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Assessing the Extent to Which Players Can Build Sustainable Cities in the Digital City-Builder Game "Cities: Skylines"

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Abstract: This paper examines whether the commercial digital simulation game "Cities: Skylines" enables players to simulate sustainable city development. The analysis consists of an analytical framework founded on the literature regarding the UN Sustainable Development Goal "Sustainable Cities and Communities" (SDG 11, United Nations). The study applies the analytical framework to the city builder, observing that many aspects of sustainable city development can be employed when building a city in "Cities: Skylines". While the analysis suggests that the in-game feedback is very neutral vis-à-vis sustainability, the game offers a vast digital space where players and pupils learning geography can practically experience and experiment with the complexity of urban geography. Thus, "Cities: Skylines" could offer the opportunity to familiarize learners with "Sustainable Cities and Communities". The analysis helps to assess the extent to which the game can be of educational benefit for geography education despite its commercial character. The paper concludes with educational implications and emphasizes the opportunity to experience sustainable city development in the digital simulation game "Cities: Skylines".

Keywords: digital simulations; game-based learning; gamification; sustainable cities; SDG 11; urban geography; geography education

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1. Introduction

Along with a constantly increasing world population, almost 70% of people will live in cities by 2050, according to Vidal et al. [1]. While cities draw an increasing number of inhabitants, problems such as a scarcity of clean water and sanitation, traffic congestion, waste accumulation, and air pollution seem condensed in cities worldwide. A lack of sustainability exacerbates these issues. Furthermore, climate-related disasters have shown a vulnerability to heatwaves and flooding. However, climate-related measures such as green roofs, efficient buildings, and sustainable urban mobility can transform cities to become a part of the solution rather than the problem. Cities such as the sponge city Shenzhen [2], the 15 min city Paris [3], or the bicycle city Copenhagen [4] are important role models. Publications such as "*Encyclopedia of the UN Sustainable Development Goals: Sustainable Cities and Communities*" [5], which includes 93 contributions by authors from all over the world, help to understand the scope of the transformation and show how sustainable cities have become a respective field of research.

Due to the complexity of cities, it makes sense to use digital simulations to improve the understanding of these ongoing developments. Cities like Los Angeles, Singapore, Helsinki, and Dubai apply the potential of digital simulations to map their plans and operations [6]. They all use digital twin cities derived from city-builder games such as "Cities: Skylines" or "SimCity" and see the technology as a "potential game changer for urban planning" that could "cut operating costs" by "testing the effectiveness of various measures" [6]. Singapore already started building its digital twin in high-resolution in 2014 and considers the project to be "the future of how we manage our city" [6]. Initially only for entertainment purposes,

commercial city-builder games (CBGs) have successfully portrayed and simulated complex cities for over 20 years. Because CBGs have evolved to be more complex and realistic, it is only consequential that cities have become interested in profiting from these simulations.

This paper will analyze the extent to which the commercially successful city-builder "Cities: Skylines" (C:S) covers the developments in sustainable urban planning. Simulations in C:S include effects of unsustainable developments such as toxic waste, pollution, noise, and congestion on the one hand and solutions such as recycling centers, electric cars, and renewable energies on the other hand. Due to widespread interest in sustainability, C:S received an expansion called "Green Cities" in 2017. Therefore, the game offers a unique perspective on sustainable urban development, enabling players to experiment with different sustainable strategies. To date, C:S is considered the best city-building game of all time [7] and sold over 6 million copies by 2019 [8]. Researchers like Lux et al. [9,10] and Bereitschaft [11,12] have already included C:S in their respective studies of educational potentials.

While we have these simulations, applying them to educational purposes might bring significant benefits. Thus, various authors have discussed CBGs and their application in game-based learning. Olszewski et al. [13] even described gamification as "one of the most effective ways to educate society on sustainable development" [9] (p. 2), as the players would be enabled to develop specific skills and problem-solving capabilities. Many of these publications discuss the use of CBGs in higher education. While Nilsson [10], for example, observed motivational aspects when the science students were building sustainable cities in SimCity, she also points out the possibility for the students to experiment with and apply the concepts of sustainable development in the game. According to Khan and Zhao [11], the research suggests that while their students were able to enhance "their critical thinking and problem-solving skills" [11] (p. 770) with C:S, the game also helped them solve previous understanding difficulties. While Khan and Zhao used C:S as a pedagogical tool in urban planning education, they observed that the students maintained considerable attention and perseverance as the game challenged them with realistic and complex problems [11]. Fernández and Caercero-Moreno [12] studied the application of C:S in a university course for environmentalists. They observed that while the students could build "a city model that solves the sustainability challenges of today's cities" [12] (p. 2), the game was also perceived as delightful and pleasant. Arnold et al. [13] observe that CBGs can "offer a safe space to experiment" and thus "foster the development of a deeper understanding" [13] (p. 1).

Bereitschaft [14] has reviewed the studies looking at commercial CBGs in educational settings, emphasizing the overall potential across all educational levels "to help students develop critical thinking, problem-solving, and systems thinking skills" [14] (p. 2). Bereitschaft also regards CBGs as effective at reinforcing "geographic concepts" and at "cultivating spatial reasoning" [14] (p. 23). One reason for the success of digital games, as Bereitschaft sees it, is the way they create an intrinsic motivation for problem solving within the game [14]. Due to the interest in complex systems and interconnected challenges, researchers in geography education have been studying the use of commercial simulation and strategy games extensively [9,10,14]. However, even though the educational benefits have been pointed out and reviewed, there has yet to be a detailed and qualitative game analysis of sustainable city development in C:S (or other CBGs). There needs to be a detailed observation of possibilities and tradeoffs between environmental, social, and economic sustainability within the game. The whole research field of sustainability has become so complex and diverse that a game like C:S could help learners to gain a deeper understanding of what sustainable city development means. Without a detailed analysis, there is a lack of substance behind the employment of CBGs in sustainable urban geography education. Furthermore, the analysis is necessary before discussing the potential of C:S for sustainable development education.

