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Jumping to the top: catalysts for leapfrogging to a water sensitive city

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Jumping to the top: catalysts for leapfrogging to a water sensitive city

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Abstract: Climate change, population growth and rapid urbanisation have severe implications for cities and the way in which they interact with water. As a response to these challenges the water sensitive cities concept emerged, which supports cities to become more resilient to these challenges while making them more prosperous, sustainable and liveable. A water sensitive city harnesses the whole water cycle through integrated water management solutions, designs beautiful blue and green urban spaces and comprises healthy communities who are strongly connected with each other and with their local environment. Indonesian cities have an opportunity to 'leapfrog' towards a water sensitive city and to bypass the negative consequences that have resulted from urbanisation and growth that developed countries have gone through. Contributing to this growing field of research, this paper synthesizes key insights from the transformative change, sustainable urban water management and leapfrogging literature. The paper defines what leapfrogging to a water sensitive city means and describes three catalysts that facilitate this transition: trans-disciplinary science, cross sectoral collaboration and innovation experiments. The paper also introduces a joint Australian-Indonesian research program that develops water sensitive city leapfrogging strategies by translating these catalysts into practice.

Keywords: leapfrogging, sustainable urban water management, water sensitive city

1. Introduction

Cities are the arena in which the battle for sustainability and resilience will be won or lost [1]. This holds especially true in Asia where 65% of urban development in the 21st century occurred [2]. Asian cities in particular are faced with severe challenges such as climate change, environmental degradation and social inequalities. In many ways cities in Asia have exceeded the carrying capacity of the natural environment to provide the necessary life supporting resources for their inhabitants in a sustainable way [3]. Researchers, politicians, decision makers, citizens and others are therefore urgently looking towards new development frameworks that help increase the resilience of their cities to these threats.

The Water Sensitive City (WSC) concept [4,5] emerged as a response to these dangers to environmental health and social stability. The framework has been used by governments (e.g. Australia, Singapore and China) and international organizations (e.g. Asian Development Bank), as a vision and strategic guidance for investment and planning. The WSC concept describes an urban development paradigm where water is managed in an integrated manner to increase the productivity, resilience, sustainability and liveability of urban areas. Cities in developed countries have usually gone through different development stages on their way towards achieving greater water sensitivity, but these stages often resulted in negative social and environmental consequences [5]. Rather than having to go through these less than desirable stages, cities in developing countries can leapfrog stages to avoid making the same mistakes developed countries made in their past [5-7]. In general terms, the concept of leapfrogging suggests that undesirable conditions that increase levels of pollution and vulnerability can be bypassed to reach the more desirable sustainable and resilient conditions. Cities in developing countries are particularly well positioned to takes these leaps forward because less resources have been invested in traditional urban water management infrastructure and institutions which makes them more receptive to water sensitive practices [6,7].

To date, most leapfrogging studies focus on the adoption and use of particular technologies, such as communication technology [8] and describe how more advanced technologies (e.g. mobile phones) can lead to the bypassing of less advanced levels of technological development (e.g. landlines). While these studies highlight the importance of innovation for leapfrogging specific technology stages, what remains less clear is: how leapfrogging at an entire sector (e.g. water, energy) or city-scale unfolds, what enabling conditions initiate and sustain leapfrogging, and how it could be best steered into a desired direction [7,9].

This paper addresses this gap by putting forward three catalysts of leapfrogging that support cities to bypass traditional development stages associated with negative social and environmental consequences and to move towards a more productive, sustainable, resilient and liveable water sensitive city. The paper begins by describing the WSC concept and how it relates to urban resilience. This is followed by an outline of the leapfrogging literature with a focus on cities and their interactions with water. On this basis, the paper defines leapfrogging to a WSC. The paper then describes two important prerequisites for leapfrogging: contextualized strategies and system capacities. To this end, the paper introduces three leapfrogging catalysts by synthesizing key insights from the literature on transformative change and sustainable urban water management (SUWM). Lastly, a collaborative research project between Australia and Indonesia is introduced. Its objective is to develop water sensitive city leapfrogging strategies by translating these catalysts into practice. Thus, this paper builds upon and contributes to leapfrogging research in developing countries and provides practical insights regarding how leapfrogging towards water sensitive cities can be catalyzed.

