ANALYSIS OF THE SOCIOTECHNICAL EFFECTS OF GREEN INFRASTRUCTURE

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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INTRODUCTION

This paper will evaluate the sociotechnical effects of the implementation of urban green infrastructure. An increasing number of urban areas are beginning to integrate more green infrastructure, such as rain gardens, green roofs, and bioretention ponds, as a means to manage stormwater runoff. As cities grow, the need for more robust stormwater management methods has increased. However, these additions of green stormwater infrastructure act as a double-edged sword, imparting positive and negative impacts on the community in which it resides. Given the complex groups and their interactions involved in the implementation of green stormwater infrastructure, it can be difficult to pinpoint how individual consequences arise. To remedy this complicated problem, the ENABLE framework is utilized to navigate the flow of benefits (be they positive or negative). The goal of this work is to analyze the flow of benefits to find where the negative effects arise and to develop a strategy to mitigate them in future green stormwater infrastructure practices.

The ENABLE framework is used to further assess the sociotechnical effects of green infrastructure. This framework was developed by the ENABLE project (Enabling Green and Blue Infrastructure Potential in Complex Social–Ecological Regions). The ENABLE framework analyzes the flow of benefits of a technology that are received by the stakeholders through three filters: infrastructures, institutions, and perceptions (Kronenberg et al, 2021). The focus of this framework is the effects the technology has, not the technology itself. These lenses can work separately or in combination for analysis. The first lens, infrastructures, refers to the implementation of the physical structures related to the technology and physical structures and/or systems already in place. Institutions, the second lens, involves public policy, ownership and user rights, and social norms (2021). The third lens, perceptions, covers how the technology is viewed and valued by the stakeholders. This framework emphasizes the technology's impact on the beneficiaries but provides little insight on the reverse. The ENABLE framework works well for this analysis because it highlights the disconnect between the perception of green infrastructure by the stakeholders. It also considers the physical infrastructure in place that hinders the installment of green infrastructure, which is a common barrier in many urban areas.

BACKGROUND

Historically, grey stormwater infrastructure has been installed in cities across the United States of America (U.S). This infrastructure consists of mainly impervious components like gutters and pipes that are designed to move runoff as quickly as possible offsite and to the nearest body of water. In recent years, green stormwater infrastructure has been implemented across the country in many cities. According to Chini et al., "green stormwater infrastructure is stormwater infrastructure that utilizes natural processes such as infiltration to reduce, slow down, and clean runoff " (Chini et al., 2017). Examples of green stormwater infrastructure include green roofs, rain gardens, bioretention basins, permeable pavement, etc. Green stormwater infrastructure better reduces runoff and pollutant concentrations than its grey counterpart (2017). Thus more cities are adopting green stormwater infrastructure as climate change

Climate change poses many challenges to cities. Raising temperatures worsen urban heat islands. As cities develop and increase the area of impervious surfaces (i.e., roads, buildings, sidewalks), more heat is trapped by these surfaces, causing urban heat islands. The addition of green space to an urban area has been shown to improve climate resiliency and urban heat island mitigation in places such as Baghdad City (Abdulateef & A. S. Al-Alwan, 2022). Heightened storm intensities and increased development of land over recent years has also increased runoff and pollutant levels. Alamdari et al. estimate the increase in total suspended solids and nutrient concentrations to reach 60% in urban areas based on their rate of development and precipitation patterns (Alamdari et al., 2022). These increases are dangerous as they can cause algae blooms that harm marine ecosystems and also pose negative health risks to humans if the pollutants end up in their water source. Therefore, cities need to improve their stormwater management infrastructure to mitigate these problems, and many have already done so by implementing green stormwater infrastructure.

Green infrastructure can also positively impact the health of the residents, especially in older, low-income neighborhoods (Cook et al, 2020). Lower rates of violent crime are another benefit to green infrastructure implementation. A case study conducted in Portland, Oregon found an inverse relationship between the number of trees present in neighborhoods and the number of violent crimes reported (Burley, 2018). While the implementation of green infrastructure yields numerous benefits, it also worsens inequity.

