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# URBANLEMMA: A SERIOUS GAME TO SUPPORT THE ADOPTION OF SUSTAINABLE URBAN DRAINAGE SOLUTIONS

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## Abstract

Long-term planning of urban drainage systems is required to prevent pluvial flooding and the effects of droughts. Sustainable urban drainage systems (SUDS), e.g., permeable pavements, detention ponds, and rainwater harvesting systems are increasingly used to manage water and build resilience in urban environments. However, the adoption of these solutions remains low due to various socio-institutional barriers. Improving awareness about SUDS and highlighting their multifunctional benefits and trade-offs through an engaging medium could help address these barriers. Serious games provide an immersive and engaging experience that can be used to motivate and impart knowledge or train skills to improve decision-making. The potential of serious games to support the adoption of SUDS has not been investigated so far. This paper presents the proof-of-concept of the serious game UrbanLemma, designed to improve awareness and decision-making of stakeholders about SUDS along with the additional goals of increased engagement and communication among stakeholders. Initial results from play-test sessions conducted with researchers at TU Delft are presented and lessons learned from the game development process are discussed.

**Keywords**
SUDS, Pluvial flooding, Urban water management, Serious games, Adoption, Decision-making.

## 1 INTRODUCTION

Urbanization has become a global phenomenon and it is expected that 60% of all population will be living in urban areas by the year 2050 [1]. A consequence of increasing urban densities is that cities across the world are facing stormwater management challenges. Pluvial flooding occurs when the underground sewage networks cannot drain the stormwater. Contrary to the assumption that pluvial flooding is a minor 'nuisance', it can lead to direct loss of life, contamination of surface bodies, disruption of transportation networks, and cause damage to property and critical infrastructure [2]. Furthermore, the drivers of climate change and increased urbanization are expected to increase the risk of flooding in the coming years [3], [4]. Extreme rainfall events may occur more frequently leading to more stormwater being processed by the urban water system and higher peak discharges due to decreased perviousness of the ground.

Piped drainage systems have been the traditional response to stormwater management. But this solution can no longer deal with the impacts of climate change and increasing urbanization [5], [6]. Given this situation, sustainable urban drainage systems (SUDS) have become a widely utilized solution to deal with the risk of urban flooding. The SUDS approach is to reduce the quantity of runoff water that enters the underground drainage system by harvesting, infiltrating, slowing, storing, conveying, or treating the runoff on-site [7]. By doing so, the downstream flood risk is managed and the risk of the runoff causing pollution of the receiving water body is also reduced. Typical examples of SUDS include green roofs, rainwater harvesting systems, permeable

pavements, swales, bio-retention systems, pervious pavements, and wetlands among many others.

Although SUDS are widely considered as a core stormwater management strategy, they have not yet received widespread uptake and their adoption remains patchy [8], [9]. Several studies exploring the barriers behind the low adoption of SUDS highlight that the barriers are not technical but rather socio-institutional in nature [5], [9]–[11]. Key barriers to the adoption of SUDS include lack of awareness/knowledge, and lack of cooperation and coordination among stakeholders involved in decision-making [12]–[15]. To overcome these barriers, suggested strategies include engaging stakeholders and raising awareness around SUDS, and promoting their co-benefits [15], [16].

Serious games are a promising solution to overcome the above barriers. These are games that not only entertain but are developed to achieve a more serious purpose such as education, skills training, understanding people's behaviours, or inducing a behaviour change [17]. Serious games have been widely used to support many urban water management problems such as water distribution, flood prevention, and urban infrastructure management [18]–[20] but their application to improve awareness about SUDS has not been attempted so far. To do so, we present a proof-of-concept of a serious game called Urbanlemma in this paper.

## 2 BACKGROUND

### 2.1 Barriers to adoption of SUDS

SUDS are generally accepted as a more sustainable approach to managing stormwater. Although they cannot replace the underground sewage networks entirely, they have great potential to reduce peak runoffs and provide additional water storage that can provide benefits such as biodiversity, heat stress reduction, groundwater recharge, recreation, and improvement in aesthetics [21]. Even though the benefits of SUDS are abundant and their technical performance is established, their adoption remains low and patchy.

