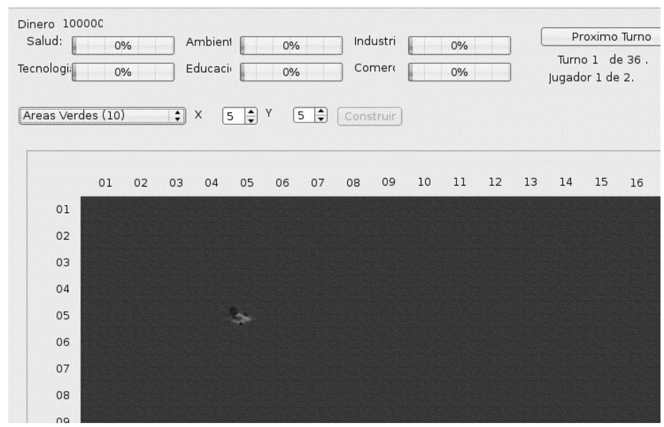

Figure 1. The initial screen in Metropolis
(*Dinero*= money, *jugador*=player, *turno*= turn)
Source: The Authors.

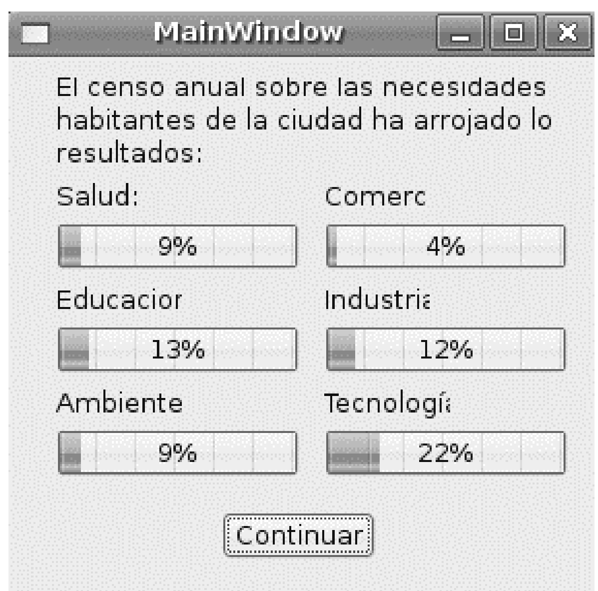

Figure 2. Development Index of a city for year one
(*Salud*=Health 9%, *Ambiente*= Environment 9%, etc.)
Source: The Authors.

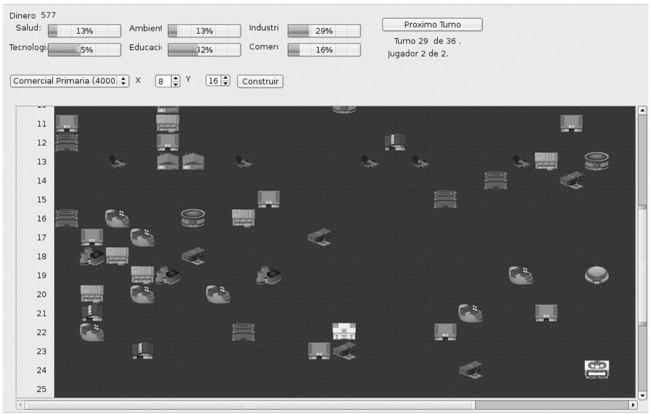

Figure 3. Case 1, turn 29
Source: The Authors.

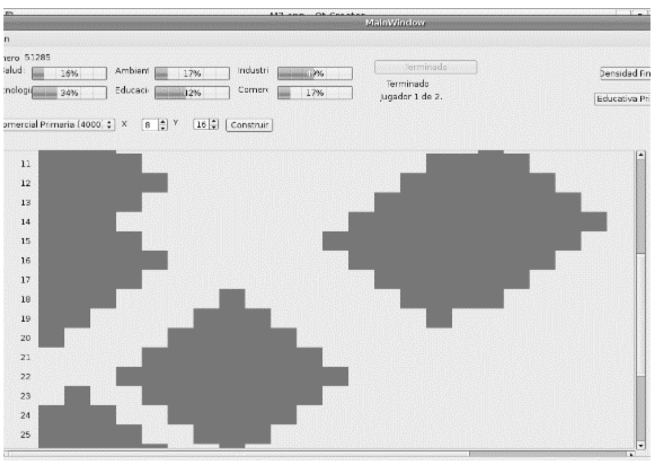

Figure 4: Density of the Educational Institutions in the city
Source: The Authors.