2. Water Sensitive Cities

Many cities throughout the world have to adapt to rapid urbanization, population growth and climate change by increasing their resilience to these challenges. These cities are increasingly recognizing that traditional urban water management approaches are ill-equipped to deal with these challenges due to deep uncertainties, changing societal values and negative environmental consequences [5,10].

In looking for a suitable way to address these challenges the water sensitive city concept emerged as a unifying vision and strategic guidance towards an urban water management approach that meets a city's water needs, but also delivers on a range of associated liveability, resilience and sustainability benefits[1]. The water sensitive cities framework has been increasingly adopted by governments (e.g. Australia, Singapore and China) and international organizations (e.g. Asian Development Bank) to guide urban development to wards this vision. At its core, a WSC is based on managing the water cycle in a holistic and integrated way rather than focusing on the different elements of the water cycle separately. This ensures that basic human needs are met while protecting and enhancing receiving waterways, reducing flood risk and creating beautiful green and blue urban spaces for healthy and happy communities. As such, the approach delivers on a range of objectives critical for the prosperity, liveability and resilience of a city such as: capacity to buffer extreme events, public green and blue space, clean and healthy waterways, pleasant and cool urban areas, connected and healthy communities, cultural significance and many others [4,5,11].

A WSC is built on three principles of practice that weave through the social and technical fabric of an urban area [4]. The principles (or 'pillars') provide the essential foundation for infrastructure development, urban design and social capital seeking to optimize the use of water resources, increase resilience to extreme events and protect ecosystem services in the urban landscape [6]. According to Wong and Brown [4] the three principles are:

a) Cities as water supply catchments: This principle emphasizes the concept of not relying on a sole source of water but instead develop more resilient, diversified system that uses multiple sources at different scales while matching the source of the water to its intended use.
b) Cities providing ecosystem services: This principle emphasizes the idea that urban landscapes actively supplement and support the natural environment and the services it provides.
c) Cities comprising water sensitive communities: This principle emphasizes the importance of institutional and social capacity, support and participation in sustainable urban water management.

A cities path towards greater water sensitivity has traditionally followed a sequential way in which each 'state' is building on the development of the previous stage. This is captured in the Urban Transitions Framework of Brown et al. [5] (Figure 1). Based on a historic analysis of the technical and institutional arrangement in urban water management over time the framework identifies six distinct city developments stages that cities go through when they progress towards greater water sensitivity.

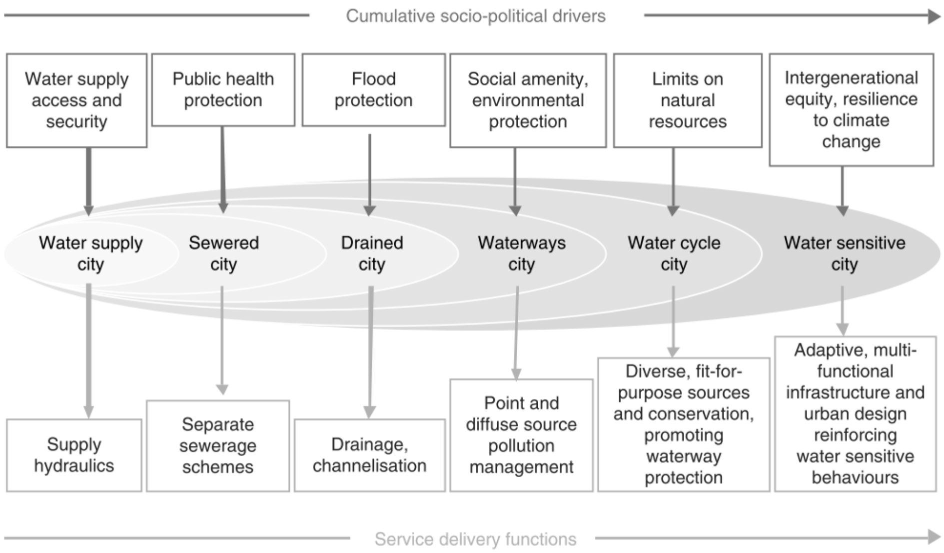

Figure 1: Urban water transition framework by Brown et al. [5]