Many studies that have explored the barriers to adoption of SUDS establish that the adoption is low not due to technical but socio-institutional barriers. These studies recognize that lack of knowledge and awareness about SUDS and their functions is one of the key barriers to their adoption [9], [11], [13]–[15], [22]. For instance, in a review of 85 studies reporting knowledge, attitude, intentions, and behaviours towards SUDS, general awareness about different types of SUDS, their ecosystem services, and stormwater best management practices was found to be low [11]. Low public awareness of urban drainage issues can impede public participation in local water management issues and create resistance to the adoption of SUDS [22]. A study conducted on residents in Amsterdam, Netherlands further shows that although citizens are aware of the problem of urban flooding, it is not enough for residents to adopt SUDS [23]. In addition to educational barriers, another category of barriers that are frequently reported relates to stakeholders involved in the decision-making around stormwater management. Lack of communication/interaction and collaboration among stakeholders is frequently reported to impede the uptake of SUDS [9], [10], [24]. Therefore, more awareness of the solutions to overcome flooding is needed along with recognition of responsibilities and interdependencies between stakeholders.

### 2.2 Serious games

Urban water management presents a complex decision-making environment involving multiple stakeholders, uncertainties, and the complexity of the biophysical environment. Serious gaming (or simulation gaming) is a method that allows capturing this complexity by simplifying the real world [25]. Serious games are those in which the primary purpose is not to entertain the target audience but to attain a more serious purpose such as education or learning, skills training, or

changing behaviours. In this paper, the game presented is an educational game designed to inform players about the consequences of drainage issues (traditional and SUDS), while providing a platform for actors to cooperate and understand their role and responsibilities in stormwater management.

# 3 DESIGN METHODOLOGY

The overall design process can be simplified into 5 distinct phases [26]–[28]. In this paper, we present the first 4 of the 5 design phases. Phase 1: *Design Specifications* starts by listing and understanding the requirements and objectives of the game. For research purposes, we executed this phase by looking at the literature on the adoption of SUDS, and shortlisting the barriers that the serious game should focus on. These were then translated into the game objectives, i.e., the game must increase awareness of different types of SUDS, and their performance and effects.

Phase 2: *Systems Analysis* involves analysis and representation of the part of the real world that is relevant to the problem being focused on in Phase 1. In this phase, important elements to be highlighted in the game, e.g. concepts, alternatives, relations, stakeholders, information, theoretical artefacts, responsibilities, etc. are captured in the form of a conceptual diagram. Information about these parameters was gathered through desk research with a focus on stormwater management in the Netherlands. The elements from systems analysis were then converted into game elements in Phase 3: *Detailed game design*. A matrix was created that mapped each system analysis element such as actors, uncertainties, SUDS, etc. into corresponding game elements such as player roles, event cards, and actions/choices in the game [29]. Furthermore, in this phase, the game concept and elements were worked out in detail on paper. Lastly, in Phase 4: *Game construction, validation, and testing*, the game was designed and made into a tangible product. This included constructing/arranging the game paraphernalia such as the game board, event cards, role cards, player pawns, SUDS, associated impact cards, etc. Once the game was translated into a playable version, a test session was conducted to debug the game and validate whether the intended message of the game is received by the players, and obtain initial feedback on aspects that can be improved in the game design.

# 4 GAME DESIGN

## 4.1 Game objective and target audience

The objective of the serious game is to raise awareness of the consequences of SUDS. It is important to acknowledge that decision-making around the adoption of SUDS involves multiple stakeholders – citizens, municipalities, commercial landowners, and housing developers who have the power to implement SUDS on public/private land.

## 4.2 Conceptual system map

The real-world problem to be tackled by the serious game revolves around increasing awareness about SUDS among stakeholders involved in making decisions about the adoption of SUDS. To analyse the real-world system relevant to the problem, we focused on 4 key components: a typical Dutch neighbourhood and built environment, the stakeholders who take decisions on adopting SUDS, the objectives/criteria they care about, and the external factors (or unknowns) under which they operate. A conceptual map was prepared. It includes the following system components.

1. *Built environment*: The built environment in a typical Dutch city can be divided into public or private land depending on ownership by an individual/company vs a government organization. Private land mostly comprises houses or apartments and industrial buildings, while public land consists of parks, pavements, roads, and other parcels of land that have not been built upon.

2. *Stakeholders*: We consider stakeholders who have the power to implement SUDS on public or private infrastructure as part of the system under consideration. These are municipalities, housing developers, homeowners, and commercial landowners. Many other actors are also involved in stormwater management but we consider them out of the system boundary as they only indirectly impact the decision to adopt SUDS.
3. *Criteria*: These are the objectives stakeholders in the system care about. We consider objectives spanning social, economic, and environmental goals and resilience to urban flooding. These categories are further divided into more specific criteria.
4. *External factors*: These are factors that are outside the control of the actors within the system, e.g., climate change, population growth, and regional hydrology. However, some of the external factors might be under the control of actors outside the system of interest. For instance, the local water boards or the national government may push for more housing development initiatives or change regulations around the acceptable return period of flooding.

