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# Rocky steps towards adaptive management and adaptive governance in implementing green infrastructure at urban scale in Philadelphia

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ABSTRACT

Many scholars have recently looked to adaptive management and adaptive governance as new approaches to implement green infrastructure. Much of the recent scholarship, however, that argues for combining the three concepts of adaptive management, adaptive governance, and green infrastructure is either theoretical, at early planning stages, or based on relatively small experiments. Since green infrastructure is now being implemented in a number of cities at large spatial scales, this paper examines how and whether combining these theories helps to solve anticipated problems compared to earlier work on environmental governance and political implementation. The city of Philadelphia has become known as a national and international leader in using green infrastructure for stormwater management. This paper therefore analyses Philadelphia's early experiences in the period from 2009 to 2015 as a test at urban scale of the usefulness of theories of adaptive management and adaptive governance in implementing green infrastructure. The city of Philadelphia found itself rapidly changing its implementation approach multiple times in response to political pressure. The city's changing responses illustrate challenges in implementing environmental policies among actors with differing levels of political power, economic interests, and participation. This paper describes the rapid changes in programs using mixed methods and data sources including quantitative analysis of the city's billing and program data, qualitative interpretation of media and public documents, and subsequent interviews with city officials. Understanding how and why Philadelphia rapidly changed its approach will be interesting to policymakers and advocates in other cities who also intend to implement green infrastructure at urban scale.

## 1. Introduction

In 2009, the city of Philadelphia in the United States (U.S.) announced an ambitious twenty-five (25) year plan to green more than one-third of the city's central area, that is, to use green infrastructure to meet its water quality goals. As one federal official said at the time, "This is the most significant use of green infrastructure I've seen in the country, the largest scale I've seen… we commend Philadelphia for breaking the ice" (Bauers, 2009). Philadelphia's plan remains one of the largest in terms of scale and financial commitment among cities in the U.S. and Europe (Hansen et al., 2019; Hopkins et al., 2018; Tsegaye et al., 2018; Wang and Banzhaf, 2018; this assertion is limited to these regions because "Sponge City" efforts in China are occurring within a different context of rapid urbanization.) As a result, Philadelphia is now known as a national and international leader in stormwater management because of its ambitious commitment to green infrastructure (Anderson, 2018; Stutz, 2018), with other large U.S. cities such as New York, Washington D.C., and Chicago implementing similar strategies (Luntz, 2019).

In this paper, we analyze whether GI implementation in Philadelphia between 2009 and 2015 confirms aspects of adaptive management and adaptive governance theories. This paper also examines how and whether these theories offer useful solutions to anticipated problems in implementing green infrastructure at large spatial scales. We begin this paper by explaining these three concepts in turn to illustrate previous scholarship that connects all three, and because of the importance of these concepts to the Philadelphia Water Department, the agency designated with implementing and planning

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water infrastructure in the city of Philadelphia.[1]

GI is a rapidly growing area of research and practice that connects concepts from urban ecosystems, environmental services, and urban planning (in this journal: Escobedo et al., 2018; Jayasooriya et al., 2017; Mell, 2014). In the U.S., GI is often more narrowly defined by federal regulators as "[using] vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments." (USEPA, 2018).

AM as a concept originally arose out of the challenge of applying scientific insight to the management of complex, non-linear, and dynamic ecosystems for which there may not be historical data or prior experience (Holling, 1978; Walters, 1997). Ecologists, admiring the ability of ecosystems to find alternative stable states, introduced the idea of an adaptive cycle for human action to learn from non-linear responses, surprises, and new information (Holling and Sundstrom, 2015). Experimentation became a critical feature of management and implementation: as Walters (1997) puts it, "The essential idea of [AM] is to recognize explicitly that management policies can be applied as experimental treatments, without pretense that they are sure to work, so that management becomes an active process of learning what really works." (p. 386)

The language and ideas of AM clearly influenced PWD's resulting approach. The primary motivation of most U.S. cities to pursue GI is regulation (Harrington and Hsu, 2018), so the fact that the first required deliverable to federal regulators was the city's "Implementation and Adaptive Management Plan" (PWD, 2011a) reveals the city's focus on this concept. This document explicitly lays out the city's AM approach to implementation, calling for the first five years of the plan to be "a period of growth, evolution and experimentation" (page 1 – 1), with a portfolio of different efforts and pilot projects to inform subsequent implementation.

AG can be broadly defined as connecting multiple actors and scales to promote participation, enable flexible collaboration, and adapt policy arrangements to changing circumstances and ecosystems (Folke et al., 2005). The concept of AG broadly combines AM with the idea of environmental governance, which itself built on interest in governance. Governance posits that a variety of actors at different levels such as individuals, companies, and non-governmental organizations can collaborate in the traditional role of governments, and environmental governance focuses on governing and managing environmental quality (Fukuyama, 2016; Gunningham and Holley, 2016).

By the time that PWD announced their GI plan in 2009, they believed that they were building on a culture of AG that included other actors at multiple scales. As far back as the 1990s, PWD had anticipated increasing costs from stormwater infrastructure. PWD therefore convened a citizens' advisory council that recommended area-based stormwater fees as a more equitable means of distributing stormwater charges among non-residential parcels, and enabling hydrological "disconnection" of impervious areas from the sewer system (City of Philadelphia, 2013; Brabec, 2009). PWD's subsequent implementation plan specifically aimed to build governance capacity based on existing partnerships throughout the city with other agencies (Fitzgerald and Laufer, 2017), and through watershed-based partnerships, advocacy, and research organizations (Mandarano and Paulsen, 2011). Another sign of acceptance of the ecological basis of AM and AG was that many of the efforts were planned through a new departmental unit, PWD's Office of Watersheds.