To address this gap, the main aim of this paper will be to analyze the extent to which the complexity of sustainable city development is implemented within the gameplay and decision making of C:S. The guiding question is the following: to what extent can players, prototypically, experience sustainable urban development in C:S? To find answers, we will

conduct a qualitative analysis of sustainable city development within the game, based on criteria from the literature. The first section will draw from the book "*Encyclopedia of the UN: Sustainable Cities and Communities*" [5] and establish an analytical framework founded on different dimensions of sustainable cities as derived from the literature. In the proceeding section, we will present the scientific methods used for the gameplay analysis. Next, the results will be outlined before the article discusses the limits and possibilities of sustainable city development in C:S. Finally, the conclusion summarizes the findings and draws educational implications.

2. Theoretical Background

According to the recent "JIM" study in Germany [15], as many as 91 percent of teenagers play digital games, emphasizing the considerable influence digital games can have on school children [15]. According to the research, digital games may offer opportunities where the formal learning environment cannot adequately accommodate all learners [9]. More practically oriented learners profit from direct feedback and learning effects within the gameplay [9]. One reason for the success of digital games is rooted in the way they create an intrinsic motivation for problem solving within the game [12]. CBGs represent a popular subcategory of digital games and offer a chance for school children to get to know the complexity of cities even though they have not been created for educational purposes. Regarding sustainable development, Meadows [16] pointed out that due to the interdisciplinary understanding of complex systems, "Geography could be considered as the science of sustainability" [16] (p. 89). The curriculum in geography education should cover cities, urban geography, and sustainability. However, teachers are confronted with the challenge of teaching complex systems and media competences. This is where the inclusion of complex commercial games and simulations in the educational setting could be helpful [9].

The concept of sustainable urban development is embedded in the 1972 report published by the Club of Rome, which pointed to "the limits to growth" [17]. Following the warning by the Club of Rome, the Brundtland Report set out the fundamentals of sustainability in 1987 [18]. When John Elkington proposed the concept of "sustainable capitalism" [19], he expanded on the idea of sustainability as a balance between different dimensions. The triple bottom line, as established by Elkington [19], is also referred to as the three pillars of sustainability. The concept suggests that the chances for successful development are limited if one of the three pillars, ecology, social welfare, or economy, is neglected. The "overall social system" can only be preserved if the subsystems "remain functional" [20] (p. 22). The three pillars of ecology, economy, and social affairs are in equally dynamic relationships [20].

The United Nations often attempted to transform the theory of sustainability into political decision making. Ambitious postulations from the "Agenda 21" to the "Millennium Development Goals", led to the extended framework of the 17 Sustainable Development Goals [21] as included within the Agenda 2030. The framework of the Sustainable Development Goals includes an individual goal for sustainable cities, called SDG 11, aiming to "make cities and settlements inclusive, safe, resilient and sustainable". The concepts behind SDG 11 paint a broader picture of sustainability than the previously mentioned pillars of ecology, economy, and social welfare. There are also other concepts and SDGs that are closely related. Among them is the concept of "people-smart sustainable cities" [22] founded on SDGs such as "Clean Water and Sanitation", "Affordable and Clean Energy", and "Climate Action".

Accordingly, there have been attempts to extend the three pillars to more dimensions. This paper will draw from a catalog called "Cities of the Future", cited by Heineberg et al. [23]. The catalog includes the three previously mentioned pillars of "environmental protection", "social housing", and "economic development" while adding "land management" and "mobility control", both highly relevant to urban development [23] (p. 145). This paper aims to align these five pillars with the encyclopedia on SDG 11 [5] by referring to the dimensions of land management, environment, mobility, social, and economy. An overview of how both the dimensions and criteria for the game analysis have been adapted from the literature is provided in Table 1.

Table 1. Dimensions and criteria of sustainable city developments as adapted from the literature.

Literature		**Dimensions of Sustainable City Development as Adapted from the Literature**				
Dimensions, as adapted from the literature	Elkington 1997 [19]		Environmental bottom line		Social equity bottom line	Economic bottom line
	Heineberg 2017 [23]	Land management	Environmental protection	Mobility control	Social housing	Economic development
	This paper	Land management	Environment	Mobility	Social	Economy
Criteria, as adapted from the literature	Leal Filho et al., 2020 [5]	Compact City, density, and mixed use	Altering land-use patterns in flood-prone areas	Attaching a price to personal vehicle travel	Education for All	Creation of green jobs
		Interconnected green space networks	Biodiversity and habitats for wildlife	Encourage walking and cycling	Equal opportunity	Energy Conservation
		Public and Green Spaces	Community Gardening and Urban Farming	Expanding public transport	High degree of participation	Energy-efficient buildings
		Spatial Resilience in Planning	Rainwater management: absorb water and cool vicinity	Reducing car dependency	High quality housing	Investment in green sectors
			Reduced air pollution		Meeting basic needs for all	Internalization of negative externalities
			Restorative and regenerative circular economy		Optimum level of public health services	Internalization of positive externalities
			Sustainable Waste Management			Renewable Energy
						Resilient and Green Building Design
						Shop Local, Local Materials, and Local Budgets

3. Materials and Methods

Following the theoretical background, this section will present the methods and materials which will help to answer the research questions of how the game's representation of sustainability corresponds to the criteria of sustainable city development. The previously established criteria and dimensions form the framework for the qualitative game analysis along the lines of Lux and Budke [24]. Similar to the approach by Lux and Budke [24], the analysis also aimed for an experimental exploration and documentation. The research methodology employs two perspectives and two forms of qualitative game analysis. The first one observes the actual consequences of sustainable city building in C:S and the feedback generated by the game. The second part of the analysis identifies and lists sustainability-related features, measures, and construction projects within the game design of C:S.

To enable the analysis, the game was studied, played, and analyzed on the Steam gaming platform using Windows and Mac devices. The authors focused on valuable extensions or downloadable content (DLCs) such as "Green Cities", "Mass Transit", "Train Stations", "Industries", "Sunset Harbor", and "After Dark". These DLCs are considered useful for analyzing sustainable city development as they introduce new components into the game. In order to comprehensively capture the scope of possibilities and game mechanics, the analysis required 305 h of gameplay, during which in-game events were documented through tables, notes, and screenshots. The playtime was conducted by one of the authors without any prior experience with the game or other CBGs. During the 305 h of gameplay, the author experimented with the possibilities of building a sustainable city. Each dimension of sustainability was thoroughly reviewed by playing the game with all the different options available.