[1]https://watersensitivecities.org.au/

The six states are mapped against two dimensions:

i. Cumulative Socio-Political Drivers: "the socio-political drivers (demands and expectations) that emerge from society's growing environmental awareness, amenity expectations and evolving attitudes toward water management" [6].

ii. Service Delivery Functions**:** "the increasingly diverse services required to address those drivers as cities transition to greater sustainability" [6].

The different stages of development. Each definition is taken directly from Brown et al. [6]:

a) Water Supply City
"The most basic state of modern water management, whereby a centralized system provides water to a growing urban population that expects cheap and equitable water for all. Large quantities of water are extracted from the environment using infrastructure such as pipes and dams. The public expects that water is cheap, harmless to the environment and limitlessly available."

b) Sewered City
"Building on the previous state, the Sewered City is drive by a desire for better public health and hygiene. Diseases caused by domestic and industrial waste effluent leads to the development of sewerage systems that divert effluent away from housing and into waterways outside of cities. As in the earlier state, it is assumed that the discarding of effluent does not harm the environment."

c) Drained City
"A need to protect homes and infrastructure from flooding is the driver behind the Drained City. The channeling of rivers enables the development of floodplains for housing and rapid urban growth. Like effluent, stormwater is directed away from urban areas and into waterways, generally thought of as dumping grounds for waste. The community expects water supply, sewerage and drainage services to be provided cheaply."

d) Waterways City
"The environmental impacts of both water extraction and waste processing are taken into account for the first time. As the social and aesthetic values of clean waterways are extolled, urban planning begins to integrate water as an important consideration. The unfettered extraction of freshwater is now being curbed, and receiving waterways are protected by filtering stormwater through bio-filtration systems such as rain gardens and artificial wetlands distributed throughout the city."

e) Water Cycle City
"In this state, water is actively conserved and supplies from diverse sources such as stormwater, greywater and recycled wastewater are used in a fit-for-purpose manner. Sustainability is now widely embraced, and the former hydro-social contract, in which government was expected to deliver risk-free water supply services, has been replaced with co-management arrangements between government, business and community."

f) Water Sensitive City
"Based on holistic and integrated water cycle management that meets the city's water needs while also delivering a range of associated liveability benefits. A Water Sensitive City manages water in a way that protects the health of receiving waters, mitigates flood risk and creates green public spaces that also harvest and recycle water. Infrastructure, technology and urban design will be flexible, recognizing the link between society and technology. The community is actively engaged with water, through recreational enjoyment of irrigated green spaces throughout the city, and have opportunities for more active involvement in the water system."

3. Leapfrogging

The concept of leapfrogging describes the potential to jump over or skip undesirable technologies or development stages such as those that are pollution intensive and to directly establish a more sustainable one [9,12]. Literature on leapfrogging has been particularly focused on how industries of developing countries can skip particular development stages that developed countries have gone through, consequently avoiding the social and environmental consequences that came with these pathways. This is reflected in the definition of Binz et al. [9] who define leapfrogging as "a situation in which a newly industrialised country learns from the mistakes of developed countries and directly implements more sustainable systems of production and consumption, based on innovative and ecologically more efficient technology". Other definitions however highlight that the concept is not only relevant for developing countries. For example, leapfrogging as described in Jefferies and Duffy [13] is conceptualised as "the idea that there are new paths to higher standards of living which bypass the mistakes that other communities made." Seen this way, the concept pertains to any community who wants to learn from another community in order to avoid making the same mistakes, consequently improving their lives. More directly related to urban water management Wong [14] states that leapfrogging is about "capturing and building on advancements and innovations in policies and technologies achieved in other places and avoiding the traditional evolutionary approach to infrastructure development and management."