Green stormwater infrastructure installation has been on the rise in cities across the United States. However, there is an unequitable distribution in many of urban areas of the United States. Walker discusses this issue in Minneapolis, a city that has deep rooted racial disparities. Walker's findings report that in Minneapolis, "From 2000-2015, census tracts that gentrified received, on average, more GSI projects, more funding per project, and more funding overall." (Walker, 2021). To ensure that the gentrification Walker discusses is due to the installation of green stormwater infrastructure, Walker analyzes the increase in housing costs and population of college-educated individuals in areas of Minneapolis where green infrastructure was implemented and found the increase occurred at rates substantially greater than the city average (2021). Thus, when green infrastructure is added to low-income communities of color, gentrification ensues as the prices of housing in the area rise, displacing the people who lived there and furthering inequality.

GREEN STORMWATER INFRASTRUCTURE AND THE ENABLE FRAMEWORK

As discussed previously, green stormwater infrastructure poses positive and negative consequences to a myriad of groups. Although it is difficult, it is important that engineers, developers, local communities, and federal, state, and local government institutions understand the implications of the installation of green stormwater infrastructure. Given all the independent papers, journals, and studies published on specific aspects of this network, it is challenging for one to comprehend the whole network of interactions associated with stormwater management. By defining the lenses through which these interactions take place, a more comprehensive model of the complex network of flow of benefits of green stormwater infrastructure can be created. To complete this task, this paper will use the ENABLE framework.

To gain a better understanding of this network, the ENABLE framework focuses on three filters and their interactions. The three lenses (infrastructures, institutions, and perceptions) were broken down into the corresponding actors as shown in Figure 1.

Infrastructures	**Institutions**	**Perceptions**
Existing infrastructure	State Stormwater Guidelines	Non-marginalized residents
	State and Local City Planners	Marginalized residents
	Private Landowners	

***Figure 1*. Lenses and their actors**

To summarize, the infrastructure actors are the existing infrastructure, both gray and green stormwater infrastructure and climate. While the original ENABLE framework would not include climate as an infrastructure actor as it tends to focus on man-made infrastructure, the definition of the infrastructure filter for this paper has been broadened to include all physical systems that impact the flow of benefits from green infrastructure. State stormwater guidelines, state and local city planners, and private landowners are the institution actors. The institution actors are essentially the decision-makers in this network. The State Stormwater Guidelines provide the standards that stormwater management practices must meet, giving the groundwork for designing stormwater infrastructure. State and local city planners design stormwater infrastructure for public spaces, while the design for stormwater infrastructure on private property is decided by the property owners. The Non-marginalized and marginalized residents make up the actors for the perceptions lens. These two groups are considered separately as they have differing views.