As mentioned, the authors pursue a qualitative analysis approach by exploring sustainable city development within C:S from two different angles. One angle is focusing on feedback within the game, while the other angle is looking at features in the game. The first part of the analysis aims to document the in-game feedback and consequences that come up when players try to implement as many sustainable features and measures as possible. Thus, each criterion and dimension from Table 1 needs to be observed to document the findings. For transparency, Table 2 lists some guiding questions, which were used to analyze the in-game feedback. The "land management" dimension is supposed to look at effects that come with interconnected green spaces in comparison to the effects small neighborhood parks have on the citizens. For the "environment" dimension, one might observe whether the agriculture industry in C:S can be combined with urban life and whether agriculture has an effect on the environment in C:S. Within the "mobility" dimension, we should look at the economic effects of prices being attached to personal vehicle travel. The "social" dimension prompts questions regarding the value educational and health care investments have in the game. Finally, in the "economy" dimension, the research could focus on the incentives for energy efficiency. These criteria and questions help assess the impact of different urban development decisions within the game. The observations should include conflicting goals, reductions, possibilities, and in-game feedback as valuable insight into the gameplay, as put forth by Czauderna and Budke [14].

To identify and list sustainability-related features, measures, and construction projects, the second part of the analysis looked at different levels in C:S, as new features are often unlocked with each new level, called a "Milestone". After identifying sustainability-related features, they were listed and categorized in a table with the different levels ("Milestones") of C:S on the y-axis. To analyze the different features, the authors used the previously established dimensions and criteria of sustainable city development and allocated the features accordingly, as can be seen on the *x*-axis in Table 3.

Table 2. Examples of how the different dimensions of sustainable city development were observed in regard to feedback and gameplay while building sustainable cities in C:S.

Dimension as Derived from the Literature	Example Criteria for Observation	Example Questions for Observation Regarding Feedback to Sustainable Planning, etc.
Land management	Compact City, density, and mixed use	Can I combine commercial districts with residential housing?
	Interconnected green space networks	How does it affect the residents when I build one park vs. a network of parks?
	Public and Green Spaces	Are parks and plazas commercial or accessible to the public?
	Spatial Resilience in Planning	Is infrastructure exposed to flood risk or landslides?
Environment	Altering land-use patterns in flood-prone areas	Is there a possibility to build green infrastructure in flood-prone areas?
	Biodiversity and habitats for wildlife	Do natural habitats and wildlife lead to positive feedback within the game?
	Community Gardening and Urban Farming	Can the farming industry in C:S be of benefit for urban life and the community?
	Restorative and regenerative circular economy	Is the garbage manageable while relying mostly on recycling?
Mobility	Attaching a price to personal vehicle travel	Is there a way to internalize the cost of environmental damages?
	Encourage walking and cycling	Is there a way to measure the modal share of walking and cycling?
	Expanding public transport	Which transport modes are most and least cost-effective?
	Reducing car dependency	Is there less car traffic once alternatives such as public transport and bicycle lanes are set up?
Social	Education for All	Is it possible to allocate sufficient funds so that all residents have access to education?
	High degree of participation	Is there any sort of participation within the game?
	High quality housing	How affordable is it to focus on green self-sufficient buildings?
	Optimum level of public health services	Is there positive feedback when a lot of public health services are provided?
Economy	Creation of green jobs	Are jobs only in industry and retail or is there also a green jobs sector?
	Energy Conservation	What are the incentives to save energy?
	Energy-efficient buildings	Is there positive feedback in the game when self-sufficient buildings are being built?
	Internalization of negative externalities	What happens when negative externalities are internalized?

Table 3. Own analysis of rising options that come with each new level in C:S combined with an analysis of options for sustainable city development as derived from the literature.

Milestones in C:S	Dimension of Sustainable City Development				
	Land Management	**Environment**	**Mobility**	**Social**	**Economy**
1. Little Hamlet (Population 460)		Recycling center		Elementary school	Tax
				Private school	Loan
		Landfill site		Medical clinic	
2. Worthy Village (Population 900)	Districts	Green buildings			Power usage
		Organic and local production			
		Forestry			
		Agriculture			
		Policies: Water usage			

Table 3. *Cont.*

Milestones in C:S	Dimension of Sustainable City Development				
	Land Management	**Environment**	**Mobility**	**Social**	**Economy**
3. Tiny Town (Population 1400)	13 parks and recreation facilities	Fishing industry	Efficient logistics	Workers' rights	
				Buildings: High school	
				Public library	
	increased effort for parks and recreation		Bicycle path	Gym	
4. Boom Town (Population 2600)		Recycle	Taxi	Cemetery	Extra insulation
			Ferry	Eldercare	Ore industry
		Plastic recycling	Bus	Child health center	Offshore wind turbine
		Fish factory	Toll booth		
5. Busy Town (Population 5000)	Tropical Garden	Algae-based water filtering	Trolleybus	Workers' union	Filter industrial waste
			Free public transport	Hospital	Geothermal power plant
			Heavy traffic ban		
			Combustion engine ban		
			Electric cars		
			Encourage biking		
			Roads with bicycle lane		
6. Big Town (Population 8000)	Tax raises for low-density Tax reliefs for high-density	Sustainable fishing	Intercity bus	University	IT Cluster
		Dolphin-safe fishing	Metro	Modern technology institute	Solar updraft tower
		Incineration plant	Tourist travel card	Education boost	Industry 4.0
7. Small City (Population 11,000)	Highrise ban		Trains		Hydro power plant
	Smart homes		Monorail		
	Yoga garden		Cable car		
8. Big City (Population 18,000)		Advanced water treatment plant		Crematorium	
		Floating garbage collector			
		Large water tower			
9. Grand City (Population 22,000)		Waste transfer facility			Solar power plant
		Waste processing complex			
10. Capital City (Population 36,000)		Eco advanced water treatment plants	Harbor		
			Cargo harbor		
11. Colossal City (Population 48,000)			Helicopter depot		Nuclear power plant
			Cargo hub		Ocean thermal energy Conversion plant
12. Metropolis (Population 70,000)			Airport		
			Cargo airport		
13. Megalopolis (Population 90,000)			Metropolitan airport		
			Cargo airport hub international		