PWD's embrace of AM and AG concepts paralleled the focus of many scholars, but we will distinguish three groups of scholars by different periods in time and their views on existing governance arrangements. First, we will describe recent work that is optimistic about the potential of AG, AM, and GI to provide fundamentally *new* governance arrangements, and then we will contrast this with earlier, more skeptical work on environmental governance, as well as the study of the political challenges of policy implementation.

Many scholars have recently and optimistically advocated for AG and AM in the implementation of GI, due to the decentralized nature and current uncertainty regarding the actual performance of GI when compared to large-scale, existing water systems that are also centralized and inflexible. For example, Green et al. (2016) advocate for AG in urban stormwater management this way:

> "Because of the uncertainty and complexities of managing for ecosystem services in urban settings, we advocate for [AG] to address, at least in some part, these barriers in post-industrial cities. [AG] takes scale and social-ecological complexity into account, encourages experimentation to reduce uncertainty, and increases the capacity to respond to changing circumstances" (acronyms substituted, p. 79).

Similarly, Chaffin et al. (2016) specifically advocate for AM of GI:

> "The uncertainty surrounding GI for stormwater management can be addressed by applying the structured decision-making processes of AM to implement GI as experiments, and to collect multidisciplinary data to assess both the social and biophysical outcomes from these experiments. Under a framework of AM, new information can be diffused throughout complex networks of urban stormwater governance (governments, agencies, non-governmental organizations (NGOs) and residents), leading to increased social learning and adjustments in GI policy based on assessments of ongoing monitoring and data collection" (page 432).

Advocacy for AG and AM approaches to GI appears in other articles at around the same time that also emphasize similar themes of: multifunctional ecological systems; connections between social and hydrological systems; collaboration between multiple stakeholders and institutions; and institutional innovation and experimentation (see for example, Connop et al., 2016; Schifman et al., 2017).

Advocacy for AG and AM differs from other work on GI that focuses on specific barriers within existing policy frameworks, such as the physical and financial difficulties of implementing GI (Naumann et al., 2011; Wilbert and Callahan, 2016) as well as social and community barriers to implementing GI (Baptiste, 2014; Mandarano and Meenar, 2017; Lim, 2017) Debate over the politics of GI are ongoing (Thomas and Littlewood, 2010; Matthews et al., 2015; Finewood et al., 2019), but two previous bodies of work are useful to understand difficulties in the process of GI implementation.

European scholars one or two decades ago produced a more skeptical body of work about the negative possibilities of AG. An edited volume by Tatenhove (2000) investigated the implications, both positive and negative, of political modernization of environmental policy arrangements. They identify potentially negative effects of environmental governance – in stark contrast with the recent claims for AG above – including: lack of horizontal and vertical coordination; increased stakeholders, pluralization, and negotiation of rules; and controversial or contradictory discourses (Arnouts and Arts., 2009). Similarly, from a European-funded project, multiple articles and a special feature issue on "New Methods on Adaptive Water Management" directly investigate the application of adaptive learning, AG, and AM to water resources (Pahl-Wostl et al., 2007, 2009). These articles are refreshingly honest about the potential limitations of the concepts of AG and AM without further empirical research: in particular, Huitema et al. (2009) suggest that multiple avenues of empirical research will be necessary to make or determine whether AG is effective in practice.

The policy and political science literatures also provide useful

[1] Henceforth we will use the following abbreviations for green infrastructure (GI), adaptive management (AM), adaptive governance (AG), and for the Philadelphia Water Department (PWD), respectively. Programs that will be discussed later in the article include PWD's customer assistance program (CAP), the Stormwater Management Incentives Program (SMIP) and the Greened Acre Retrofit Program (GARP).

concepts to interpret the unpredictable process of policy implementation. Bardach (1977) emphasizes that implementation can be thought of as pressure politics, in which:

> The bargaining and maneuvering, the pulling and hauling, of the policy-adoption process carries over into the policy-implementation process. Die-hard opponents of the policy who lost out in the adoption stage seek, and find, means to continue their opposition when, say, administrative regulations and guidelines are being written. (p. 38–40)

Furthermore, implementation can be used to delay, in which "politics appears primarily defensive. Actors seem more concerned with what they might lose than with what all in general might gain" (p. 42). Finally, thinking about implementation metaphorically, "the idea of 'games'… directs us to look at the players, what they regard as the stakes, their strategies and tactics, their resources for playing, the rules of 'fair' play… the nature of communications (or lack of them) among the players, and the degree of uncertainty concerning the possible outcomes." (p. 56). Finally, much of this literature is concerned with how policy design and implementation diverge, either because of difficulties in establishing clear goals or effective policy designs (May, 2003), translating between levels of government (Pressman and Wildavsky, 1984), or between different managers and agency staff (Lipsky, 1980).

