Digital Solutions for Early Phase Stormwater Planning

Des solutions digitales dans les étapes préliminaires de planification pour la gestion des eaux pluviales

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RÉSUMÉ

Le changement climatique et l'urbanisation en combinaison avec une insuffisance des systèmes d'assainissement mènent à une augmentation des inondations dans les zones urbaines. L'état de l'art propose l'implémentation de techniques alternatives (SUDS) pour réduire ces inondations. L'implémentation de ces solutions est, néanmoins, problématique, vu que les ingénieurs de gestion de l'eau rentrent couramment dans le processus de construction des bâtiments très tard pour influencer la disposition physique des projets. Dans ce papier, nous avons examiné une nouvelle approche pour l'inclusion avancée des systèmes d'assainissement dans les projets d'aménagement, à travers de la révision de pratiques existantes et de leur combinaison avec des nouveaux outils digitales. Des facteurs clés pour l'efficacité de la gestion de l'eau ont été identifiés à travers une revue de littérature. Les facteurs ont été évalués avec un système de score basés sur la proximité relative aux conditions naturelles. Un modèle français fût ultérieurement utilisé pour la modélisation des SUDS. Deux cas réels ont été testés avec différentes solutions pour optimiser la gestion de l'eau. Les résultats ont montré une variation significative dans la performance des SUDS pour les différentes propositions de bâtiments et topographies, en allant d'inondations faibles à fortes. Ceci implique que les SUDS sont fortement dépendants du contexte, ce qui montre l'importance d'inclure les SUDS dans la planification urbaine préliminaire. Cette inclusion est donc primordiale pour assurer la durabilité induite par les SUDS.

ABSTRACT

Climate change and urbanization, in combination with insufficient drainage systems, lead to increased flooding in urban areas. The state of the art to alleviate such flooding consists in using sustainable urban design solutions (SUDS). Implementing such solutions proves, however, problematic, since the water management engineers typically enter the building process too late to influence the physical layout of major projects. In this paper, we examine an approach to early inclusion of drainage systems in development projects, by a review of existing practices and combining them with novel digital tools. Two real-life cases with different configurations were simulated by means of an existent SUDS model, in order to optimize the stormwater management at a building scale. The results showed a significant variation in the effect of the SUDS for the different building proposals and topographies, ranging from little to considerable flood reduction. This implies that SUDS are highly context dependent, which makes it important to include SUDS in early urban planning. This is paramount in order to ensure that SUDS serve the much-needed resilience they have proved to provide.

KEYWORDS

Artificial Intelligence, Digital Learning, Stormwater Management, SUDS, Urban Planning

1 INTRODUCTION

Climate change and urbanization in combination with insufficient drainage systems lead to increased flooding in urban areas. The state of the art to alleviate such flooding consists in using sustainable urban design systems (SUDS). Implementing such solutions proves, however, problematic, since the water management engineers typically enter the building process too late to influence the physical layout of major projects. This often results in less than optimal solutions and, at worst, inadequate solutions. A recent study by Drageset (2017) inventorying the SUDS for 17 recent property developments in Oslo, Norway, showed that there were faults with all the projects. Common faults were suboptimal placement of SUDS on the properties, and incorrect grading of the terrain, leading to insufficient stormwater capture in the SUDs. The 17 cases represented a selection of public and private development of various sizes. The study indicates that there is a large potential for functional improvement with better early phase planning for SUDS.

When diving into all the literature describing field and modelling studies of SUDS, it is evident that SUDS are viable and effective. However, when it comes down to implementing the solutions in real development projects, the information on placement, sizing, as well as other design criteria, are not as tangible. Considering the multi-functionality of SUDS, the need for interdisciplinary cooperation has been identified as paramount to successful planning and implementation (Kuller et al., 2018). As a result, numerous papers have been written on the subject of planning support systems (PSS), as well as guide lines and frameworks with the main aim of providing an interdisciplinary base for collective learning and collaborating (e.g. Lerer et al., 2015; Ven et al., 2016; Zhang et Chui, 2018). However, these PSS are often very data demanding and unsuitable for planning SUDS early in the development process. In early planning phases, little to no detailed data, such as field observations, are available. This indicate a need for novel approaches to SUDS planning with the objective to accommodate the complexity of SUDS using fewer inputs.

Improvements in data technologies such as machine learning and artificial intelligence are emerging and thus providing great opportunities for development of digital solutions for stormwater management. The complexity of SUDS is identified as a barrier to successful implementation, but the degree of complexity that new software can handle surpasses that of SUDS. An example of such novel technology is the site proposal generator developed by the company Spacemaker. This software allows to explore numerous spatial layouts of a development project and can be used to sort out the best site utilization by analyzing e.g. sun conditions, noise levels, etc. (Spacemaker, n.d.). Integrating stormwater in such a tool could help ensure that stormwater is accounted for early in development planning (i.e. before the physical layout of building mass is determined) and that area is reserved for SUDS.

Norway has adopted a three-stage approach to stormwater management. It is based on the principal of local handling of stormwater and refers to three levels of solutions depending on the rainfall intensity and volume. The first stage applies to every-day events for which the objective should be to retain and infiltrate the water. The second stage refers to medium events and the aim is to detain the water by delaying the flood peak and subsequent runoff response. The third stage addresses large events leading to urban floods, in which case the aim should be to secure safe flood paths.