For cities and their interactions with water, this means to skip over development stages which have been shown to create environmental, social and economic vulnerabilities by managing water in a fragmented, technocratic way and to advance to a stage that is characterized by greater productivity, resilience, sustainability and liveability [14] (See Figure 1). The difficulty to advance to a WSC in developed countries is that technological and institutional path dependencies lead to changes being incremental often resulting mere optimizations of unsustainable practices with limited potential for systematic change. Sunk costs and vested interests are very high through decades of investment which have aligned organizations, legislations and infrastructure with a particular set of practices and 'locking-in' the status quo [15]. The opportunity to leapfrog in developing countries comes from their relatively low levels of investment in traditional infrastructure and institutions which makes existing practices less entrenched. These conditions constitute a major opportunity for latecomer countries as technological and institutional lock-ins and path dependencies are not as strong, making them more receptive to adopt water sensitive practices [6,16]. This makes these cities well-placed to leapfrog directly to an urban water management system that enhances their productivity, resilience, sustainability and liveability rather than following the incremental evolution of urban water infrastructure and institution many cities in developed countries have gone through.

Based on the understanding outlined above we define leapfrogging for the purpose of this paper as systemic, vision led and irreversible change that bypasses traditional practices, infrastructure and institutions associated with less desirable city states to achieve a more productive, resilient, sustainable and livable city state.

3.1. Prerequisites for leapfrogging

The presence of contextualised strategies and absorptive capacity are considered to be imperative for leapfrogging to unfold [12,16]. To develop these prerequisites three particularly relevant leapfrogging catalysts are put forward in this paper: a) transdisciplinary science b) cross-sector partnerships and c) innovation experiments.

3.1.1. Contextualized strategies

The leapfrogging literature highlights a range of barriers that leapfrogging strategies face in developing countries. These barriers are predominantly found in the institutional, cultural or organisational domains within a sector [17, 18]. A core element of these barriers is the misalignment of problems and solutions between developed and developing countries. Hence, a barrier to these leapfrogging strategies is that of "contextual fit" where learned experiences and recommendations from elsewhere may prove dysfunction or even counter-productive [18]. Echoing this insight Sauter and Watson [12] highlight that there is no standard model of leapfrogging. The authors caution against a 'one size fits all' approach and emphasize that leapfrogging pathways are always unique and that case specific resources, strengths and weaknesses need to be considered when leapfrogging strategies are developed. In addition to the importance of spatial context, Shah et al. [18] recommend that leapfrogging strategies should consider the temporal context and in particular the necessary short (e.g. resource allocations), mid (e.g. legislative system) and long term (e.g. cultural norms) changes as well as interactions between these layers.

3.1.2 Absorptive capacity
In addition to contextualised strategies, successful leapfrogging also requires conducive conditions that enable these strategies to be adopted, to take hold and to grow. Underlying this notion is the conceptualisation of cities as a complex adaptive system [19]. In such systems, leapfrogging can, per definition, not be the outcome of a specific action or top-down implementation program as the complexity of the system blurs direct cause and effect relationships between what individuals and organisations do and system level outcomes [20]. This is compounded by the fact that leapfrogging requires efforts by many stakeholder groups which contribute in different ways and at different times to the leapfrogging process. Based on these insights, scholars propose to focus on developing the potential of a system that allows change to unfold into a desired direction [16, 21]. In the context of leapfrogging this potential has also been described as absorptive capacity or a systems' "ability to learn and implement the technologies and associated practices of already developed countries" [22].

3.2. Leapfrogging catalysts

3.2.1. Transdisciplinary science
Historically, mono-disciplinary and engineering dominated urban water management sectors worldwide. This led to a command and control approach to water management which in turn led to the development of large scale and centralized infrastructure. Over time engineering became supplemented by economic rationalities which supported narrowly focused economic efficiency agendas and short-term cost optimizations [23]. A pattern that has also been observed in Indonesian cities [24]. Whilst such predominately mono-disciplinary approaches have managed to improve water related health and safety to a certain extend they fall short in delivering on basic and higher order societal needs without severely increasing vulnerabilities to future uncertainties or leading to environmental degradation [25].