Philadelphia's experience therefore should be of interest to policymakers, academics, and advocates elsewhere. Many U.S. cities are considering similar stormwater user fees (Kea, 2015), but few cities have made the same commitment as Philadelphia to implementing GI at urban scale, and therefore have not yet encountered the same challenges. Governments often imitate each other's efforts, so the early experience of Philadelphia is likely to inform efforts in other cities (Piña and Avellaneda, 2018). This paper also builds on and complements recent work focusing on other aspects of GI implementation in Philadelphia including equity, organizational learning, and comprehensive assessment of neighborhood efforts (Heckert and Rosan, 2016; Fitzgerald and Laufer, 2017; Zidar et al., 2017).

## 2. Methods

Due to the rapid and successive program changes in a short period of time, this paper necessarily uses mixed methods and sources to describe PWD's program changes. In this methods section we will first detail the various programs, and then describe how we studied each of them, leaving the evaluation and interpretation of these programs in terms of using the theories of AG and AM for the subsequent results and discussion sections. This paper uses the U.S. Customary system of units with SI units in parentheses, since that is how people, newspapers, and public documents in Philadelphia discuss basic financial and physical measurements.[2]

Building on its previous AG efforts throughout the 1990s and early 2000s, PWD's plan to encourage GI adoption was to implement a stormwater fee, and to offer opportunities to receive credits and design assistance, but this encountered immediate pushback. Table 1 shows the phased introduction of the stormwater fee and mitigation programs, and the paragraphs below describe each of the programs in greater detail.

### 2.1. Stormwater user fees (2009)

Stormwater fees have been used in many countries as a user or

[2] For units of area, one acre is approximately 4046 square meters and one square foot is approximately 0.1 square meters. For length, one foot is approximately 0.3 meters. Currency measures in U.S. dollars are how they were discussed at the time, that is, they remain unadjusted for inflation.

**Table 1**
Philadelphia's plan, policy drivers, and changes between 2009 and 2017. Numbers assembled from PWD bond prospectuses where available.

| Fiscal Year | Plan Year | Plan area (greened acres) | Total area (greened acres) | Policy drivers (federal, state, local) | Policy changes |
|---|---|---|---|---|---|
| 2009 | | | | PWD submits plan to state and federal government; begin negotiations | PWD announces phase-in of new stormwater fee over four years |
| 2010 | | | | | Stormwater fee, design assistance, and credit programs all commence |
| 2011 | 0 | – | – | PWD signs consent order and agreement with state and federal governments | Customer assistance programs (CAP) immediately begin |
| 2012 | 1 | – | – | Philadelphia city council holds hearings on stormwater fee; proposes a ratemaking board | Stormwater management incentives (SMIP) and greened acre retrofit programs (GARP) begin |
| 2013 | 2 | – | 190 | | |
| 2014 | 3 | – | 392 | | Ratemaking board approved |
| 2015 | 4 | – | | | |
| 2016 | 5 | 744 | 1000 | | First rate proceeding |
| 2017 | 6 | – | – | | Stormwater billable area begins to decline due to greened acreage |

**Table 2**
Program participation records.

| Program | Date range | Unique parcels |
|---|---|---|
| Appeals | 2010 – 2014 | 2,957 |
| Credits | 2011 – 2014 | 923 |
| CAP | 2010 – 2015 | 530 |
| SMIP/GARP | 2012 – 2015 | 129 |

pollution fee to attach the economic (externality) cost of pollution either to the production process or underlying property rights (Benson, 1992; Busco and Lindsey, 2001; Parikh et al., 2005; Tasca et al., 2018). Such pollution fees are intended to incentivize polluters to minimize pollution, to pay for damages or for others to curtail their pollution, or to invest in new and cleaner technologies, whichever is more economically efficient (Baumol and Oates, 1988).

PWD planned to transition its stormwater fee structure over four years from 2010 and 2014. As noted above, changing to an area-based fee had been in the works for years. PWD expected that "this transition [to an area-based fee] will result in more equitable stormwater charges that closely match the cost of managing stormwater runoff from each property. Current calculations show that the majority of large meter customers will see a reduction or otherwise minor impact on the stormwater component of their water and sewer bills" (PWD, 2010). Also, many vacant or unoccupied properties – 40,000 parcels, or nearly half of the listed parcels in Philadelphia – received bills from the PWD for the first time after the stormwater fee was imposed. By 2014, PWD planned to charge commercial parcels $4.75 per 500 square feet (or $0.102 per $m^2$) of impervious area per month, in addition to gross area and connection charges.

### 2.2. Design assistance and credit programs (2010)

PWD also offered credits to incentivize commercial properties to treat stormwater runoff from impervious areas, which can be counted towards the city's goal of 10,000 greened acres. These efforts are similar in other cities, but the credits offered by Philadelphia are significantly larger than the credits offered elsewhere and were considered to be one of the strongest financial incentives for property owners to retrofit existing properties (Black and Veatch, 2014; Kertesz et al., 2014; Valderrama and Levine, 2012). Since GI on public land and in the right-of-way was found to be more expensive than on private property, encouraging commercial property retrofits was considered to be a very important source of obtaining low cost GI for PWD (Valderrama and Levine, 2013). PWD also provided free engineering design assistance for customers seeking engineering plans for proposed retrofits.

### 2.3. Customer assistance (2011)

In response to immediate criticism from large and industrial property owners, PWD decided to phase-in the stormwater fees more slowly. Bill increases were capped at 10 % a year over much longer periods of time. PWD later began referring to this as their customer assistance program (CAP).