### 4.3 Game set-up and mechanics

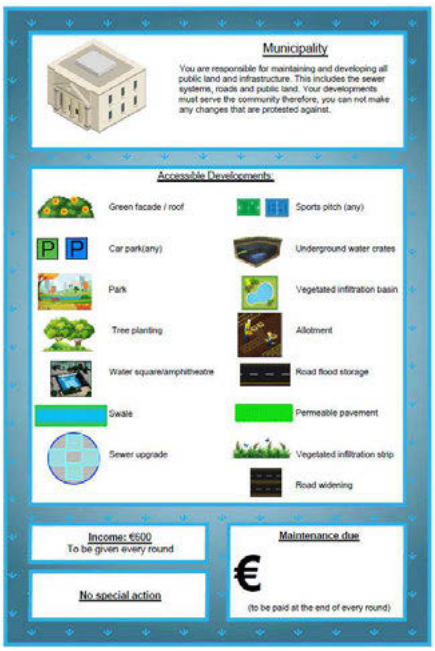
The game revolves around a hypothetical town containing a mix of impervious areas, e.g., houses and apartment buildings, schools, shops, roads, and pervious areas such as gardens, parks, undeveloped land pockets, and a river. The town is struggling to develop in a way that balances protection against flooding, environmental quality, and social standards while staying within available financial budgets. In the game, players adopt one of the roles – home-owner with garden, housing developer, commercial land-owner, and municipality. Each role comes with access to different developments. They aim to win against the game by cooperatively developing the town while achieving flood resilience, environmental quality, and high social standards with available budgets. On the way, they have to deal with uncertainties such as climate change, changing budgets, acceptable return periods, or increasing flood risk, among others.

A set of paraphernalia is used to visually represent the game elements and facilitate the dynamics of the game:

- Game board (see Figure 1): The game board spatially represents the neighbourhood in which the game is set. It also visually represents the game scores against the Environmental quality and Social standards criteria, and the sewer and flood capacity.
- Role cards (see Figure 2a): The 4 playable roles of the game have a role card that describes the role, what developments they have access to, any special actions, and their maintenance and income.
- Development cards (see figure 2b): Each development option has an associated development card that describes the development and its impacts.
- Event Cards: External influences on the system are represented through event cards to be revealed throughout the game.
- Flood damage cards: Cards explaining monetary costs associated with a level of flood damage.
- Weather forecast card: Card outlining the number of dice to be rolled per round.
- Development blocks: The options for developments to place on the board are represented by small blocks that fit onto the squares of the board.
- Water cubes: Volume of rainwater represented by water cubes.
- Protest tokens: physical representations of the limited protests a role can spend.
- Score maker: A transparent block to be placed on the score scale bar to represent the current score.
- Play money: Money to represent the economics of the system.

- Dice: To roll for a weather event.
- Erasable pen: To update maintenance costs.


*Figure 1. Game board of UrbanLemma*



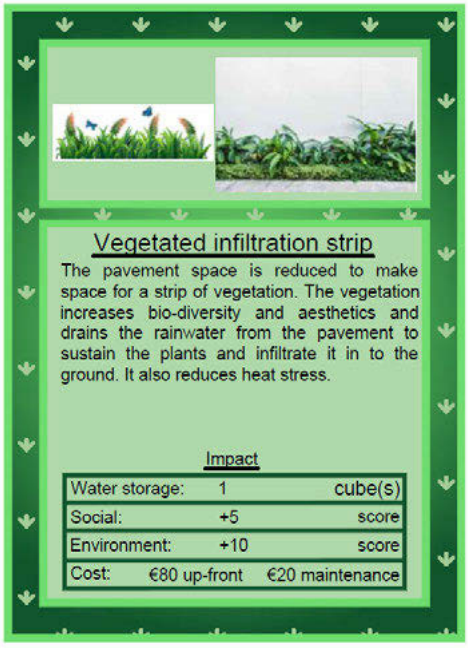




*Figure 2a (left): Example of a role card, 2b (right): Example of a development card*