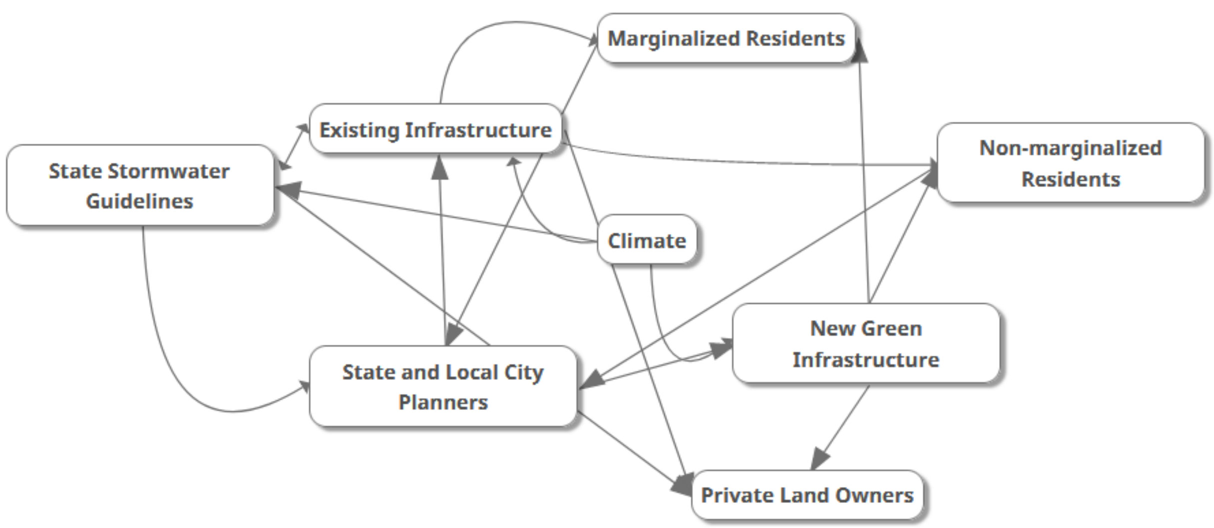

Figure 2. **Stormwater Infrastructure Flow of Benefits Network**

Following the definition of the three filters mediating the flow of benefits, this flow can be better illustrated in a map as shown in Figure 2. The first set of interactions discussed will be through the infrastructures filter. The current climate conditions (precipitation levels, pollutant concentrations, temperature, etc.) affect the performance of the existing stormwater infrastructure and influence the design of new green infrastructure. The performance of the existing stormwater infrastructure impacts the perceptions of the residents and private landowners. To explain, if there are elevated levels of precipitation and the existing stormwater infrastructure is unequipped to accommodate the amount of runoff, causing flooding and negatively affecting residents. These residents in turn may alter their perceptions of stormwater infrastructure.

Hence, the lenses not only facilitate the flow of benefits but interact with each other as well. Depending on the performance of existing stormwater infrastructure, residents might not have a stance on stormwater infrastructure. If all is functioning well and there is little pollution or flooding, residents may never think about stormwater management. This lack of consideration prevents them from becoming involved with the stormwater infrastructure designing done by the state and local city planners. Therefore, this lack of knowledge contributes to community members' lack of input on new stormwater infrastructure implementation. This gap in communication between stakeholders gives rise to gentrification since the interests of the marginalized residents are often not considered during the design process.

The institutions at work in the network of stormwater infrastructure benefits also contribute to gentrification and inequitable distribution of green stormwater infrastructure. State stormwater guidelines are becoming increasingly strict year after year, requiring cities to either retrofit existing stormwater infrastructure or implement new stormwater infrastructure. Many cities are opting for green stormwater infrastructure over gray stormwater infrastructure. However these city planners have a vested interest in making money for the city, and thus choose to implement the new green infrastructure in wealthy, white areas and tourist districts to increase the city’s revenue (Walker, 2021). This choice results in an increase in housing costs, pushing marginalized residents out of the area.

DISCUSSION

Like any other analytical framework, the ENABLE framework has its limitations. There is an inherent bias in the publication of successful project reports, as it is often times more important to focus attention on problem areas, not systems that are operating correctly (Kronenberg et al., 2021). Thus, there may exist a gap in the knowledge of the positive impacts in the stormwater infrastructure network. However, this paper tries to avoid this issue by concentrating on the negative effects of green stormwater infrastructure implementation for the purpose of their mitigation. Another complication is trade-offs. Often the mechanism causing negative effects on one set of beneficiaries also causes positive impacts on a different beneficiary group or even the same one. Therefore, these effects must be weighed, and the conclusions drawn by various analysts may differ between them (2021).

Based on the analysis conducted by this paper, it can be concluded that the negative impacts of green stormwater infrastructure implementation arise from lack of communication and cooperation between stakeholders. A possible solution to this issue is for a “town hall” meeting to be held on green stormwater infrastructure that is proposed to be implemented. This meeting would allow city planners and marginalized and non-marginalized community members alike to come together and discuss how the proposed infrastructure will impact them and suggest changes that will result in infrastructure that benefits the whole community while minimizing harm.

CONCLUSION

The implementation of green stormwater infrastructure is a complex endeavor that poses differing impacts on certain groups. Specific impacts include the issues of gentrification and inequitable distribution of green stormwater infrastructure. By analyzing this system using the ENABLE framework, the mechanisms from which these negative consequences spring can be identified, and recommendations can be made to mitigate their effect produced by new green stormwater infrastructure projects.

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