### 2.4. Stormwater Management Incentives Program and Greened Acre Retrofit Program (2012)

PWD began its Stormwater Management Incentives Program (SMIP) and Greened Acre Retrofit Program (GARP) in 2012. These programs allowed commercial properties to apply for loan or grant funding from PWD to subsidize the construction costs of building GI on their properties. These subsidies started at approximately $90,000 per acre ($22.25 per $m^2$) to groups of properties that were already organized and aggregated, reducing the cost of administration to PWD. These programs were also intended to mobilize consultants to help find, inform, and recruit property owners into PWD's programs.

### 2.5. Ratemaking board (2013)

Philadelphia, like most cities in the U.S., has an executive branch (the mayor) and a legislative or representative branch (the city council). In response to public concerns, the city council held hearings with concerned property owners and the PWD about the new stormwater fee. In 2013 and 2014, the Philadelphia city council passed an ordinance changing the city charter, and the mayor signed it into law, specifying a new ratemaking board to oversee all rate processes for water, sewer, and stormwater services.

The following sections describe the mixed methods required to study these rapid policy changes occurring over the period from 2009 to 2015:

### 2.6. Program participation and billing record analyses

PWD provided information on the stormwater bills sent to customers on June 30, 2010 and on June 15, 2014. We joined the two data sets using a unique parcel identifier. Properties that did not receive a stormwater bill in 2010 but did in 2014 were kept in the dataset as "new customers" resulting from the redistribution of the meter-based fee to the area-based fee. This resulted in a dataset containing 85,948 total parcels.

PWD also provided administrative data for its programs including appeals of the stormwater fee; applications for stormwater credits; and participation in the CAP, SMIP, or GARP programs. Any parcel applying for any PWD program was considered as participating. Table 2 shows each program and the start and end dates of the records within the dataset.

We also obtained an extract from the city's water billing database maintained by the Philadelphia Water Revenue Bureau on August 1, 2015 including lien dates and status. Any property having an open lien was considered "delinquent" in our analysis. We obtained geospatial classifications from OpenPhilly.org and merged some of its land use categories. We then joined the data on billing, program participation, land use category, and delinquency by unique parcel identifiers or by spatial joins if unique identifiers were not available. The compiled data was used to trace the changes that parcels experienced in their stormwater billing and their subsequent responses. We also performed simple statistical correlation analyses to understand better how sub-groups of property owners participated in the various programs offered by PWD.

### 2.7. Public documents and newspaper accounts

As one of the city's main environmental initiatives, PWD has written many public-facing documents about its "Green City, Clean Waters" program (PWD, 2009, 2011b). Since utilities are capital-intensive, frequent bond prospectuses are another source of public data about how PWD's actions, perceptions, and rationales changed over time (PWD, 2010a, 2010b, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019). The cost of the PWD plan also sparked public debates in local newspaper accounts that are cited throughout this paper.

### 2.8. Interviews

We conducted subsequent interviews with three policymakers who devised PWD's programs before, during, and after the period from 2010 – 2014, in order to explain the reasoning and considerations that went into the evolution of the program changes (PWD interviewees, 2018). These interviews explain why they decided to modify the PWD policies in this initial period, and we corroborated them with public documents from PWD and media accounts from the time.

