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Policies, institutions, and regulations: PIRs of a stormwater management system

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ABSTRACT

Urban services, like stormwater management, are complex tasks that depend on many actors and involve activities that fall within several fields of knowledge, but infrastructure solutions have been known for a long time. Recently, the view that urban water should be treated in an integrated way has become more pronounced, breaking the pathway dependency that treated it in isolation. Since the last decade, the perception that policies, institutions, and regulations (PIRs) condition good results has become more pronounced. The key question lies in incentives capable of mobilizing actors to produce aligned PIRs in a governance system. Better results can come from transformations in the incentives that currently exist for PIRs. The compatibility between incentives, which are not always identical for all involved, aligning them toward results, is the main objective. Based on these premises, aspects related to the necessary ideological change are analyzed here, that is, at the level of ideas and conceptions, which reflect the perception of objective, involving all actors, public and private, attracting them to solve the challenges posed, for example, the delivery of services according to sustainable development goals (SDGs). Examples of this in-progress transformation, a paradigm shift, are presented as support for reflection and experimentation.

Key words: drainage, institution, policy, public services, regulation, stormwater

HIGHLIGHTS

- The public services provided by urban infrastructure, such as rainfall runoff, are considered from the point of view of policies, institutions and economic regulation and performance (PIRs).
- The incentives for actors (public, private and civil society) present in the governance system involving the PIRs are treated as the driving force for achieving positive results in stormwater management.
- The alignment between incentives, governance and PIRs is presented from the perspective of the paradigm shift in stormwater management in various countries.
- Policies, institutions, and regulations in stormwater management.

1. INTRODUCTION

The urban drainage systems do not always meet the population's expectations when precipitation, increasingly intense due to climate change, occur. With global warming, the amounts of water suspended in the atmosphere grow and obeying patterns that are not always predictable. The moisture in suspension in the atmosphere forms the so-called 'atmospheric rivers' (Salati & Vose 1984) that do not present, either in terms of quantity, volume, or geographical dispersion, early signs of how and where they will precipitate, even though weather forecasts seek this signaling through sophisticated equipment such as radars and satellites.

The most recent examples of flood events in Pakistan in 2022 (Pakistan 2022) and floods and snowfall in California (Flavelle *et al.* 2023) in early 2023 demonstrate the consequences of these phenomena. For example, in Pakistan, it was estimated that one-third of the population, or 33 million people, was affected and a damage of $16.3 billion needs to be recovered (Pakistan 2022).

In this context, urban risks, classically defined as the probability of rainfall multiplied by the magnitude of probable damage, for each location and typology, make predicting and controlling associated with precipitation a difficult mission.

In addition to this non-linear reality, there is the public and private management of the phenomena and ageing infrastructures in charge of tasks related to urban water, precipitation, or not, but all interrelated.

The issue requires multidisciplinary and multisectorality, which involve urban and land use planning, public health, and technical aspects, such as solutions for slums and peripheral bangs of the cities, where traditional solutions have not been adequate. In addition, solutions are required for economic aspects, such as the financing of services, through subsidies and other mechanisms that enable the participation of the lower-income population.

Decisions made by those who govern are materialized through public policies that direct actions toward previously defined objectives and can be implemented through different institutions and instruments such as laws, regulations, specific actions, or funding priorities. Policies can account for leveraging incentives for sustainable service delivery and for enhancing and transforming the existing institutional and regulatory framework (Mumssen *et al.* 2018).

Policies, understood as choices made on a scale of preferences and conflicts, mediated by institutions, reflect the degree of influence of different actors (Sarti *et al.* 2018). They result from consensus, but not unanimity, among the actors involved in the management of public services and are the starting point for establishing what is important to society and what should receive resources. Policies influence institutions, which are the rules, both formal (laws, decrees, and regulations) and informal (habits and customs), of the game to which the actors submit themselves, but are also influenced by the existence of institutions (Schout & North 1991). It is through institutions that the actors interrelate.