window displays the development rates of the city, as shown in Fig. 2. For the first year in this example (see Fig. 2), the highest development rates were for education (13%), technology (22%), and industry (12%).

At the end of each year, an amount of money is added to the city budget (equivalent to the taxes, donations, etc., received by the city), and the development index changes accordingly for each year. Urban patterns begin to emerge, for example, zones with only educational institutions. Fig. 3 shows the emergence of the industrial zone on the left side after turn 29.

When this game was completed, we studied the density of each type of construction in the city. Fig. 4 indicates the density of educational institutions in the city once the game ended.

The densities show an emerging urban behavior based on decisions taken by the agents. Urban zones have emerged, based on the players' personality profiles, i.e., the city's communities. Basically, this behavior consists of patterns that are generated within the city based on groupings of similar buildings within the same zones. If we use *Metropolis* as a tool for e-decision-making in a smart city, the patterns that emerge are products of the city's adaptation to its citizens. The patterns are determined by the collective decisions of the citizens. If we assume that their decisions are based on their personalities (their needs and requirements), then an adaptation process has clearly emerged in the city.

This development is very important, because recognizing urban patterns in a smart city can help it to define public policy, including the local urban plan for the city, and other specific policies, meaning that the city can now make intelligent decisions about future investments, social rules, etc., during city planning sessions. Specifically, used as an e-participation tool, *Metropolis* allows smart cities to tailor development closer to citizen needs and to improve a city's responsiveness. (See Sections II.D and [13], where we outline the pillars of e-participation in a smart city.)

In this first scenario, we see that e-participation allows urban patterns to emerge, in a context in which *Metropolis* allows its citizen-players to recognize its importance. Our tests show how *Metropolis* behaves like an emerging serious game that educates players about e-participation.

4.2. Case 2: study of city patterns based on the specific needs of agents

In the second case, Agents 6 and 8 were configured, and the rest were generated randomly. Playing time was set to 2 years and the number of players to 4, the other two being artificial agents--see section III.B. The configuration for Agents 6 and 8 was:

- Agent 6: hypochondriac, industrial, difficulties with education.
- Agent 8: hypochondriac, environmentalist, thrifty, and self-taught.

Fig. 5 shows the state of construction in the city after the game has ended. The Development Indexes of the city for the first year are: Health (27%), Commerce (0%), Industry (33%), Environment (8%), Education (9%), and Technology (6%). In the case of the second year, the Development Indexes are: Health (34%), Commerce (4%), Industry (41%), Environment (8%), Education (23%), and Technology (11%).

Figure 5: Map of the city after the game has finished (Case 2)
Source: The Authors.

The final results for the city are consistent with the personalities of the agents, since their basic needs were concentrated on health, education and industry. (See Fig. 6.) We see a pattern emerge in the city that satisfies those needs. In the case of the industrial index, even with an environmentalist player (Agent 8), we obtain an industrial rate (41%) higher than the environmental rate (8%), due to the fact that the rest of the players are industrialists (Agent 6 and the artificial agents).

We also observe another type of emergence, the personality of the city, which is basically the union of the different personalities of each agent. This personality is used to achieve a common goal in the smart city, that of improving the city's rate of development.

In Fig. 6, the personalities of the agents are translated into an overall pattern in the city, i.e., its personality, or in other words, the appropriate pattern of behavior for society's members.

The personality of a city guides the interests to be addressed by city planning efforts. This personality specifies the needs and requirements of each citizen, and a smart city should devise a plan for fulfilling them.