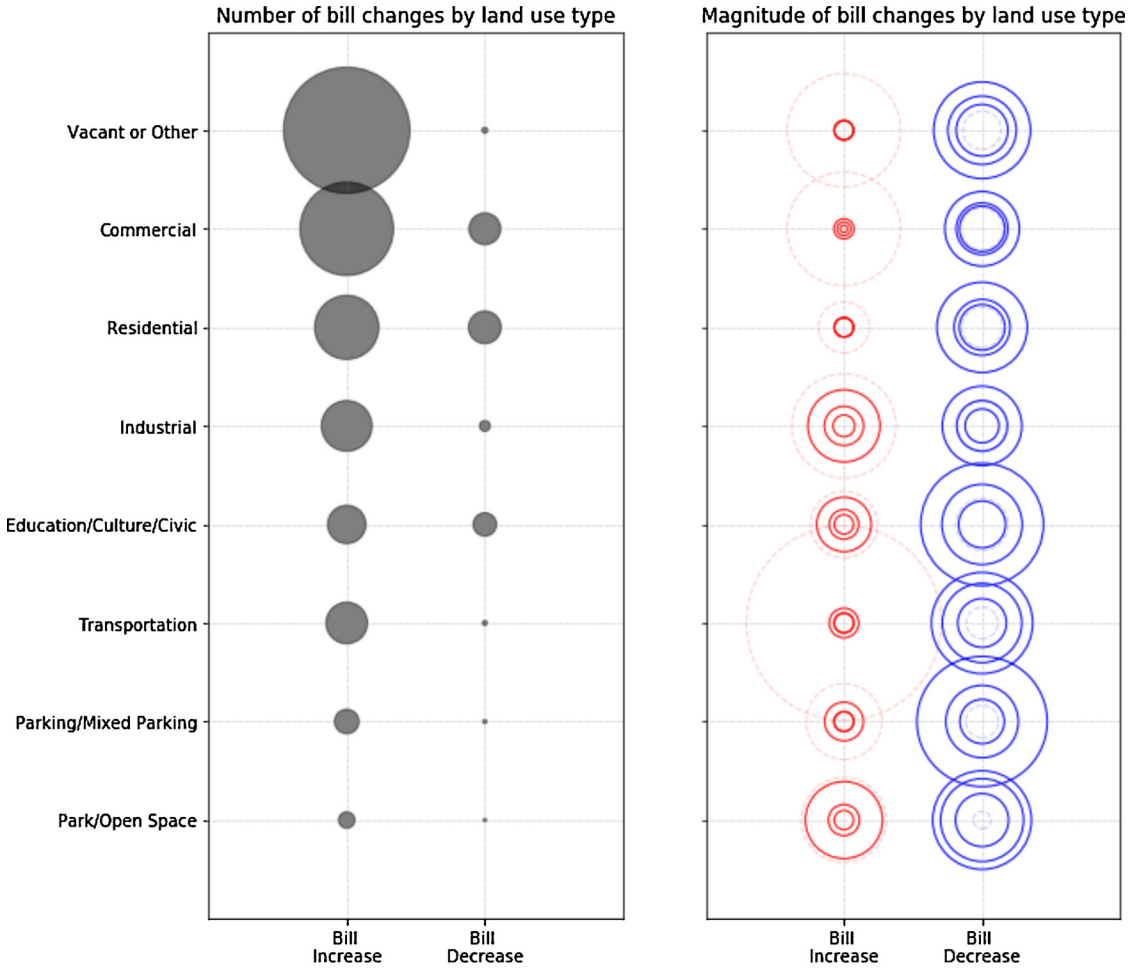


**Fig. 1.** Left: Relative frequencies of bill transition types and land uses. Right: Bill change magnitudes by land use type. Solid circles represent 25th, 50th, and 75 % percentiles of bill change magnitude (online in red: positive, online in blue: negative). Dashed outer circle represents maximum bill change magnitude per land use type, and is on a different scale greater than that of the solid circles (divided by 100) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

## 3. Results

This section will first summarize the quantitative analysis of the program changes. We then narrate the disproportionate and asymmetric response among property owners. Finally, we describe how PWD responded in turn by changing its programs.

### 3.1. Fee changes and land use types

Of a total of 85,948 total parcels that received a stormwater bill in 2014, 52,804 (61%) were new customers, 6335 (7%) were existing customers whose bills decreased, and 26,809 (31%) were existing customers whose bills increased. While the majority (83%) of the 2014 bills were within $50 of their 2010 bill (for new customers, within $50 from their previous bills of $0), the biggest changes were also highly skewed, with a maximum decrease of $10,278 per month, and a few customers receiving very large increases, with a maximum increase of $142,538 per month. Fig. 1 shows the distribution of increased and decreased bills across the land use types. New customers were included with the group that experienced bill increases, and the distributions of magnitudes of bill changes experienced across land use types.

New customers were dominated overwhelmingly by vacant or other (undefined) land use types. This category is the largest in the billing dataset (35,256 or 41% of all parcels). The second most numerous combination for land-use and bill transition was for commercial properties that experienced bill increases, which would soon become the most difficult political problem.

### 3.2. Limited initial awareness

At the time when the stormwater fee was implemented, PWD was still surprised that many people did not know more about the plan:

> [We] must have been out there for years… two years before we went live, we mailed every non-residential customer a copy of what their bill would look like, a projected bill… A lot of people didn't pay attention to that mailing until we were ready to go live, unfortunately…. when it actually went live, people went nuts. People were unhappy and started to yell and scream. (PWD interviewees, 2018)

Despite PWD's best efforts, the stormwater fee did not receive much attention until customers received those first bills, which were dramatically higher for particular sub-groups.

### 3.3. Asymmetric reactions against the stormwater fee

As Fig. 1 above showed, the largest affected groups were vacant properties that were enrolled as new customers; and the number of commercial and industrial customers that experienced bill increases were much larger than the number of customers that had bill decreases. Fig. 2 is a Sankey diagram showing the reactions of property owners when the new stormwater fee was imposed: they either became new

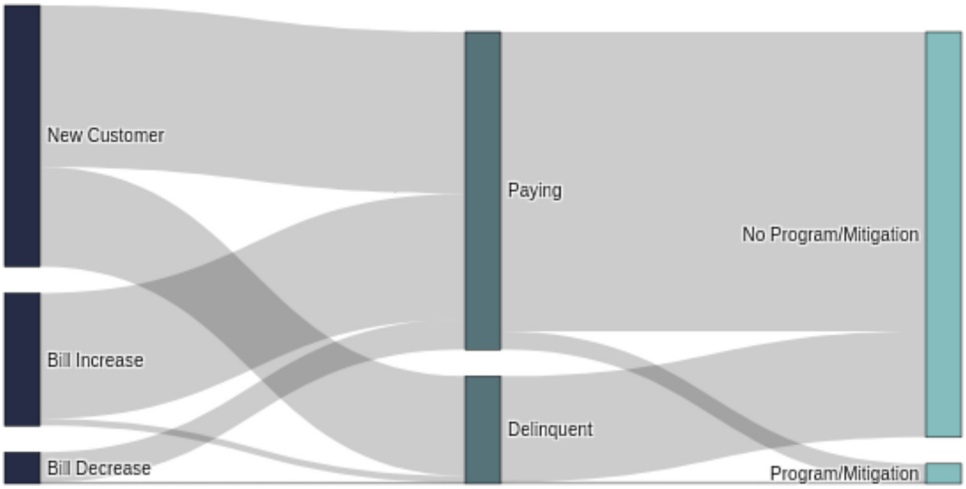


**Fig. 2.** Sankey diagram showing property owner reactions to stormwater fee transition.

customers, or experienced bill increases or decreases; they either became paying customers or were deemed delinquent on the payments; and some joined new programs later.