The policy, institution, and regulation (PIR) system, or tripod, is completed by the presence of regulation, in charge of controlling and realigning to achieve the objectives and goals previously outlined by the policies, in a governance system that performs the concert, or agreement between actors, of everything and is accepted by all. A good policy design, according to the peculiarities of each location, aligned with the institutionalization of services and sources of resources for financial and continuous support, in addition to participatory structures and regulation, can attract private **sector** participation (PSP). In this way, it can obtain resources and skills unavailable in the traditional hierarchical government paradigm, centralized, and focused on command and control, in which there is no participation of many actors. Zurbriggen clarifies that governance is different from the hierarchical and market control model by a greater degree of cooperation between government and public administrations and non-governmental actors of public policies, based on collaboration, consensus, and participation of different actors, improving results and performance (Zurbriggen 2011).

The existence of various urban stormwater management terminology and policies demonstrate that this is a global issue, materialized, for example, in Australia by the policy called the Water-Sensitive Urban Design (WSUD), in China by Sponge Cities, in the UK by the Sustainable Urban Design (SUD), and in the USA by Stormwater Utilities (SWUs) (Fletcher *et al.* 2015).

The policy is defined as 'a course of action adopted and pursued by a government, party, ruler statesman, etc.' (Hill & Varone 2021) and thus, for example, in Australia, the WSUD can be considered a policy because constitutes courses of action that have been adopted and purposed by governments and professional institutions (Morison & Brown 2011). In each place, policies are characterized by specific aspects, which concern existing conditions related to institutions, organizations, regulations, and governance. They also have, as common important aspects: climate change, ageing infrastructures, and the difficulties in providing resources to meet the growing demands and decreasing sources of financial support, as well as difficulties in understanding by society.

In accordance with the Australian Environment Protection Authority: *Stormwater is rainwater that flow across outside surfaces into stormwater drains and gutters in the street* (Environment Protection Authority 2003). The broader view of watersheds does not always prevail, stormwater and its impacts do not follow administrative divisions but are perceived by all. Issues related to rainwater are perceived as being under the responsibility of the public local entities where the rainfall occurs, or of those regions to which the water is directed.

From the urban point of view, the economic and financial support for the policies is the responsibility of both public and private entities. Stormwater reflects the different degrees of existing waterproofing and, according to recent studies, are around 50% for the public sector, including streets and squares, and the other half under private responsibility (Montenegro 2019). Thus, everyone should participate in the solutions.

Policies must be addressed by considering local, regional, and global issues, considering the participation of public and private actors, with consideration of existing institutions and regulation, within an established system of governance.

The text brings aspects that escape the logic of technical engineering solutions and that the answers lie in addressing the issue from the standpoint of the PIR tripod. This approach is immersed in a governance system in which the incentives produced within these three aspects reinforce each other and can produce better results when aligned.

In addition to this brief introduction, this article comprises seven chapters. In Section 2, the paradigm shift is analyzed. Then, the third section addresses the institutions. Section 4 deals with the regulation, and health issues are examined in Section 5. Section 6 approaches the economic aspects. Section 7 discusses the results obtained and, finally, Section 8 concludes the paper.

2. THE PARADIGM SHIFT

2.1. Overview

The paradigm shift from traditional to sustainable stormwater management involves several aspects, both conceptual and practical (Novaes & Marques 2022b), as shown in Table 1.

Rainwater is a technical term used for precipitation that falls on a property and once it leaves the property, it becomes stormwater (Cutter & Pusch 2021) which is the portion of rainwater that flows onto the land, either draining inside or flushing over it (Dhakal & Chevalier 2016). The concept has been evolving and transforming understanding to conceptualize rainwater not as a problem, but as a valuable resource (Moissan 2013) for solving diverse and varied urban issues, such as water scarcity, urban thermal comfort deficits, represented by heat islands, and others (Vietz *et al.* 2018).

The absence of the subject on policy agendas reflects not only unknown, but also barriers to change, concerning concepts, and a lack of the structures and actors responsible for changing or initiating the transformations. The question is how to institutionalize the change and based on which factors. Path dependence has a strong weight importance when we talk about institutional (the rules of the game) and governance changes. Governance changes, however, can mean just Good Governance or Good Enough Governance, like Grindle's, establish: *'what's essential and what's not, what comes first and what should follow, what can be achieved in the short term and what can only be achieved over the long term, what is feasible and what is not… Working toward good enough governance means accepting a more nuanced understanding of the evolution of institutions and government capabilities; being explicit about trade-offs and priorities in a world in which all good things cannot be pursued at once; learning about what's working rather than focusing solely on governance gaps … and grounding action in the contextual realities of each country'* (Grindle 2004).