The observation method was deemed appropriate as it allowed for the documentation of in-game events through tables, notes, and screenshots; helped to identify conflicting goals, reductions, and possibilities; and the feedback was received from the game. Thus, the observation also served as a kind of reality check to examine the actual consequences of building a sustainable city in C:S. The content analysis was chosen as it enables the identification and analysis of sustainability-related features, measures, and construction projects in the game, which could be assigned to the established dimensions of sustainability. Overall, the combination of content analysis and observation enabled a thorough exploration of sustainable city development within the game.

This section has presented the methods and materials used in conducting a qualitative analysis of C:S to explore sustainable city development within the game from two different perspectives. The next section will present the findings of the study, describing the results of the first part of the analysis and summarizing the second part of the analysis in Table 3.

4. Results

After establishing the methods and the analytical framework, we will proceed with the results. Because not all aspects can be discussed within the limited space of this paper, Table 3 is supposed to give an overview of the results. Through the exemplary discussions of some of the findings, the reader may gain a deeper understanding of the results.

In Table 3, the features of each level are listed and categorized with the levels along the y-axis and the dimensions along the *x*-axis. To analyze the different features, the authors used the previously established dimensions and criteria of sustainable city development and allocated the features accordingly. Therefore, Table 3 provides an overview of the scope of options in regard to sustainable city development within the game. The scope of options regarding sustainable city development is seen as an indicator of the quality of simulated city developments in C:S. The different levels in C:S as listed in Table 3 are reached with increasing population size. When players attain a certain population size in their city, they reach a new level ("Milestone"). Each new level comes with new features such as land, buildings, loans, and policies. Sustainability-related features are listed and categorized on the y-axis. The previously established dimensions and criteria of sustainable city development are allocated on the *x*-axis in Table 3.

To give an example, we can look at the fourth level in C:S called "Boom Town". The first step of the analysis shows that added toll stations offer new possibilities to attach "a price to personal vehicle travel", which is a criterion within the sustainable mobility dimension in Table 1. However, because the cost of a toll station is higher than the cost of a cemetery, the goal of attaching a price to personal vehicle travel can conflict with the goal of a healthy city, which is part of the social dimension. Thus, due to an always limited budged and the importance of burying the dead, the player has to deal with a polytelic situation [14]. Another example for the results of the analysis within this paper can be found in the sixth level of C:S called "Big Town". This level comes with a swath of new features that could all be deemed as beneficial for sustainable city development. However, because not all features can be implemented within the limited budget, players have to decide, for example, between tax raises for low-density developments, which are neither compact nor sustainable, and investing in the policy of an educational boost, strengthening the goal of social sustainability. However, this can lead to further conflicts of interest, e.g., polytelic situations, because raising taxes may lead to citizens leaving town, thus negatively affecting population size and budget. All the while, the budget needs be high in order to invest in an educational boost or university. These examples and Table 3 show that each new level brings new possibilities in C:S and Table 3 also shows that many of the unlocked features can be aligned with the dimensions and criteria, as established from the literature.

The analysis shows that all dimensions of sustainable city development derived from the theory are included in the game design and can therefore be experienced by the player. It also implies that the scope of available sustainability measures increases significantly over the course of the game. While in the first level, only a few measures in the environmental,

social, and economic dimensions of sustainability are available to the players, and land management and mobility measures cannot be carried out yet. Finally, in the last level (level "Megapolis", see Table 3), comprehensive measures for sustainable city development are available in all dimensions. This progression probably corresponds with the constantly increasing skills of the players on the one hand and with an actual increase in complexity and planning possibilities on the other hand. After all, Table 3 gives an overview of the increasing potential of building a sustainable city with each new milestone. However, because players can hardly implement all features, buildings, and policies at once, we will now take a closer look at how the different dimensions have been implemented in the gameplay and what typical feedback is included in the game.

4.1. Land Management

At the beginning of the game, it is both possible and advisable to build mixed-use, compact, and dense infrastructure corresponding to the criteria and indicators of sustainable city development as documented in Table 1, because there are simply not enough resources for urban sprawl. Thus, players can build a dense, mixed-use 15 min city corresponding to what Paris and Barcelona are trying to achieve [3]. In this context, Figure 1. shows, for example, the possibility of simultaneous use of an area as an interconnected green space and as a traffic route for public transport.