One aspect of the new stormwater fee that initially surprised PWD was that some new customers simply began paying their stormwater bills, but did not engage with PWD's suite of programs to mitigate their bills or their stormwater impact. As one of our PWD interviewees (2018) said:

> Something that we've learned more about is the property situation. A lot of those commercial businesses … the owner is in New York City, and they have the occupants of the property or other tenants under a triple net lease.

A triple net lease is one in which the costs of property ownership are passed onto the tenant, such as real estate taxes, insurance, and maintenance. Increasing stormwater fees would likely be included, and as a result, the interviewee continued,

> No one's really motivated to do anything. The owner probably has been upping the lease costs every year anyway because [they] can…. for some of these property situations, the effect of the stormwater fee did not make a difference…. The trend is that Philadelphia is going through a bit of a renaissance, so property values are increasing anyway. The stormwater fee is just getting rolled into increasing costs for tenants.

The second biggest affected group was comprised of large commercial and industrial property owners whose bills went up more dramatically, and as anticipated by the implementation literature, their immediate reaction was to dispute the legitimacy of the fee itself (Kostelni, 2012). As one business owner said to the newspaper: "They want me to pay $50,000 a year for God's water to go from my roof into the sewer" (DiStefano, 2010). The same owner organized a "group [that] has pleaded with City Hall, hired a lobbyist and threatened litigation. In animated meetings with [PWD], it has resisted implementation of the new bills." (Rahim, 2012). "[A local business owner] is talking to [other] landlords…. driven to the brink of leaving the city, he says – not by "crime, taxes, dumping, graffiti," or other urban ills, but by Philadelphia's new storm-water fees… Dozens of other inner-city factory and warehouse owners and nonprofit groups [have joined together] to protest to Mayor Nutter and City Council." (DiStefano, 2010).

From PWD's perspective, they were unable to engage this group in meaningful discussions:

> The [business group] was continually loud, wrote letters to council, they sat down with us a number of times. They were never happy, no matter what we offered to do. And they did not initially want to take advantage of any of our grant programs. We talked about [different options:] we talked to them about providing free design assistance, we talked to them about working with us. We'll figure out how to mitigate your property, mitigate your bill, but they wanted nothing to do with that (PWD interviewees, 2018)

Echoing that sentiment, another small business owner said at the time that he was "skeptical that those solutions are reasonable, or affordable, for built-up urban properties like his…. 'maybe they can lower our real estate tax, because they've just devalued the property'" (DiStefano, 2010). Property tax, however, was and is not in PWD's control.

In contrast, for the property owners whose bills went down, PWD felt that "you probably [didn't] hear from them, because they're happy" (PWD interviewees, 2018).

### 3.4. Political influences on implementation

The group of commercial and industrial businesses, however, identified an alternative approach to force changes in PWD's implementation of its programs. Despite the initial perception that PWD as an independent enterprise agency was not subject to political influence (Shaheeli, 2012), the commercial and industrial property owners eventually influenced how policies were implemented through public hearings and threats to leave the city. As one city official said:

> "Businesses have much more traction. I'm a businessman, I employ lots of people in the city, you jacked up my taxes five times, I'm moving out, goodbye. That gets the attention of every council person, including the mayor, instantly. I'm not saying that they have a disproportionate voice, but that's a very powerful argument…. It is very hard for a mayor or for a councilperson to ignore that" (PWD interviewees, 2018).

Newspaper articles sought to balance PWD's environmental goals while highlighting the disproportionate impact on small businesses (West, 2012, 2012a, 2012b).

While the group of businesses forced discussion of the impacts of stormwater fees, it is noticeable that they did not force any re-discussion of the city's obligations to federal regulators, or propose any alternative mechanism to achieve the city's environmental goals, which were already mandated and agreed to with the federal government.

### 3.5. Changes to PWD programs

Implementation forced three major changes in the speed, process,

and alternatives to the stormwater fee.

First, PWD responded immediately with rate relief when the first stormwater bills were issued. The business group also succeeded in gaining slower phase-in of the stormwater fee for many of their members, which became the customer assistance program or CAP (WHYY, 2011). As one city official said:

> CAP was our first response when people were outraged. And it really just allowed us dampen the anger, to give them some breathing room, and then we had a better, long-term solution that really knocks out that stormwater fee for you. And CAP is just this kind of intermediary holding phase (PWD interviewees, 2018)

Second, the process for setting PWD's rates forced a fundamental change in the city charter, unanimously passed by the city council after hearings in 2012. As another city official said:

> I can tell you it had a pretty dramatic effect on this utility in that, it basically caused a fundamental change of how we do our rate structure now. We used to be able to essentially set our own rates. The commissioner would essentially have the ultimate say. Because of the change, people were so angry and went to city council, we now have a rate board in place… [which was] a direct reaction to us changing the stormwater fees (PWD interviewees, 2018)

Third, and finally, PWD also changed how its loan and grant programs worked due to feedback from businesses that it was too expensive and costly to build GI, which became the SMIP and GARP programs.