2.2. Sustainable development goal policies

As a right, 'water and sanitation for all', was recognized by the United Nations (Resolution 64/292) and the Human Rights Council (Resolution 15/9) in 2010 and concerns universal access to related services equitable way and, therefore, the need for policies that take them into account. Universalization includes all services related to water and sanitation, including stormwater, with affordable tariffs, so as not to constitute obstacles to universal provision (Neto & Camkin 2020). In 2020, according to the United Nations, although hand washing is the easiest, cheapest, and most effective way to prevent the spread of diseases such as coronavirus, it was estimated that 3 billion people did not have this possibility in their homes. Inexplicably, nothing is said about rainwater, which, absent from statistics and analysis, can be considered a useful resource for solving urban shortage problems (Tjandraatmadja *et al.* 2015). The water stress level (SDG 6.4.2), characterized by high water consumption, from natural resources, is a phenomenon that occurs in most regions of the world and should rely on rainwater use policies, at least for non-potable uses.

Table 1 | Concepts and practical aspects of the paradigm shift present in urban stormwater management

Traditional	Sustainable
Water is a problem	Water as a resource
Fast runoff	Slow runoff
Engineering solution	Multiple areas solution
Centralized technical	Technical decentralized
Centralized decision (command and control)	Participative decision
End-of-the-line treatment	Source controlled treatment
Greater is better	Scale adapted
Urban floods	Water cycle

A World Bank study estimated that to achieve SDG 6 targets 6.1 and 6.2 (water supply, sanitation, and hygiene), from 2015 to 2030, the expenditure would be USD 116 billion per year. Only for water supply the expenditure would be USD 37.6 billion per year, which could be lower if rainwater was considered a resource (Hutton & Varughese 2016). This study considered 140 countries, representing 84% of the population in 2015 (6.12 billion out of 7.13 billion total). In terms of the gross product of the 140 countries (GP140), the capital required to meet water and sanitation service deficits is 0.39% of GP140, or three times the global historical average of 0.12% of GP140. Thus, policies regarding fundraising and financing are needed at the same time as institutional changes. The consideration of rainwater use policies can change these estimates and therefore deserves to be considered, contrary to what is currently perceived.

2.3. Funding and financing policies

Economic support and funding policies follow the perceived needs of coalitions of actors, especially those in power, and this is the case for the funding of stormwater infrastructure. Urban water policy funding has historically focused on water supply and wastewater, leaving stormwater in the background. Since the end of the last century, with the perception that pollution, water scarcity, heat islands, and urban flooding are related to stormwater and have negative impacts on the quality of life, policies related to stormwater are increasingly implemented. Thus, stormwater has received more attention, understanding that it can become a useful resource and no longer a problem within the logic of the urban water cycle (Goulden *et al.* 2018). As a result, stormwater infrastructures began to receive a larger number of resources, but still insufficient, given the number of demands. The ways to obtain these resources are varied, from the general budget (federal, regional, and local) to specific public budgets and contributions from users, the private sector, and donations.

In the USA, there are several ways to obtain resources, among which we highlight the so-called SWUs with dedicated funds through fees and tariffs (Environmental Financial Advisory Board 2020). In a survey published in 2016 by the Environment Protection Agency (EPA), it was estimated that USD 67.2 billion will need to be invested in the separator and combined systems over the next 20 years. This amount is equivalent to what was spent in the past to upgrade all wastewater treatment plants (EFAB-USEPA 2020).

In Brazil, between 2014 and 2033, the capital required for financing, according to the National Plan for Basic Sanitation (PLANSAB) is USD 33.6 billion over the next few years, or USD 1.7 billion per year (Montenegro 2017).