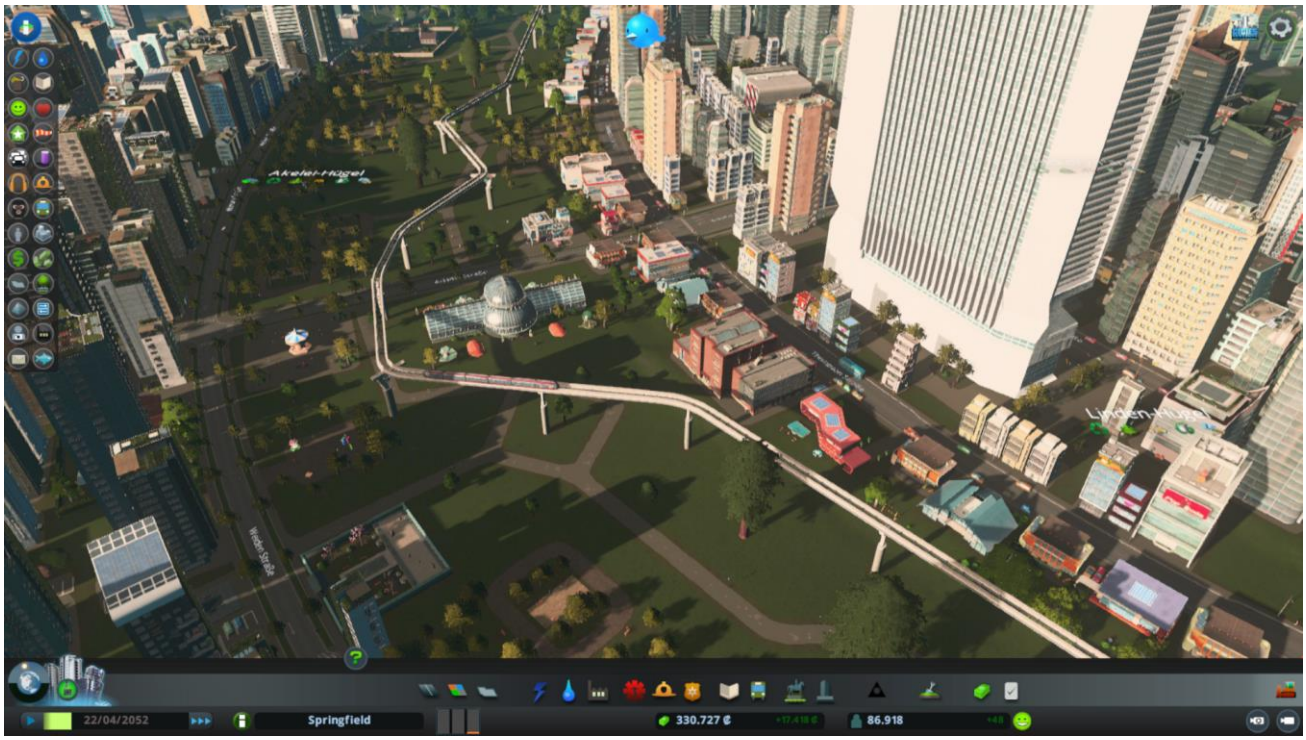

Figure 1. Screenshot showing mixed-use and green infrastructure including parks, plazas, and monorail in C:S. (Source: Picture with approval from Paradox Interactive's award-winning and critically acclaimed video game Cities: Skylines).

Compactness becomes less critical in the latter stages of the game as new squares are added with new milestones. Thus, players do not need to dedicate that much attention to compactness, mixed use, and short distances at the later stages of the game. This development is emphasized by the dependence on pollution-heavy industries and energies which becomes less and less severe in the later stages of the game (Table 3). However, noise pollution, air pollution, and soil contamination stemming from industrial areas make it much harder to achieve the goal of building a sustainable mixed-use city, because the amount of pollution may lead to parts of the land becoming uninhabitable and affect the

health of the population. Only in the final stages of the game do modern technologies and clean energy solutions become much more affordable due to the increasing budget available to the player with each new level. Pollution-heavy industries can then be replaced with office buildings and renewable energies (economy, Table 3), making the goal of a sustainable city much more accessible. However, as the city grows, the density may become so high that residents in C:S begin to complain about the noise in narrow streets with high-rise buildings. In that case, it only helps to further increase the sustainability by banning combustion engines and building tree-lined avenues and green spaces between the buildings (dimensions environment and mobility, Table 1).

In contrast to the sustainability paradigm, the wide-open green spaces that dominate the map initially do not have a qualitative effect on the gameplay. Players must invest in green infrastructures such as parks and plazas to obtain the positive feedback of birds circling in the sky and to satisfy the citizens. Making the wide-open spaces impervious by expanding the city does not affect the citizens or birds, thus contradicting the aim of a sustainable sponge city. Ambitious projects like a Central Park, or a large green belt, as seen in Figure 1, look nice in the game but do not satisfy the residents in the game more than small parks and squares spread across the city, even though interconnected green space networks are more sustainable (land management, Table 1), and they also feature mixed-use development of sustainable transport, offices, accommodation, and leisure in the gamely example (Figure 1 and Table 1).

4.2. Environment

The landscape at the beginning of the game depends on players choosing between "boreal", "european", "temperate," "tropical" climates, and more. Independent of the chosen map or climate, the players have the possibility to add biodiversity (environment, Table 1) with a biotope for birds and bees that can be landscaped like the wide variety of parks later on. The "Green Cities" DLC adds green buildings (economy, Table 1) to the equation, so that the built infrastructure can also contribute to water infiltration, photosynthesis, and air cooling (rainwater management, environment, Table 1). This enables the city to become more sustainable and act like a sponge, thus adding resilience to heatwaves and floods.

With the "Industries" DLC, agriculture, forestry, and mining are introduced to C:S. However, these industries are not sustainable per se, because mining causes pollution while agriculture and forestry mainly consist of monocultures, cattle farms, slaughterhouses, tree plantations, and sawmills. Nevertheless, the "Industries" DLC offers a chance to establish a local supply chain (economy, Table 1). A local supply chain does not only make agriculture more sustainable (urban farming, environment, Table 1) but also helps the green energy sector to source resources needed for solar panels or electric car batteries locally. In addition, local forestry can be of great importance for sustainable timber construction in the building sector, as in the green buildings (resilient and green building design, economy, Table 1) featured in the "Green Cities" DLC.

As far as the water supply and sanitation are concerned, there are various possibilities for water treatment, even some very sustainable methods such as ecological algae treatment. However, for in-game success, the water management does not necessarily need to adhere to the sustainability standards from Table 1. As long as the wastewater flows downstream and away from the city, the citizens are just as happy and healthy as with a sustainable water management strategy. Because the game is limited to one city, there is no feedback from any city further down the stream.

As far as the need for green areas in contrast to impervious surfaces is concerned, the game has the feedback of birds drawing circles in the sky over self-built green infrastructure like parks and plazas. However, the game does not feature feedback regarding the abundant open green spaces that make up most of the blank map at the beginning of a game or any other part of the city. Thus, in contrast to sustainable city development, the sealing of green spaces does not have the negative feedback it should have.