The game starts with a short briefing, followed by 10 game rounds, followed by a debriefing session. At the start, a facilitator explains the problem, storyline, objective, and rules of the game. The rules that players need to follow deal with the placement of infrastructure developments and water cubes on the board and managing money-related matters. A round consists of each player taking their turn during which they can take two out of four actions: (1) Remove a block, (2) Add a block, (3) Evoke special action, or (4) Pass. At the end of the round, players perform the following actions:

1. Drain the board: empty sewer, empty flood meter, remove 1 water cube from each SUD
2. Pay maintenance and receive income
3. Pick up an event card and follow the instructions
4. Roll dice for the weather forecast and place the required number of water cubes
5. Check for flooding and pay damages if necessary

The players play the game until they either win or lose. Players win the game if they achieve and maintain the maximum score on environmental and social standards for 2 rounds without any flooding or debt. They lose after 10 rounds, if they have 2 major floods in a row or if the players cannot collectively pay the flood damages. The game is concluded by a short survey and a discussion about aspects of the game that can be improved.

## 5 GAME VALIDATION

To test if the game designed in the previous section has the intended impact, a validation session was conducted in May 2022. This was done to get an overall sense of how the game is perceived by the players, whether the game mechanisms work as desired, and to debug potential errors. A gameplay session was organized with four Ph.D. researchers in the field of water management (see Figure 3). The session started with a brief explanation of the game setting and rules, followed by 9 rounds of gameplay, and a post-game survey followed by a short discussion on the players' game experience. The survey assessed 7 criteria scored on a 10-point Likert scale: realism, learning, fun, interaction among players, feeling of engagement throughout the game, cooperation among players, and clarity of rules. The session lasted for 2 hours. The game was facilitated by the second author while the first author observed the gameplay and took note of aspects for further improvement.

*Figure 3: Validation session in progress with researchers at TU Delft*

Overall, players found the game to be fun and engaging, and game rules were perceived as clear, reflected in scores > 8 (out of 10). Two out of four players liked the cooperative aspect of the gameplay, while others appreciated the overall design and realism of the game. On the other hand, aspects of realism, learning, and interaction among players could be improved. Concrete suggestions were mentioned, such as giving players more useful and realistic powers to influence the conditions of another role, or adding more status-quo developments to emphasize conflict of choice and trade-offs concerning flood prevention, cost, social and environmental quality impacts.

Assessing the learning outcomes, players noted that they learned about the need for prevention and SUDS' ability to prevent flooding. Interestingly, all players identified a different purpose: "demonstration of the importance of installing SUDS to avoid flooding", "cooperation", "prevention of floods", and "raise awareness on climate change in urban environments". This implies that although the game increases awareness of flood prevention more broadly, the focus on SUDS and their consequences is still missing. In terms of the level of challenge, players found the game to be moderately challenging, as it was easy to achieve the maximum environmental and social score in the game. To remediate this, it was found that the use of event cards could be exploited more, e.g. by having to draw a positive and negative event card in each round. Although players appreciated the cooperative nature of the game, they suggested that personal competition could be introduced between roles as it is more realistic that different stakeholders have their own, conflicting objectives. This could motivate the players further and increase game difficulty. Lastly, the game structure could be adapted for different numbers of players by reducing the number of actions or increasing the winning criteria.

## 6 DISCUSSION AND CONCLUSION

Although SUDS are widely recognized as a sustainable and future-proof approach for stormwater management, their adoption remains patchy. Many educational and stakeholder-related barriers have been identified that hinder the adoption of SUDS including lack of awareness and lack of interaction and cooperation among stakeholders. This paper presents a prototype of the serious game UrbanLemma, aimed at increasing awareness of urban flooding prevention needs and SUDS' ability to respond to these while enabling players to understand the benefits of cooperation between roles and responsibilities of different stakeholders in stormwater management.

The game was developed by following common design phases proposed by [28]. Several jumps and iterations between phases were required during the design process. It is argued that the design specification cannot be fully addressed without input from the phase that follows it, the system analysis. This is particularly apparent when addressing the aspects of realism that should be contained in the game. In addition, it is difficult to fully construct and respond to the matrix of system components and gaming elements without considering the game format first. If considered at a preliminary stage, the game format can inform the gaming elements that feature in the matrix. As the game design is a rather creative process, different other creativity techniques could be used, such as writing a report of the game concept [28], or concept and mind mapping to visualize game elements and their interactions.

The prototype was overall well-received by the small number of participants in the validation session. Several recommendations to improve realism and interaction between players were made. Systematic testing and evaluation are required to understand whether the game has the intended impact.

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