The need for funding is growing from ageing infrastructure, regulatory requirements, degradation of stormwater network quality, and pattern precipitation changes, but the cost of doing nothing can be much higher. Thus, all resource alternatives deserve consideration. Considering the impervious surfaces, determining who is responsible for the resulting stormwaters, and making rate structures part of public policy, according to the types of use and to the polluter pays principle, as with U.S. SWUs, is one solution. Accounting for the areas and assigning costs to each one, however, is not a simple task and requires the use of mapping technology, for example, through satellite images, and has several types of barriers to its effectiveness (Rydningen *et al.* 2022). In the USA, a barrier has been the litigation of collections, with questioning as to the calculation methods and the ownership of the collection, mostly by non-residential users (Black & Veatch 2021), but the courts have usually given won for the SWUs. In Germany, rainwater use incentives, for example, through exemptions for those who build retention devices on their lots, have been used successfully, bringing benefits such as the extension of the deadline for the execution of new storm pipelines or even their dispensation (Geyler *et al.* 2019). All these issues demonstrate that urban stormwater systems are complex and require the participation of many actors, with the solutions of quantities, or precipitation volumes, being only a part, since there are issues related to the quality and its treatment before disposal in the receiving bodies.

The financing and economic support policies for these infrastructures involve multiple aspects: social, economic, environmental, organizational, and institutional, and thus demand multidisciplinary and multiplicity of players so that the results to be obtained can be robust, according to the expectations of the values and paradigm changes that society longs for (EFAB-USEPA 2020).

3. INSTITUTIONS: THE RULES OF THE GAME

Institutions, considered as the rules of the game, according to the neoinstitutionalist theory (Schout & North 1991), involve formal rules (laws, decrees, and regulations) and informal rules (customs and usages), according to each society, but usually carry path dependence, that is, institutions are transformed, but obey logics linked to what was previously established. The prevalence of responsibility for water services, according to the principle of subsidiarity, falls on the institutional capacity

aspects of municipalities, including the paradigm shift from traditional to sustainable management. This capacity is addressed under three aspects: human resources, organizational, and managerial. The change in conceptualization and focus of urban stormwater management requires compatible institutional and organizational structures (Dhakal & Chevalier 2016), going beyond aspects of just resolving urban flooding and rapid rainfall conveyance.

Governance is a broad concept and a complex mechanism of multi-level participation that involves decision-making processes that encompass all stakeholder groups interested and responsible for collective decisions in which none of the parties has sufficient power, information, knowledge, or resources to unilaterally dominate the decision-making process (Kooiman & Jentoft 2009; Biswas & Tortajada 2010). Thus, governance is based on shared decisions while the government is based on decisions made by a formal authority. Governance differs from management in that the latter is about objectives and goals, while the former refers to basic values, concepts, and principles. Governance is built around choosing values and principles that facilitate choices in difficult decisions. Governance begins by determining what values are at stake and identifies core principles. Principles express which values and norms are valid and determine which goals are ethical and reasonable. From there, choices and decisions can be made, and the means are determined (Kooiman & Jentoft 2009). It is considered a form of governing, as are hierarchies, markets, and networks, but can be seen as a hybrid form of all the others.

Governance refers to the management and transformation of structures and processes of society or parts of it (Rijke *et al.* 2012). Governance as a structure deals with shaping the institutions and mechanisms through which social order is produced and reproduced, and governance as a process concerns governing, that is, activities whose purpose is to guide, control, and manage sectors or aspects of societies (Kooiman 1993). Urban water governance concerns structures, processes, and multiple actors (state, private actors, and civil society) in urban water management (Dobbie *et al.* 2017). Traditional, centralized governance, based on command and control, is not in line with the ongoing transformations that consider decentralization and multi-stakeholder participation in key aspects, that is, governance with a different strategic and operational focus. Therefore, there is a paradigm shift underway: from territory management, within administrative boundaries under local administration, to the boundaries of river basins, compatible with integrated water resource management, according to the hydrological cycle. Basin governance crosses not only administrative, but institutional, organizational, and political boundaries, taking management beyond existing hierarchical and power relations (Graefe 2011) and can be understood as the depoliticization of management and the consensual arrangement between institutions (Swyngedouw 2009).

