



The development of a participatory assessment technique for infrastructure: Neighborhood-level monitoring towards sustainable infrastructure systems



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ABSTRACT

Climate change and increasing natural disasters coupled with years of deferred maintenance have added pressure to infrastructure in urban areas. Thus, monitoring for failure of these systems is crucial to prevent future impacts to life and property. Participatory assessment technique for infrastructure provides a community-based approach to assess the capacity and physical condition of infrastructure. Furthermore, a participatory assessment technique for infrastructure can encourage grassroots activism that engages residents, researchers, and planners in the identification of sustainable development concerns and solutions. As climate change impacts disproportionately affect historically disenfranchised communities, assessment data can further inform planning, aiming to balance the distribution of public resources towards sustainability and justice. This paper explains the development of the participatory assessment technique for infrastructure that can provide empirical data about the condition of infrastructure at the neighborhood-level, using stormwater systems in a vulnerable neighborhood in Houston, Texas as a case study. This paper argues for the opportunity of participatory methods to address needs in infrastructure assessment and describes the ongoing project testing the best use of these methods.

1. Introduction

A frequently referenced definition of sustainable development is from a publication entitled *Our Common Future*, also known as the Brundtland Report which defines sustainable development as: “Meeting the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs” (Brundtland, 1987, p. 292).

Furthermore, sustainable development is anchored by the triple bottom line of environmental conservation, economic prosperity, and social equity (Campbell, 1996). Situating these broad concepts in the context of infrastructure, we define sustainable infrastructure as systems that have the capacity to endure over a long period of time; enabling the human-built environment to thrive and providing an opportunity for human society to improve its quality of life, without compromising the integrity and availability of natural, economic, and social assets for future generations. Recent extreme events and resulting disaster impacts across the globe, including Hurricane Maria in Puerto

Rico, earthquakes in Mexico, monsoon flooding in Bangladesh, flooding and landslides in Sierra Leone, and Hurricane Harvey and Irma in the USA and Caribbean have highlighted the importance of sustainable infrastructure systems, especially in historically disenfranchised communities and hazard-prone areas.

The proper management of infrastructure assets over a life cycle affects the integrity and level of service of these systems and thus the infrastructure sustainability. Proper management can include new development and installation as well as maintenance and rehabilitation of existing components. Historically, public infrastructure development has been disconnected from management of existing infrastructure assets and has contributed to years of deferred maintenance of existing systems and the contemporary infrastructure crisis (Harris, Shealy, & Klotz, 2016). Public and private agencies have begun to develop sustainability plans that focus on protecting physical systems along with community capital and public health in light of disasters and climate change (Campanella, 2006; Wilkinson, 2012). However, these emerging developments require cooperative long-term management, investments,

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and coordination among multiple agencies and sectors, at the same time that communities are facing constrained budgets and reduced capacity to address looming environmental impacts (Cutter et al., 2014, chap. 11; Halfawy, 2008).

Many urban areas in the U.S. and across the world are in need of affordable and effective approaches to infrastructure condition assessment. Assessment and data collection procedures will support decision-making to properly address repairs and preventative maintenance needs as well as implement endurance and sustainability measures (Chang, 2014; General Accounting Office (GAO), 2004). Without infrastructure condition assessments, municipal officials manage maintenance projects with limited knowledge of the full extent of infrastructure needs or ability to prioritize those needs, and thus, may make investment decisions that do not efficiently increase the sustainability of the city as a whole. A growing body of literature in infrastructure engineering and management are beginning to explore nontraditional approaches to infrastructure management that could address these assessment needs. For example, studies have examined public-private partnership (PPP) approaches to asset management utilizing private engineering firms to support infrastructure management through contractual agreements (Anastasopoulos, Haddock, & Peeta, 2014). These studies have shown that PPPs can successfully facilitate maintenance and rehabilitation outcomes, but these partnerships often lack insight on the social and political contexts of the local communities in which they operate and provide standard rather than context-specific approaches. Similarly, PPP's can represent a conflict of interest in terms of planning for the public good versus generating profit. This conflict could have implications for safety measures and sustainable outcomes (Regan, 2012). Public entities may consequently be stifled in attempting to moderate public works through a private market (Shrestha & Martek, 2015).