Managing the garbage in a way that keeps the population happy and healthy can be relatively demanding in C:S, even more so when aiming for sustainable waste management (environment, Table 1) or a circular economy with close to zero waste and a high degree of recycling. A "Metropolis" (highest milestone, see Table 3) needs a minimum of 10 waste handling facilities, 12 recycling centers, 1 waste processing plant, and 395 garbage trucks. Players need to be careful that there are no gaps in the supply, that all houses can be reliably reached by garbage trucks, and that none of the facilities are overcrowded. Otherwise, warning symbols with the note "piles of rubbish" appear. If the issue is not resolved quickly, the building is in danger of being vacated. When housing is constructed near an incineration plant, the population is also at risk, because garbage managing facilities cause heavy pollution, as can be seen in Figure 2. Even though recycling centers are essential to sustainable waste management and cause lower pollution levels in their surroundings (environment, Table 1), recycling does not accomplish wholly avoided residual waste in C:S.

Figure 2. Screenshot showing dead trees and bushes as impact of waste handling facilities on the environment in C:S. (Source: Picture with approval from Paradox Interactive's award-winning and critically acclaimed video game Cities: Skylines).

4.3. Mobility

When players look for a sustainable solution to the traffic problem, bus transit (expanding public transport, mobility, Table 1) is the only possibility at the beginning of the game and is only introduced with milestone 4 "Boom Town" (Table 3). While a comprehensive bus network adds to the residents' satisfaction, the gameplay entails the risk that the traffic problem is worsened when buses clog the streets. Other sustainable infrastructure such as regional trains, subway trains, and monorails are added as the game progresses (reducing car dependency, mobility, Table 1). However, the construction of infrastructure for these measures is relatively expensive and can lead to a conflict of interest. The subway tunnels are particularly costly and require money, which may then be missing or needed more urgently elsewhere, thus signifying a conflict of interest, characteristic for the political landscape. Nevertheless, the game has significant advantages over real world transport policies, as no construction time needs to be considered and no political decision process is involved. Therefore, even ambitious infrastructure projects like train or subway networks can instantly add to the quality and sustainability of the public transport network in C:S.

Suitable policies can accompany and support all mobility measures. Players can enact a sustainable transport directive to promote cycling (mobility, Table 1), they can offer local public transport free of charge, and players can comprehensively restrict motorized

traffic. The restrictions are enacted through toll stations and guidelines prohibiting high traffic volumes or internal combustion engines (attaching a price to personal vehicle travel, mobility, Table 1). These measures are supplemented by the possibility of funding electric cars (reduced air pollution, environment, Table 1). As far as the essential and sustainable transport mode cycling is concerned, the "After Dark" DLC entails the option of building separate cycle paths in milestone 3 and roads with cycle lanes in milestone 5 (Table 3). Strangely, there are no tree-lined avenues available that have a cycle lane. As a result, residents are dissatisfied when a street with cycle lanes replaces a tree-lined avenue. In addition, the influence of cycling on traffic remains questionable because no data on cycling can be found in the gameplay statistics. The game visualizes a lot of bicycle traffic on the routes provided, but no effects can be recognized, thus turning bicycles into simulation without any impact on the success of the game.

Contrary to the sustainability paradigm, roadbuilding is an essential part of playing C:S from the very beginning. Wrong decisions and small streets in the initial stages of the game can lead to significant traffic problems as the game progresses. Congested streets then lead to health and security issues because emergency vehicles and garbage trucks are stuck in traffic. These problems can be expensive to resolve. In order to cover previous mistakes, players might have to build an excessive number of bridges to fix the mobility network (see Figure 3) or players might have to tear down whole neighborhoods to add train tracks and stations. The focus on roadbuilding is emphasized by the number of suggestions and info-panels, which repeatedly appear on the screen explaining how to achieve better traffic flow. The proposals include roundabouts, motorway junctions, and a reduction in intersections.

Figure 3. Screenshot showing the infrastructure necessary for convenient mobility for goods and people in C:S. (Source: Picture with approval from Paradox Interactive's award-winning and critically acclaimed video game Cities: Skylines).

4.4. Social

Regarding the growth and happiness of the population as parameters for success in C:S, sustainable social aspects such as education, health care, and workers' rights (social dimension, Table 1) all contribute to a successful game. One aspect of healthy and sustainable cities is sport venues and parks providing the opportunity for physical education and adding to an optimum level of public health (social dimension, Table 1). However, while horse riding, basketball courts, skate parks, and large gyms are all available, the game does not show a measurable effect on the citizens' health.

Health care is rather used as an indicator of problems with rubbish, noise, and pollution, prompting players to provide sufficient health care services with hospitals and doctors' offices on the one hand and prompting players to protect their citizens from any harmful impact on the other hand. Children's hospitals and retirement homes supplement these options. When adding crematoria and cemeteries to the equation, the overall demand of the health care sector becomes challenging to meet, especially when players also aim to prioritize education in line with the SDG 11 goal of "Education for All" [25]. Many schools need to be built to educate all citizens. Educational facilities include elementary schools, high schools, universities, and public libraries.

For the citizens' satisfaction in the game, it is vital to develop a qualified workforce through good education for all (social dimension, Table 1). The education tool in C:S provides an overview over streets with good educational provision in green and others in grey (see Figure 4). If the streets stay gray, a school should perhaps be built there. Providing an excellent educational supply to all residential areas, including libraries and higher education, is very costly across the game (economy, Table 1). However, the effort is necessary because uneducated citizens pile up the rubbish and do not qualify for jobs, resulting in businesses going bankrupt, thus limiting revenue and green growth. Therefore, it is not only the goal of social sustainability that drives the importance of education in C:S but also the importance of education for the labor market, taxes, and the cities' budget. Here, one should also take the importance of sufficient funding for renewable sustainable energy, sustainable housing, and mobility into account. Therefore, players need to pay attention to the incoming revenue, taxes, and ongoing expenses, leading us to the next dimension of the economy which can be additionally affected by social measures such as occupational safety, trade unions, workers' rights, and labor laws (social dimension, Table 3), all featured in C:S.

Figure 4. Screenshot showing the demand for educational facilities along the grey-colored streets in C:S. (Source: Picture with approval from Paradox Interactive's award-winning and critically acclaimed video game Cities: Skylines).