Traditional stormwater governance, more suited to traditional management, is based on the mentality of rapid removal of precipitated waters. Despite favorably modifying the flood hydrograph, attenuating the maximum points, it reduces infiltration and affects the quality of the receiving media. These are two facts that are considered negative, the first by reducing groundwater recharge, disfavoring the waters available for drought periods, and the second by favoring the carriage of pollutants. For some decades, however, the adoption of green infrastructures has sought to mitigate these effects by bringing a paradigm shift in governance, from centralized and technocratic, focused on command and control, to distributed and participatory (Dhakal & Chevalier 2016).

The recent floods which occurred in California in 2023 (Flavelle *et al.* 2023), have raised the issue of flood mitigation by 'providing' rivers with space for their floodplain to mitigate downstream effects. The U.S. Army Corps of Engineers has been innovatively positioned in favor of 'making more space for rivers.' The 2023 floods in California were the result of atmospheric phenomena that added up, such as increased precipitation from several consecutive waves of 'atmospheric rivers,' from snow melt, as well as dry soils that make it difficult for precipitated water to penetrate (Flavelle *et al.* 2023).

Finally, the major obstacles to paradigm shift are not only technological but social and institutional (Brown & Farrelly 2009).

4. REGULATION: THE VISIBLE HAND

Regulation, defined as the control of policies and actions, involves the establishment and application of rules in activities that have value to society and is carried out through contracts, public agencies, or self-regulation. It establishes and ensures the application of quality and economic rules and may include, where necessary, goals for access and equity in service provision (Novaes 2022).

The regulation of urban stormwater management systems is divided into technical regulation and economic regulation. The former has as its main objective the quality of the environment through pollution control. The quality of stormwater can meet requirements, depending on the different types of use and quality of the urban environment, aiming at the well-being of

citizens through, for example, the so-called amenities such as urban lakes and rivers. The requirements, present in technical and quality regulation, however, affect costs and consequently tariffs, affecting the economic regulation of services. Economic regulation can provide incentives for efficiency in the provision of services. For example, incentives are provided through the application of tariffs that encourage the optimization of land use, with less sealing of areas, and by encouraging the use of rainwater on private lots instead of sending it to the public network. Another face of efficiency is achieved by encouraging the provision of services by the consortium of municipalities, when this is feasible, producing economies of scale and reducing the transaction costs of shared management (Narzetti & Marques 2021).

The current tariff structures, which in many places include, in a single tariff, both supply and wastewater disposal tariffs, disincentive to complement water supply with rainwater, because this can lead to revenue losses, discouraging the implementation of rainwater use and constituting a barrier to one of the goals of regulation, the universalization of services (Machete & Marques 2021). Universalization in itself brings efficiency by bringing resources from a larger base of taxpayers, a kind of economy of scale in meeting demand, but tariffs must be affordable and, according to Gomes *et al.* (2008), taxation should not exceed 5% of income for water, urban property, and land use services. The regulation also brings an aspect of inefficiency related to its implementation and operation costs, but these can be reduced through multisector regulation, through which the regulation structure can have its costs diluted by regulating several service sectors (water, gas, electricity, etc.) under a single regulation structure.

Regulation, however, despite being little present in the minds of the population and policymakers, is not only a matter of choice, but of better technical and economic performance. Regulation, when well designed, reaches public and private agents and contributes to the universalization of services with equity of access and use. However, it requires resources for investment and maintenance, alignment of incentives within the PIR optics, as well as unusual solutions (technical-economic and social) to deal with slum areas and urban fringes, where traditional solutions are not able to solve all the issues involved. The share of the population living in slums and informal settlements that do not have a safe water supply is significant, reaching, for example, in São Paulo a high percentage of 30% (Staddon *et al.* 2020). Alignment of incentives is necessary because individuals and organizations can pursue different goals and thus reduced incentives to coordinate vertically (across different levels of government) or horizontally (across organizations), reducing the achievement of those goals. Incentives can be defined as the stimuli or influences driving actors to behave in a certain way, for example, tariff regulation can incentivize demand management of consumers and encourage efficiency gains of service providers. Conditional access to finance by central governments can be another kind of incentive by performance-based mechanisms, like performance-based contracts with the private sector (World Bank 2022).