> Most of the people begrudgingly said, I guess 10 percent I can take. They weren't happy with that, but that is manageable in a big city. But there were still others who were not happy, that's why we had to do two more programs. We had to figure out what to do with what we call the direct dischargers, and then we had to do a SMIP/GARP grant programs to help people that are still heavily impacted [by rising stormwater fees]. All of those three programs together got us to a point where [the fee] is accepted (PWD interviewees, 2018)

Based on feedback from the community, however, the city began funding the cost of capital construction entirely:

> When we got some of our initial grant applications, we realized that us fully funding 100 percent isn't a bad decision for anyone. We were seeing greened acres at a really cheap cost compared to our own capital program. And so it made sense to move forward with 100 percent grants in some cases (PWD interviewees, 2018).

There were initial concerns about the balance of programs between groups with different interests in the stormwater fee. As another city official added, "a lot of the environmental groups were worried about CAP diminishing the effectiveness of SMIP and GARP. They think people wouldn't be motivated, but that's not been the case at all. We actually see them working hand-in-hand" (PWD interviewees, 2018).

Program data is inconclusive about the relationship between participation in various fee mitigation programs. We analyzed correlations between participation in the four programs – appeals, credits, CAP, and the SMIP/GARP program – among all of the billed parcels and among the subset of parcels that participated in any program. In Table 3, two-way correlations in program participation among all 85,498 parcels were all weakly and positively correlated. However, in Table 4, the correlations between programs among the 4,013 participating parcels exhibited stronger negative correlations: a property owner who filed an appeal was much less likely to apply for credits, participate in the CAP program, or participate in the SMIP program.

## 4. Discussion

This section discusses this paper's findings related to the literature and theory presented in the introduction.

While the original stormwater fee was developed by PWD with citizen input, it is clear that most real estate owners did not know or understand the impacts that the fee would have on their properties until they actually received the bill. The transition from water-meter-based billing to area-based billing in Philadelphia did not initially drive property owners to mitigate their costs through the programs offered by PWD: instead, the vast majority of properties either paid their bills or became delinquent on their payments. Much of this reaction is explained by the high rates of vacancy and absentee property owners in Philadelphia. Our results were therefore statistically significant, but provide contradictory conclusions on how to implement future programs. Among the general population, properties that were awarded relief from their stormwater fees were more likely to adopt green infrastructure on their properties, but among the small subset that entered into any rate relief program, only credits are positively correlated with actually building more GI or greened acres towards the city's goals.

Philadelphia's implementation of GI shows mixed results for the main focus of AM theory on experimentation and structured learning. One might argue that the AM process specified in the city's formal regulatory agreements allowed for experimentation and evolution of the city's programs, also as recently proposed as "reflexive governance" (Feindt and Weiland, 2018) or improved stakeholder engagement (Reed et al., 2018). PWD's learning from experience, however, can also be viewed as the illuminating light shed by a near-death experience. The city's application of a stormwater fee across the entire city led to a strong and asymmetric reaction by business owners against the policy. This required the utility to mollify many of their customers through rate relief and additional subsidies, which contradicted both the economic theory of the policy itself as well as the goals of the environmental community. The legitimacy of the utility's policies was questioned and ultimately modified by the imposition of a rate board, which will limit the utility's scope of action in the future. This initial period of experimentation confirms many possible negative aspects of environmental governance including: lack of coordination; increased stakeholders, pluralization, and negotiation of rules; and controversial or contradictory discourses, for example, as in the focus of property owners on their rights and role in job creation over the social or environmental benefits to the general public.

From the perspective of AG, while the city's approach in engaging NGOs around civic, watershed, and scientific issues may have built support among environmentalists, the biggest problem revealed by the city's planned engagement process was that it left out the two largest groups that were ultimately affected by the stormwater fee, namely vacant property owners and commercial and industrial property owners. The city tried to engage the first group of vacant property

**Table 3**
Correlations in program participation among all billed parcels (n = 85, 498).

| Program | Appeal | | Credits | | CAP | | SMIP/GARP | |
|---|---|---|---|---|---|---|---|---|
| | rho | p-value | rho | p-value | rho | p-value | rho | p-value |
| Appeal | 1.000 | | | | | | | |
| Credits | 0.165 | < 0.001 | 1.000 | | | | | |
| CAP | 0.074 | < 0.001 | 0.135 | < 0.001 | 1.000 | | | |
| SMIP/GARP | 0.032 | < 0.001 | 0.092 | < 0.001 | 0.120 | < 0.001 | 1.000 | |

**Table 4**
Correlations in program participation in the subset of parcels who participated in any fee mitigation program (n = 4013).

| Program | Appeal | | Credits | | CAP | | SMIP/GARP | |
|---|---|---|---|---|---|---|---|---|
| | rho | p-value | rho | p-value | rho | p-value | rho | p-value |
| Appeal | 1.000 | | | | | | | |
| Credits | −0.514 | < 0.001 | 1.000 | | | | | |
| CAP | −0.471 | < 0.001 | −0.040 | 0.011 | 1.000 | | | |
| SMIP/GARP | −0.228 | < 0.001 | 0.011 | < 0.001 | 0.062 | < 0.001 | 1.000 | |

owners, but the initial results of billing revealed that the policy did not have the effects expected because the bills were either passed on to absentee owners, or were not noticeable amidst rising property values.

For the second group of commercial and industrial property owners, they did take notice of the new and much higher bills, but their reaction was instead to challenge the legitimacy and application of the fee rather than try to work within the programs that PWD had devised. The business group also waged a defensive strategy that did not propose any alternative. The literature on the politics of policy implementation clearly anticipates some of these events: even if property owners had not known or paid attention to the stormwater fee during its conception, implementation became another phase for them to influence and pressure PWD.