Again, using *Metropolis* as an e-participation tool allows players to develop a smart city better focused on citizen needs. Additionally, it increases citizen involvement and their capacity to get involved, since it incorporates a learning process for collective decisions within an emerging serious games framework. Thus, the smart city develops in a transparent way. See [13] for more details about the pillars of e-participation in a smart city.

In this second scenario, we show two relevant properties that *Metropolis* analyzes: the importance of citizen e-participation in the democratic decision-making processes of a smart city, and how the smart city can adapt to the real needs that its citizens have. The results of the game reveal to the players that their participation in the life of the city is required, if they want the city to adapt to their needs. That is, e-participation in smart cities allows cities to adapt to their citizens. This adaptation occurs when *Metropolis* is implemented as a serious game, thus allowing players to learn about the importance of e-participation.

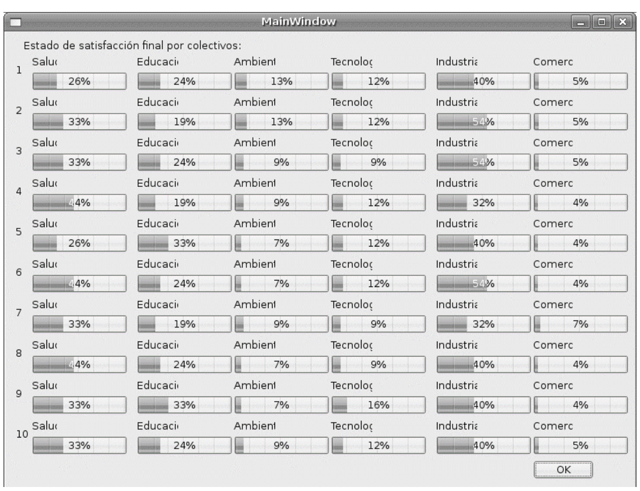

Figure 6: Case 2: agent happiness (*Estado de satisfacción final por colectivos,* final state of satisfaction per collective).
Source: The Authors.

Table 1.
Happiness Index of the city for different types of players

Scenario	Happiness Index for the city
1-A	25.3
2-A	3.2
1-B	69.4
2-B	10.3
1-C	24.7
2-C	8.6
1-D	30.2
2-D	16.7

Source: The Authors.

4.2.1. Metropolis in the context of e-participation

We conducted several tests to probe the decision-making process for different characteristics of the players. In one scenario, we defined 2 player types: 1) players representing social communities, and 2) players representing individual interests. Possible profile relationships between players included (a) antagonistic interests, (b) similar interests, (c) different but non-conflicting interests, and (d) different interests that require collaboration. Based on these, we calculated the Happiness Indexes that emerged in the city. (See Table 1.)

According to Table 1, players that represent community interests always obtain the best results (Case 1). Additionally, when individuals follow their own interest and do not collaborate, the city's overall Happiness Index is very low (Cases 2-A and 2-C).

4.2.2. The relationship between metropolis and smart cities

The previous scenarios allow us to verify our hypothesis about the important role that emergence plays in a smart city, mainly, that emergence allows the smart city to adapt to its citizens' needs.

One of the main features of smart cities is their use of ICT in all aspects of life [19, 24]. But one point of tension in smart city implementation concerns citizens *engagement* and *participation*, and the relative lack of both in actual practice and research results related to this issue [21, 22]. E-participation addresses this issue, since is a core component in the process of developing communities with socially inclusive governance [13, 14, 23]. E-participation becomes inclusive when it focuses on citizens' needs and requirements. Although technology is a main component of e-participation, we must also consider the capability and willingness of citizens to participate in decision-making processes and to collaborate with public institutions. E-participation is one tool that engages citizens and promotes collaboration between citizens in governance [22]. E-participation can be applied [13,14,21]:

- In the context of administration.
- In the context of defining, executing, and monitoring public policies.

- In the context of service delivery, so that citizens can participate in both the provision and use of services.
- Finally, in the context of decision-making processes, where democratic schemes are required.

The last case is where *Metropolis* can be used to teach citizens about the different aspects of the decision-making process: its components, control mechanisms, the citizens' roles, etc.—all necessary for a real democratic, decision-making process guided by a society's collective goals.