5. HEALTH ASPECTS

Actions related to urban stormwater management are strongly linked to the public health of city dwellers and cannot be dissociated from urban sanitation issues. In this respect, the presence of vectors, like mosquitoes, from various points of view, is linked to sanitation infrastructure issues, such as those related to stormwater runoff and wastewater, but also to water supplies, especially residential storage reservoirs, and to the collection and care of solid waste. The inconstancy of the supply leads the population to store, often precariously, in containers without cover, enough water to support the no supply space of time. In areas of an impoverished population, such as slums and urban fringes, however, even if there is no intermittent water supply, there is a lack of household reservoirs, which causes, as a result, the same type of supply, precariously, with the chance of proliferation of vectors in these improvised reservoirs (Caprara *et al.* 2009). Additionally, in many cities, when existing, the stormwater infrastructure carries the wastewater that overflows, or flows through the streets, mixing with stormwater and, eventually, with solid waste not collected or collected intermittently, which also provides environments for the dissemination of vectors and diseases. In Brazil, for example, besides the problems and situations already mentioned, there was a positive correlation between the number of dengue cases with the Human Development Index (HDI), problems in supply systems, and lack of urban stormwater management systems (Novaes *et al.* 2022).

6. ECONOMIC ASPECTS

6.1. Funding and management mechanisms

Among the incentives applicable to the provision of services are the financing and management mechanisms, particularly, when it comes to increasing demands due to demographic or other reasons, such as the ageing of stormwater infrastructures

and precipitation patterns change, as mentioned above. There is also a shrinking of resources for several reasons, legal, budgetary, and others, among them the resistance from private actors and the population. To cope with, or get around this scenario, which presents itself globally, in all countries, several forms have been created, among them the so-called SWUs, often present in the USA and Canada.

In the USA, increasing rules regarding the quality of stormwater have caused costs to grow while budgets have decreased in the face of demands related to, for example, ageing infrastructure and population growth. Charges, on the other hand, were pressured against expansion through legislation (e.g., California, 1978), leaving only tariffs as an alternative way to raise funds. At the same time, opportunities arose for people to receive support to finance stormwater infrastructure from the needs arising from hurricane events such as Katrina and Sandy. In this context, the opportunity arose for the implementation of fee-based SWUs as a mechanism to obtain resources for the management of urban stormwater services based on efficient land use and equity principles such as the polluter pays principle. However, its implementation presents several barriers such as: the need for local (state) legislation; tariff calculation models (in the USA there are nine types of models), with a predominance of the Equivalent Residential Unit (ERU) model; knowledge and information; the need for field research to determine waterproofed areas (use of aerial and satellite images); and litigation of issues (mostly regarding the right and form of tariff collection). Despite the success obtained with SWUs, these reasons, among others, contribute to the small number of SWUs that exist in the USA. Until 2022, only 1,851 out of a possible 22,389 SWUs, or less than 10% of the total (Campbell & Bradshaw 2021).

6.2. Private sector participation

The attractiveness of urban stormwater management services for private participation lies in the fact that it allows for additional investment capacity of the private sector and its flexibility and efficiency in risk management. Private SWUs are based on tariffs. However, there are controversies regarding the required return on investment for the private sector, when compared to the necessary inhabitants' contributions in each location, solely considering the population's ability to pay through tariffs. So, the combination of tariffs paid by society and resources contributed from public budgets is the key to enable the provision of services in certain locations.

PSP, however, is not limited to the best-known format, that is, concessions through public–private partnership (PPP) arrangements, either fully paid by the users or partially paid from the public budget and tariffs paid by the users of the services. There are other ways such as full privatization of services, or the sale of a stake, alienated to the private sector by launching shares of the public companies on the stock market (Novaes & Marques 2022a).