In this study, the three-stage approach provides the framework for selection of SUDS based on key factors identification and categorization. The aim is to identify the interface between the data needs and the data availability for planning of SUDS at an early stage, to facilitate the integration of stormwater in novel technologies and digital solutions. The study addresses the following research objectives: (1) develop a tool that is able to accommodate the complexity of SUDS by use of fewer inputs, but still provide grounds for selection, placement and dimensioning of SUDS and (2) demonstrate the applicability of the tool through a set of case studies in Oslo, Norway.

2 METHODS

The method applied involved a preliminary literature study in order to ensure a state of the art point of departure. Following the literature review, the analysis consisted of two main steps. First Geographical Information Systems (GIS) was used for initial slope and flow accumulation calculation. Secondly, SUDS performance was calculated using a newly developed model for long-term simulations of the hydrological dynamics of SUDS. The second step was performed in an optimization routine.

2.1 Literary review

The first step of this study consisted of a literature review aiming to identify the key factors of the most viable solutions for urban stormwater management. Eckart et al. (2017) have reviewed the current state of research considering optimization, modelling, monitoring and maintenance of SUDS and this was considered a particularly valuable source as it provided relatively fresh information on the state of research. This article and its bibliography were further used to obtain 9 additional articles and design guide lines regarding (optimization, modelling, monitoring and maintenance of) SUDS.

Through the literature review, a simple scheme was made in Microsoft Excel where investigated SUDS were assigned to a column with a list of factors. The factors listed were then categorized into three main groups; *Sizing Factors, Placement Factors* and *Other design considerations.* The objective of this research was limiting to which key factors to include in the defined groups. Hence, only the key factors one can obtain without a field research were included. The next step was therefore to investigate each key factor, aimed to obtain information on where local data for this factor could be found as well as the importance of the factor to various SUDS, target values, which physical processes it includes, what rain events it can handle etc. This database was used to identify key factors and determine which SUDS are possible to design to a satisfying extent of certainty/viability without performing field measurements.

SUDS are part of a sustainable urban development and can be designed and developed with multiple objectives concerning both ecological, social and economic qualities. In this study, the focus is upon handling water quantity and reducing flood peaks. Hence, the key factors are identified and categorized with this in mind. We also assume that digital elevation models (DEM), land use maps and soil maps are available in the early stages of a development project. The three-step strategy also lays a basis for categorizing the key factors based on the rain events they apply to. Furthermore, a scoring system was developed to favor the solutions with the largest proximity to natural conditions. It was considered most important to handle the flood events by preserving the natural streamlines post development. In addition, minimizing the runoff from the site was an overall objective.

2.2 Modelling

In order to test the viability of this approach, a modelling study was performed. Different building proposals for one given development site in Oslo, Norway, were evaluated based on the obtained database. For each of these site proposals, one or more SUDS were planned and designed based on the key factors obtained from the database.

A digital elevation model (DEM) was used to find the flow accumulation path using a geographical information system (GIS). The GIS analysis is performed by the open source program QGIS® v. 2.18.13 with implementations from the open source program SAGA© GIS v. 2.3.2. The output of the GIS analyses are several maps, which show urban planners potential SUDS areas based on slopes and flow accumulation. The method used is further described in Muthanna et. al (2018).

The model used for SUDS performance calculations was developed by INSA (Institut des Sciences Appliquées), Lyon, France, under the collaboration of *Nidaplast/Siplast/AS2C* companies. This model is able to simulate long-term hydrological dynamics of stand-alone as well as combinations of SUDS throughout lumped conceptual models, at the scale of buildings and blocks. This makes possible to assess long-term performances of a given configuration of SUDS for a specific construction project. The principle of the model consists in simplifying different types of SUDS, such as green roofs, infiltration basins, rain gardens or permeable pavements, to a set of interconnected boxes that represent *e.g.* the storage zone or the substrate of each structure (Bertrand-Krajewski and Herrero, 2016). The input for the simulations are the physical sizing values of the particular SUDS such as the surface area, the storage depth or the depth of substrate; besides long-term time series of rainfall and potential evapotranspiration (estimated from temperature, humidity, wind speed and solar radiation). The meteorological data should correspond to the local conditions of the project, although different time series are proposed by default for projects in which this information is not available.

3 PRELIMINARY RESULTS

The three- stage approach proved to be a useful tool to categorize and prioritize the key factors.

However, the scoring system developed through the research implied that a reversal of the three steps would make more sense in terms of planning. The amount of data needed to assess flood paths is low and also readily available early on in development projects. By assessing the strategy in this order, the most crucial effects of SUDS would be prioritized

Structuring the scheme based on the three-stage approach also gave a very visual impression on the data need in order to accommodate to different rain events. In addition, the priority factors, categorized into *placement factors* and *sizing factors*, represent the data need for early planning, whereas the factors categorized as *other design considerations* are more detail-oriented design factors that need to be considered later in the planning process. Preliminary results of the literature review also showed a significant variation in the effect of the SUDS for the different building proposals and topographies, ranging from little to considerable flood reduction. This implies that SUDS are highly context dependent. It is expected that model simulations will confirm this hypothesis.

4 CONCLUSIONS AND IMPLICATIONS

Including overall stormwater management objectives in an early-phase planning has the potential to greatly improve the performance of SUDS through improved SUDS selection, placements, and resilience. Implementing SUDS performance and placement selection in the early-phase, when the placements of buildings and the first layout of the property is assessed, opens for the possibility to include it in new digital solutions, such as the architectural optimization developed by Spacemaker.

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