This paper describes one infrastructure assessment technique that brings together engineering and social science. Sustainable infrastructure draws upon research from both civil engineering and social planning due to the multifaceted nature of physical systems operating in a social world. This social dimension specifically illuminates the need for infrastructure management to be polycentric or decentralized and allow for contextualization, experimentation, and innovation (Goldthau, 2014). Moreover, civil engineering scholarship recognizes that physical processes have received the majority of attention and human indicators should be included and weighted equally (Dasgupta & Tam, 2005; Kaminsky & Javernick-Will, 2013). Yet because the infrastructure design and installation process is often fragmented in time and space, unintended poor outcomes result for certain communities and the surrounding environment (Harris et al., 2016). Inclusive strategies for sustainable infrastructure design, construction, and maintenance throughout a systems lifecycle support the dynamic nature of human communities. Furthermore, data collection methods that involve a wide range of actors provide opportunities to ensure the triple bottom line of sustainability is fulfilled. Cooperation between actors in infrastructure management can improve due to lifecycle linkages (Lenferink, Tillema, & Arts, 2013). There has been very little work to date in the engineering literature on stakeholder training strategies that exchange knowledge with community members, although participation can positively impact sustainable infrastructure (Opdyke & Javernick-Will, 2014). By providing a technique by which community members can receive a degree of training, exchange knowledge with public officials, and that knowledge is recorded visually and spatially, the technique we describe contributes to the design, construction, and operations and maintenance phases of sustainable infrastructure development.

Urban residents provide one avenue of knowledge that has not been fully utilized in infrastructure assessment research, even as citizen science programs are growing across a variety of other scholarly domains (Silvertown, 2009). Residents interact with public infrastructures and built environments daily and have experience with how well (or poorly) these systems function. Community members have knowledge of local

socio-political contexts that impact the management of infrastructure. Therefore, a participatory approach that provides alternative means for assessment and identification of physical infrastructure vulnerabilities could help transform the way cities manage built environments. Social equity is the most overlooked element of sustainable development. In considering providing equitable critical services, sustainable infrastructure is a critical component, especially for communities already living at the social, economic, and political margins of society (Goldthau, 2014). Sustainable infrastructure should include communities in the planning, provision, decision-making, management, and installation of infrastructure systems in light of current environmental and social conditions (Agyeman & Evans, 2003; Choguill, 1996). Communities to be served need the capacity to diffuse, adapt, and implement plans and assessment innovations to have agency in their own affairs. These innovations should be bottom-up, build capacity, and facilitate community change. Incorporating innovative techniques along with community engagement might shift the neighborhood culture regarding infrastructure management with positive implications for future improvements on multiple levels and sustained physical, social, and economic capital. Furthermore, Bullard and Wright (2009), who is often described as the father of environmental justice, challenges the literature to redefine environment to include infrastructure problems that threaten the fabric of our communities and their inhabitants. The broader environmental justice literature also recognizes that currently the burden of proof for environmental issues typically falls on the communities that are being impacted. With the emergence of new technologies such as smartphones and public applications that use Geographic Information Systems (GIS), crowdsourcing, citizen science, and other participatory approaches in many scientific disciplines, the capacity to undertake such research is ripe.

In this paper, we suggest a method of combining existing assessment techniques used by infrastructure engineers to develop a participatory assessment technique for infrastructure (PATI) that is accessible to the general public while maintaining validity and reliability of the data. The primary goal in developing this technique is to provide a user-friendly approach to condition assessment that considers both hydraulic capacity and physical conditions of stormwater infrastructure systems for asset management. This paper discusses several fundamental topics as it relates to participatory infrastructure assessment and briefly highlights historically low-income and communities of color as an example where a method such as this could be especially transformative, nudging decision-makers to employ a whole systems design resulting in more sustainable infrastructure systems. PATI provides an opportunity that could be transformative for environmental justice communities and beyond. More specifically, we (1) provide context for environmental justice and sustainable infrastructure issues and the need for this tool at the grassroots-level, (2) discuss the basis of participatory action and the potential to expand this method in collecting infrastructure assessment data, (3) describe the development of the participatory infrastructure assessment tool, and (4) discuss opportunities, challenges, and broader impacts of such an approach.

2. Environmental justice and sustainable infrastructure

Hundreds of environmental justice studies have documented unequal exposures by race, ethnicity, and economic class regarding waste and petrochemical facility siting (Hernandez, Collins, & Grineski, 2015) as well as the distribution of urban trees (Landry & Chakraborty, 2009), liquor stores and bars (Romley, Cohen, Ringel, & Sturm, 2007), and urban green space and parks (Boone, Buckley, Grove, & Sister, 2009; Wolch, Byrne, & Newell, 2014), and bicycle lanes, off-road trails, and transit services (Hirsch, Green, Peterson, Rodriguez, & Gordon-Larsen, 2017), among others. Additionally, there is a growing body of work that shows how climate change, disasters, and critical infrastructure create unequal impacts on communities of color, indigenous peoples, the poor, and in low-income countries (Mohai, Pellow, & Roberts, 2009). Climate

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