These experiences more generally point to a problem of AM and AG theories in general, which is whether these theories can be empirically tested at scale, that is, in heterogeneous and complex cities, in ways that can be both generalizable and useful. While the perspective of AM and AG might treat the early experience of PWD as valid and useful results from experiments, it is not clear how these same insights could be gained from smaller and less risky experiments within cities. PWD felt that they had sufficiently discussed and piloted these approaches, but putting the theory into action revealed groups that either did not know or chose not to engage in PWD's process of experimentation and engagement.

The experience of Philadelphia also points to some of the likely problems that will emerge as GI goes to urban scale. As the scale of our environmental and ecological problems increase, so will the stakes and number of affected groups, many of which will not necessarily engage in any common environmental discourses, but instead will choose to contest the choice of discourse, as predicted by Dryzek (2013) and others. This paper finds earlier, more skeptical views on environmental governance useful, if only because they argue that structural changes may not necessarily lead to the outcomes that policymakers or advocates want. Not only do we need to design structures and policies for abstract goals like learning, we need to build and execute these designs in the real world with the actual people that will be affected by these policies. Furthermore, the literature on the politics of policy implementation points out that the political power and interests of affected groups will have inevitable effects on the implementation process.

As an early case study of a large citywide effort to implement GI, this paper's results are important for a number of reasons. First, this paper evaluates the early experiences of citywide GI policies when applied to the existing non-residential parcels of Philadelphia. The existing literature has studied the effectiveness of different GI policies in managing stormwater mainly on residential properties, but engagement with commercial property owners is particularly important in GI programs to meet public environmental goals, given the size of their properties. These empirical results point out likely challenges for similar GI policies as they are implemented in other cities. Second, while much of the international, academic literature on GI has focused on the transformative potential of GI at the scale of particular projects, neighborhoods, watersheds, and/or ecosystems, there have been relatively few studies based on the actual policy experience of implementation, if only because relatively few cities have resolved to build GI at such a large scale. Third, this particular experience is important because in most countries, local governments have a significant institutional role, legal jurisdiction, and financial resources to build infrastructure systems in a way that other groups lack. Fourth, this paper also presents how policy implementation was affected by the diverse and heterogeneous population of the city itself. The actual policy experience of the city of Philadelphia and PWD should inform the future development of implementation approaches that are more viable, both politically and at large scales.

Given the rapid changes in the short period of time, our findings have several limitations. Our interpretation of events relies heavily upon a small number of interviews with PWD officials, public documents, and media accounts. While we have corroborated the interviews, there are limited numbers of people who have been involved with the programs before, during, and after the period that is studied in this paper. Furthermore, our analysis above almost exclusively relies on data from PWD to understand who participated in their programs. Given the high cost of installing GI and PWD's activities, however, we believe that it is unlikely that many property owners have built GI without claiming available credits.

## 5. Conclusion

At the time of this writing, the city of Philadelphia and PWD remains committed to GI. PWD is experiencing rapid increases in water rates that are nationally rising much faster than inflation – like many cities in the United States – and so the cost of maintaining water infrastructure will continue to strain the city's budgets and the willingness of property owners to pay. Now under a new mayor, a new water commissioner said recently, "We're not the first ones to do green infrastructure, but we're first to do it on this scale… We're learning as we go, and trying to make improvements as we go" (Maykuth 2018). At the time of this writing, PWD is close to completing the first ten years of its 25-year plan. PWD's programs are expected to remain in place and continue in the same direction, but must accelerate rapidly in coming years to deliver the mandated 10,000 greened acres.

Many other cities around the world are likely to encounter similar implementation challenges as Philadelphia as they seek to scale up GI or nature-based solutions as they respond to increased extreme weather events and begin to adapt to climate change. On one hand, given the urgent need to address these problems at all time scales, it is important for all stakeholders and the general public to start developing environmental plans, goals, and programs now. On the other hand, as Philadelphia shows, any planned future approach will inevitably be contested, debated, and changed. There remain inherent and inevitable challenges in reconciling three things: the need for rapid environmental action; sustained and measurable progress towards long-term goals; and the participation of stakeholders in environmental management.

PWD definitely changed its approach in response to criticism during the implementation stage, a lesson that other cities seeking to implement similar programs should heed. As one PWD employee said in retrospect:

> The lesson for any utility who wants to change [their fees] is gradualism. [Do it] very carefully and very slowly… People in a major city are used to taxes going up a little bit. If you can cap that limit, and slowly make that change, it will go over much better than ….

suddenly (PWD interviewees, 2018)

Philadelphia's experience is also taking place amidst changes at the national level, which is affecting how the federal government regulates cities. The Trump administration recently announced that they would not enforce or press cities to continue towards their water quality goals, causing a number of cities to reconsider the pace and size of their water quality programs, especially affecting stormwater management (Flavelle, 2020). Philadelphia continues to lead in implementing GI, and while it remains to be seen if and how other cities will follow, Philadelphia's early experiences show that current theory so far does not guarantee success.

## CRediT authorship contribution statement

**David Hsu:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. **Theodore Chao Lim:** Investigation, Methodology, Software, Writing - review & editing, Visualization. **Ting Meng:** Writing - review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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