4.5. Economy

While sustainable wind turbines are available from the start of the game (Table 3, Figure 5), it is nearly impossible to solely rely on wind power (renewable energy, economy, Table 1) while building a city from scratch. Wind power does not satisfy the energy needs of a small but growing city. Hence, players rely on unsustainable energy sources and fossil fuels. New features added in milestones 4 and 5 make the goal of green investments, energy, and jobs much more attainable. Adding renewable energy sources such as offshore wind turbines, geothermal energy, and solar plants to the energy mix helps to reduce pollution and helps to build a sustainable city (economy, Table 3).

Figure 5. Screenshot showing a city in C:S with wind turbines and a geothermal power plant close to the chimneys of pollution-heavy industry. (Source: Picture with approval from Paradox Inter-active's award-winning and critically acclaimed video game Cities: Skylines).

When it comes to economics, the most challenging feature of C:S is balancing the budget with the energy supply because it is always cheaper to rely on fossil fuels than on renewable energies. However, with the compact layout at the beginning of the game, pollution can risk the citizens' health if one relies on coal-fired power plants. On the other hand, a city can run out of money very quickly and go bankrupt when players try to rely on expensive renewables too early. Thus, building a city with coal power is easier, especially when the pollution is separated from residential areas. If the industry is built a little further away from the city, with commercial areas in between, the pollution has little effect on the residents' satisfaction. This way, C:S offers a path to completely ignore sustainable energy sources, because energy can be generated cheaply right from the start of the game without significant negative impact on the residents' satisfaction or the growth of the city. On the other hand, Table 3 shows that the variety of energy sources in the game offers the unique opportunity to envision a carbon-neutral economy.

5. Discussion

In order to interpret the results, we will discuss the possibilities and limits that come with sustainable city development in C:S, and the question of why some aspects seem integrated into the gameplay while others seem neglected. In Table 1, the analytical

framework initially divided sustainable urban development into the five dimensions: land management, environment, mobility, social dimension, and economy. For each of the dimensions, Table 1 also derived indicators from the literature [5,19,23], serving as a measure for sustainability in the analysis. In the subsequent section, this paper then decomposed the scope of possibilities and gameplay mechanics in each dimension.

As an essential outcome of the analysis, it seems to be clear that C:S incorporates a high scope of possibilities regarding the scientific criteria and indicators of sustainable city development. While Lux et al. already emphasized the potential for players of CBGs to "explore the connection between different concepts relevant in cities" [10] (p. 25), the number of measures contributing to sustainability in C:S seems noteworthy. For example, C:S entails not only a wide range of sustainable transport networks and renewable power plants but also a variety of progressive policy measures (e.g., workers' rights and unions, social dimension, Table 3).

The in-game feedback in C:S is only concerned with the residents of one isolated city which is currently being built, thus making it easier to focus on the sustainability of one particular city. While renewable energies seem to be the state of the art in C:S (thermal, nuclear, and solar, economy, Table 3), it would be desirable to be one step ahead in other areas as well. Especially in urban farming, there are cities like Singapore with aquaponics [26] and New York City with community gardens [27] that show how social and environmental sustainability can align in the urban context. Furthermore, there are no new technologies that can be applied in C:S regarding waste disposal and recycling, thus making it impossible to reach the goal of a circular economy, and it is impossible to experience what a circular economy might look like in cities of the future. The number of waste facilities and waste trucks that are deemed necessary seems to be very high, compared to the population, while offering no chance of reducing the amount of waste in the game. However, even if players were aiming to reduce waste in their city, it is only realistic that no solution has been included in the game yet. Once cities make progress in the elimination of waste, these solutions would probably be included in the game as well.

It may also be important to emphasize that players do not have to build sustainable cities in order to be successful, they only have to build a large and prospering city with happy residents. Players not paying particular attention to sustainability do not necessarily risk their city descending into garbage and pollution. In fact, it seems as if cities solely relying on coal-fired power plants and dirty industries, and cities completely lacking public transport, can still be prospering cities with happy residents, while players are not seriously confronted with the consequences via in-game feedback. The only prerequisite seems to be that the pollution from coal-fired power and sewage stays on the outskirts of town and traffic is kept out of the neighborhoods. If the dirtiest sewage is drained into the nearest river, it does not upset the residents and does not affect success as long as the current carries the polluted water away.

Thus, C:S does not really seem to make the concept of "sustainable urban development" tangible but rather uses "sustainable urban development" as a ploy that does not seem significant for the in-game success. Success rather comes along with satisfied residents and an increasing population. Additionally, it appears questionable that many of the measures which add sustainability to the city do not include significant in-game feedback, thus leaving it mostly to the player to apply sustainable urban development. Other scholars have also pointed out the CBGs seem rather unbalanced in their focus on infrastructure [9,12]. This also seems to be true for C:S where the gameplay time seems predominantly occupied by infrastructure management rather than the socio-cultural challenges of growing and diverse cities [12].

When looking at the limitations of C:S both within the results of the analysis and within the literature, the following questions should be considered: Why is there no significant in-game feedback for sustainability? Do we need in-game feedback for educational benefits? Why do the developers have this intense focus on building infrastructure? Why is there recycling without the possibility of implementing a circular economy even though the

range of possibilities is so high in other sectors? Why do the effects of unsustainable city development only include one city? Why does the game reward growth rather than quality or sustainability? Discussing possible answers to these questions leads us to three different explanations. The first is that the game is more entertaining with these limitations, one points to potential biases within the game development, and the third considers a rather simple lack of awareness regarding current trends and research in sustainable urban development.

It would not be surprising if C:S focused mostly on infrastructure and technology as this seems to be a common characteristic as Lux and Budke have pointed out [9]. Additionally, it makes sense that, as Czauderna and Budke [14] have emphasized, the scope of measures needs to be limited in order to "ensure motivation" (p. 12). However, this leads us to the possible second explanation. The limitations of the games could also point to biases and preconceptions in the way the game was constructed by the game developers. As Bereitschaft [11] poignantly put it, "every selection implies a risk of being biased" (p. 51). The bias stems from the prejudice and assumptions the developers have "regarding how cities ought to look and function" with one example being the way C:S focuses on roadbuilding [11] (p. 51). Still, biases are not the only sources of misconceptions in game development. What if the limitations rather stem from a lack of awareness? If the developers are not aware of community gardens, the goal of a circular economy, or the overall potential of truly sustainable cities, it comes as no surprise that these features are not included. However, it would be helpful if the developers of C:S took a closer look at current scientific research and the UN Sustainable Development Goals for any future developments.