Metropolis is a game that facilitates training in how to participate in democratic decision-making processes. Thus, it is a serious game in which players can learn to make collective decisions, where common goals are more important than individual goals. With *Metropolis*, users can learn to define these common goals and to take rational collective decisions based on these goals. *Metropolis* presents different situations that require collective decisions that must balance the interests of specific citizens with the collective goals of the society. Specifically, *Metropolis* facilitates:

- Learning about the importance of e-participation in the context of the smart city, so that the real needs of citizens' are considered (serious game).
- application as a mechanism of democratic decision-making in the city (e-participation in a smart city).
- emergent behaviours in a smart city context, such as its adaptation to the needs of its citizens, which then generate urban patterns in the city and a set of general features for the city (its personality), and other effects of emergent games.

The previous test scenarios show how *Metropolis*' capabilities adapt a smart city to its citizens.

4.2.3. A comparison between *metropolis* and smart city applications

In this section, we compare *Metropolis* with several recent applications based on the following criteria. (See Table 2): a) whether they fall within the domain of smart cities; b) whether they propose e-participation approaches; c) whether they constitute serious games; d) whether they analyze emergent behaviors; and e) how they fit in the context of urban planning.
Overall, there are several urban planning applications based on serious games within the context of smart cities, but they don't explicitly incorporate e-participation, let alone an analysis of the emergent behavior of the city based on collective decisions. *Metropolis* is the only game that encompasses all these criteria.

Table 2.
Comparison with other applications

	[6]	[12]	[14]	[24]	[26]	[33]	[35]	[36]	Met
a	x		x	x	x	x	x	x	x
b			x				x		x
c		x					x	x	x
d						x			x
e				x	x	x	x	x	x

Source: The Authors

5. Conclusions

The city is a living entity that is constantly changing and evolving [3]. The way that its residents interact generates effects that can be analyzed at a deeper level. We face a phenomenon in which simple behaviors generate complex patterns and organization on a larger scale [3]. The underlying factor at play is the exchange of information between urban components.

The city is a dynamic system whose evolution does not depend on one, two, or several agents, but depends on what emerges within it as the product of the collective decisions of its agents, which produces upward forces that directly affect its overall structure. These forces are unpredictable [2, 3].

The *Metropolis* game studies the dynamics of the city. City behaviors emerge from the decisions taken by its agents regarding the type of constructions that interest them. The behaviors that emerge correspond to urban patterns configured within the city structure, e.g., certain buildings attract similar constructions within their proximity, resulting in the emergence of urban zones composed of like buildings. Another behavior is the pattern of the city, reflected in its development rate. Towards the end of the game, the city's pattern stabilizes in order to incorporate the needs arising from the fusion of the residents' personalities within the society, combining in some way these personalities.

We show how *Metropolis* can be used in a smart city context. Specifically, its emergent behavior produces two very interesting results [2, 16, 17]: the city's urban and citizen patterns. They are constructed as the result of playing the game. A smart city can extract this information and apply it to urban planning problems. One of *Metropolis*' unique features is that it can be used to build these patterns for a smart city's self-management operations.

In conclusion, *Metropolis* is an *emerging serious game* that can be used in a smart city to achieve various goals. It can be used as an e-participation mechanism to reach consensus opinions, in order to build a collective urban vision of a city that takes into consideration the interests of its citizens. Additionally, it can be used as an e-decision-making tool to facilitte the emergence of urban patterns, products of the adaptation of a city to its citizens, thus allowing the development of a smart city that focuses more on citizen needs.

In summary, this research makes many contributions. It defines the importance of e-participation in the decision-making processes of the smart city. It show how *Metropolis* can be used as a serious game to teach citizens about e-participation in a smart city. Finally, it describes the emerging characteristics of a smart city (e.g., the city pattern, urban spatial distribution) derived from e-participation.

This last aspect is very important, because emergence is a core characteristic of the smart city that enables behaviors adapted to the necessities of smart city citizens [2]. *Metropolis* teaches players about democratic and collective decision-making processes. It helps players understand the different aspects of these processes, e.g., budget management, interaction mechanisms, etc.

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