On the public sector side, besides the budget restrictions already mentioned, there is a history of poor results with low universalization, quality, and institutionalization, and a lack of financing structures for the services. However, the public sector has greater management capacity in sectors that are interconnected, such as urban planning, public health, and economics. Finally, public policies, such as, for example, stormwater reduction policies, can lead to a decrease in investments in systems, as they make it possible to reduce the volumes to be transported and treated, or even, use precipitated water, which provides the addition of value to precipitated water and eventually revenues. In several countries, PSP is observed, through various mechanisms including disconnection strategies and application of tariffs, in Germany; incentive to Sponge Cities, with the use of PPPs, in China; water markets, in Australia; integrated water management, in Argentina; upstream and downstream management, in Portugal; and several actions, but still with gaps in institutionalization like, for example, in Brazil, despite recent legislation bringing innovations aimed at encouraging the attraction of PSP (Novaes & Marques 2022b).

7. DISCUSSION

Australia is one of the countries where there is a perception of PIR alignment, but also a perception that incentives for users and providers are part of a context where results are sought. There are social subsidies provided by the government, so as not to dilute the providers' focus on results and revenues. In parallel, provider performance is rewarded for efficiency gains and users for reduced WSS tariffs (Radcliffe 2018). In the USA, the perceived alignment refers to some sites and aspects, but not all, remembering that in only 10% of possible sites the management and financing structures, known as SWUs, are applied (Campbell & Bradshaw 2021). There is a broad legal and institutional framework, subjecting operators, public and private, to various regulations. In countries where alignment is more perceived, such as the USA and Australia, questions remain to be answered, that is, how path dependency and institutional inertia contributed

to alignment. Australia has been improving its water management for more than three decades, moving from a highly subsidized system to one where private participation plays an important role. In the USA, management has been improved for decades, since the Clean Act of 1972, and now the existence of SWUs shows that the trajectory of reforms and transitions is an important determinant. In terms of regulation, in the two countries, USA and Canada, where PIR alignment is perceived, the results are positive, both in terms of economic and environmental sustainability (Johns 2019). In some Canadian cities, like Mississauga, Ontario, a dedicated stormwater funding, based in a user fee-system (proposed in 2012) aided the stormwater management planning which was a key to transition the stormwater service 2016 level to a 2019 sustainable level (just 3 years after the user fee operation) because the dedicated and predictable funding created the possibility to builds important projects and a reserve for when stormwater assets reach their service life (Sahib 2020). However, in the city of Toronto, Ontario, the City Council rejected the 2017 Stormwater Charge initiative (Table 2).

In France, there is no total alignment, which can be attributed to a complex institutional framework, due to the pulverization of communes that makes performance verification complex. Regulation is by contract and policy focus is centered on pollution control, using best practices (Barraqué 2017). In Germany, municipalities are subject to self-regulation, making it difficult to verify the alignment between PIRs. The general policy focuses on pollution to which various local objectives are added, and there is no alignment. The predominant policy in the UK is flooding vulnerability control, applying the Sustainable Drainage System (SuDS). The rules of the manual drawn up by the Construction Industry Research and Information Association (CIRIA) are followed (Woods *et al.* 2015), and regulation is divided into two aspects: quality, through the Environment Agency (EA) and costs by Water Services Regulation Authority (OFWAT), added municipal rules. There is no perception of explicit PIR alignment.

In Chile, the main policy is Integrated Water Resources Management (IWRM), but there is no major concern with urban stormwater and PIR alignment. China develops manuals for the application of a policy, called Sponge City Program (SCP), with 30 pilot cities where, by 2030, 80% of their land will be drained. Encouraging PSP and PPPs, but also focusing other financing options, like Green Bonds and payment for ecosystem services, China seeks for institutional investors and local citizens and business, but all options are still lacking experience (Mitchell *et al.* 2022). These probably are due to a kind of China's path dependence, relative to centralization of decisions, still present, with institutions dedicated to systematic centralization In Brazil, there is still no alignment of PIRs, despite the search for IWRM and a new regulation law, however, there is an expectation that maturing toward PIR alignment will require time.

8. CONCLUSIONS

The transition underway requires an ideological change, that is, a change in the level of ideas and mentality as a way of thinking about the ways of providing urban stormwater management services. This change involves three aspects: cognitive (knowledge to want change), normative (norms that create the duty to change), and regulatory (regulation that encourages and directed change).

It depends on governance in transition through *structures* that shape the institutional design and contain *mechanisms* through which the social order is produced and reproduced, and *processes*, that establish and enforce the rules of the game. In this context, the breaking of institutional inertia and path dependency may be necessary.