After all, C:S prompts players to decide between different sustainable and non-sustainable measures on a limited budget without offering a clean energy pathway. Thus, the game might be considered the right game for our time and not for the implementation of the city of the future. Players must make individual decisions and focus on variables such as the budget and the overall happiness of the population. These variables make it impossible to build a city without significant environmental impact. Still, C:S offers the possibility to experience conflicting goals and polytelic situations that are characteristic to decision making in the context of sustainability politics and city planning [28]. The complexity of sustainable city development with differing needs, goals, politics, and limited budgets can therefore be experienced within the game. This benefit was also pointed out by Czauderna and Budke, who stated that commercial strategy games could be used "to facilitate a better understanding of complex problems and teach reasonable decision-making" [14] (p. 1). While C:S offers the benefit of being detailed and complex, the way the game nearly omits the possibility of focusing on sustainable city development seems fairly conventional.

However, limitations of this study include its focus on only one computer game, which limits the generalizability of the finding. Additionally, the study relied solely on observation and content analysis and did not include interviews or surveys, which could potentially introduce bias through researchers' interpretations of the game's features.

6. Conclusions

With the discussion of possibilities and limits of C:S in mind, we will now conclude with a look at educational implications and an outlook for further research. Altogether, the analysis underlined the opportunity for a deep dive into sustainable urban planning within the gameplay of C:S. A deep dive also offers the chance to take the time and reflect on the gameplay, leading to more successful learning outcome, as put forth by Lux and Budke [29]. Thus, it makes sense to consider the application of C:S to an educational setting, such as a geography classroom covering urban geography and sustainability. Pupils have to learn about the human–environmental interaction between topics such as resources, climate, cities, and more [24].

While C:S offers the chance for young learners to experience the complexity of sustainable city development, teachers can utilize the shortcomings to discuss urban planning in an

educational setting. This approach was put forth by Czauderna [30], who suggested using the shortcomings of the strategy game "Democracy 3" as a prompt for learning outcomes in school. Thus, teachers could ask the pupils about the shortcomings and discuss in class which kind of feedback they would have expected [29]. Comparing C:S to "Democracy 3" also leads to the critical issue of a limited number of actors included in C:S. Players reign with autocratic power and do not have to discuss their decisions with democratic institutions. Thus, teachers using C:S in an educational setting must be aware of this lack of democratic understanding. This aspect was also pointed out by Bereitschaft [11], who poignantly referred to the almighty single players as "gods of the city". Therefore, teachers should carefully consider the limited number of actors. Khan and Zhao (2021) also point to the "vital role" of the teacher in order to "draw out the maximum pedagogic potential" [31] (p. 769). The recommended "experimental learning" approach with a "debriefing", i.e., a joint reflection on the possible gaps and shortcomings, was also emphasized by several researchers [30–32].

Another aspect that could prompt a debriefing or reflection in class is the prevalence of economic growth in C:S. In the context of education for sustainable development, the pupils could compare and discuss how the city development in C:S aligns with green growth and degrowth to come up with an informed opinion that reflects the economic interest and "the limits to growth" [17]. When utilizing C:S in geography education, there could also be a discussion of how the SDGs could be implemented and prioritized. Can we consider all 17 sustainable development goals equally important, or is "SDG 13 climate action" [18] the most urgent goal with significant effects on all other goals? While no specific goal was prioritized during the analysis of C:S, there were clear interactions between goals such as clean energy and good health [18]. These interactions led researchers such as Alcamo et al. (2020) to suggest that countries should focus on goals that combine to "synergy drivers" and avoid negative interactions leading to "trade-offs" [33] (p. 1562).

A similar concept to that of the sustainable city, evolving around similar SDGs, is the concept of the smart city or "people-smart sustainable city" as put forth by the United Nations [22]. The SDGs this concept refers to are "good health and well-being", "clean water and sanitation", "affordable and clean energy", "decent work and economic growth", "industry, innovation and infrastructure", and "responsible consumption and production" [22]. The mentioned SDGs can be seen parallel to the previously established dimensions. Thus, they offer an additional option for C:S in geography education.

A different way to apply C:S to a school setting could be to play short C:S scenarios, thus limiting the playtime and providing an overall theme. Scenarios in C:S are short games with an established city where the goal is to solve a given problem. These problems relate to a city's carbon footprint, water pollution, traffic problems, or green infrastructure. The developers of C:S even tried to tailor specific scenarios for educational purposes; however, the educational partner "TeacherGaming" went out of business in 2021 due to a lack of commercial success [34]. After all, the analysis showed astonishing detail and many scientific criteria that are included in C:S. When combining these findings with the motivational benefits of digital games, there is a clear potential to expand the theory of urban geography and sustainable cities with experimental learning and gamification. While sustainable city development remains complex and will evolve, we can expect to see the game C:S evolve, with the sequel called "Cities: Skylines 2" already in preparation. The official announcement trailer on "Youtube" had two million views within two weeks, further emphasizing the importance of this article [35].

In conclusion, C:S offers a vast digital space of urban development where learners can practically experience the interconnectedness of urban geography and sustainable cities. By engaging in the game, learners can understand the complex criteria behind the sustainable development goal of "sustainable cities and communities" and explore different solutions while having meaningful fun driving their simulated cities towards more sustainable futures. Further research is suggested to explore ways of incorporating elements of C:S into lesson plans to maximize meaningful learning for learners of different ages

and backgrounds. There is also potential for research on balancing tangible learning goals regarding sustainability and urban geography with fun and engaging game mechanics in C:S. Finally, research could be conducted to better understand the real-world implications of players' decisions and practices in C:S.

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