Finally, the last aspect of incentives for change is economic support, whereby policy decisions can bring gains in socio-economic and environmental aspects and drive change, emphasizing that regulation can add value (value for money – VfM).

The alignment of incentives for PIR depends on endogenous and local aspects, rather than general, although it is exogenously influenced by various factors, such as international funding sources.

The study reveals some limitations regarding several aspects such as sustainable development goals (SDGs); governance in transition; lack of neighborhoods disaggregated data; resulting examples; costs actions implementation and transaction costs; tariffs collection capacity; funds application; performance comparisons; and other quantities, as the estimated future precipitation volumes.

Concerning the next studies, it seems important to delve deeper into determining the population's willingness to pay for the services; knowing the results of Sponge Cities with PPPs; analyzing disaggregated data on the costs of sustainable infrastructures; comparisons between the two governance models (traditional and sustainable) and aspects of the implementation of SDGs, concerning urban stormwater management.

Table 2 | GDP per capita of some searched countries, PIR alignment, governance system, and the overall picture of urban stormwater management

Country (GDP/capita in US$, 2021)[a]	Policy (P)	Institution (I)	Regulation (R)	Governance system	PIR alignment
The USA (70,181.1)	Pollution control, Low Impact Development – Best Management Practices (LID-BMP)	Environment Protection Agency (EPA) rules, Stormwater Utilities, Federal Acts, state and municipal laws	EPA Rules, MS4, NPDES, state and municipal laws	Good enough governance	Aligned in many places, but not all aspects
AUSTRALIA (61,977,2)	Water-Sensitive Urban Design (WSUD)	Multisector regulators, IPART (Independent Price Authority Regulatory Tribunal) and ESC (Essential Services Commission) rules	Each state has its own regulatory body and its own rules	Good water-sensitive governance	Aligned
GERMANY (58,784.1)	Pollution control and multiobjectives	Federal, Local (Länd) and municipalities laws and water companies' rules, verbänd (river managers) guidance, water framework directives	Self-regulation	Municipal governance	Not aligned
CANADA (58,348.0)	Green infrastructure	Metropolitan areas governance (Toronto, Vancouver, Montreal) federal, provincial and municipal laws and codes	Provincial land use Municipal plans Zoning by-laws	Good enough governance	Well aligned
FRANCE (50,998.9)	Flood-control	Communes (municipalities)laws, 6 agencies de l'eau rules, watershed institutions, contractual rules, Water Flood Directive (WFD), Water Directive (WD)	Contractual arrangements	Multi-level complex governance system	Not aligned in all aspects
UK (49,765.1)	National funding of reduction flooding vulnerability, Sustainable Drainage System (SuDS)	Water Services Regulation Authority (OFWAT), Environment Agency (EA), Drinking Water Inspectorate (DWI) and municipalities rules. Flood and Water Management Act, 2010	No stormwater regulation, Construction Industry Research & Information Association (CIRIA) – SuDS guidance[b]	Market governance	Not aligned
CHILE (28,105.1)	Integrated Water Resources Management (IWRM)	Superintendencia Servicios Sanitários (SISS) rules	No stormwater regulation	Market governance	N/a[c]
CHINA (19,335.0)	Sponge Cities Initiative – Low Impact Development (LID)	Technical guidelines	No stormwater regulation	Centralized governance	N/a[c]
BRAZIL (15,424.0)	IWRM	Municipalities laws, all levels of agency independent regulators rules	Federal, state, and municipal initiatives	Governance in transition	Not aligned

[a]OECD (2023), Gross domestic product (GDP) (indicator). Doi:10.1787/dc2f7aec-en.
[b]Ballard *et al*. (2015).
[c]Not applied.

Some questions come to the fore in terms of paradigm shifts in stormwater management that should be further studied: How do policies and institutions change and what social forces, actors, coalitions, or events mobilize the changes? How do transaction costs play out? Can urban stormwater management occur as a policy without public participation, setting up what is called a 'Policy without a public'? Is there influence of Gross Domestic Product per capita, private participation (e.g., UK) or decentralization (e.g., France and Germany) on PIR alignment?

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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