In response to these developments SUWM scholars point to the importance of transdisciplinary approaches to advance towards a water sensitive city [26-28]. Advancing towards a WSC requires solutions in different domains (e.g. infrastructure, community, governance) which no single discipline can develop by itself. To deliver social, environmental and economic outcomes the cross fertilization of ideas from multiple disciplines is better suited to develop solutions that fit the desired outcomes [27,28]. Ruiz et al. [28] point to the importance of harnessing and strategically combining formal knowledge (that is expert knowledge validated by scientific methods) as well as informal knowledge (that is tacit, practical or experiential knowledge from specific local contexts) which transcends sectors and particular stakeholder groups. The authors argue that transdisciplinary approaches are the key avenue for building knowledge and envisioning solutions from a holistic point of view instead of an isolated technocratic point of view and are consequently essential for the realization of a WSC. As such, transdisciplinary approaches are required for developing a shared vision of water sensitivity that is grounded in local aspirations and for devising solutions that take these into account. Furthermore, the advantage of transdisciplinary research that includes political scientists or community experts for example, is the translation and operationalization of research findings for policy makers and community representatives, thereby facilitating the uptake of new insights in policy and practice. Context specific leapfrogging strategies therefore require transdisciplinary approaches as the connection of WSC principles to local policy and practices requires knowledge from different fields and backgrounds.

3.2.2 Cross sector collaboration
Partnerships between stakeholders from different sectors (e.g. academia, business, government or civil society) usually involve a type of structured form of working together towards converging interests and the development of aligned objectives [29]. Such partnerships have a long history in public sectors and have also been identified as critical for advancing towards a water sensitive city [30]. However, they are difficult to set up and sustain because of diverging aims, power imbalances, different modes of operating

and different ways of communicating. Scholars therefore propose a process model for such partnership which suggests that they change over time with changing requirements [31]. Research from the urban water management sector in Australia illustrates this. Brown et al. [30] found that partnerships between academia and industry were particularly important when new water sensitive technologies were introduced to the sector. At this early stage, these partnerships allowed the testing of innovative solutions, their evaluation and adaption in close collaboration between universities and industry to ensure that solutions are high performing while being suitable for real world application. At later stages, these partnerships became wider and increasingly involved policy makers to evaluate and support water sensitive practices at a more strategic level across the entire planning, implementation and management chain [30]. This highlights that partnerships are critical for developing solutions and implementation strategies that take local biophysical and institutional particularities into account.

As previously described, leapfrogging involves many stakeholders with different value frames and is based on learning from the mistakes and successes of others. As such, it places a premium on cross sectoral partnership that enable social learning which is described as a collective process between different stakeholders in which a number of actor develop shared meanings, values and understandings through interactions [32]. While social learning can take on different forms (e.g. informal, formal) bridging organization or intermediaries are often highlighted in the literature as key conduits for creating such learning situations and for long lasting partnerships [33]. They broker knowledge between otherwise separate stakeholders, facilitate technical or managerial skill development and nurture trust and relationships between partners which are all critical processes for creating the capacity of a system to move towards water sensitivity [6,21].

3.2.3 Innovation experiments

Innovation experiments are considered a critical means for developing contextualized solutions for a specific problem while supporting the development of a professional and organizational culture that embraces reflection and learning [34]. The key to achieve this is their setup. While they can either focus on the technical (e.g. decentralized flood mitigation) or social domain (e.g. new governance arrangements for watershed management) their most critical design parameter is that they are implemented and monitored outside the traditional isolated environments of research laboratories. Instead, such experiments involve the application of innovative ideas in a real-world context specifically designed for experimentation, reflection and learning based on participation and end-user involvement [35]. They represent a learning by doing and doing by learning approach that can significantly enable searching, learning and knowledge sharing opportunities and thereby provide an important means for finding new or adapting existing solutions to the developing country context. Additional benefits are that they build stakeholders confidence for different solutions, develop trust amongst the different parties involved and ultimately influence capacity building and policy formulation [36].

Because such experiments implement often new and radically different urban water management practices outside of traditionally save university settings they usually face a range of different barriers. These were found to be predominantly situated in the socio-institutional setting rather than in the technical realm and relate to an inherent conservatism that underpins a ‘fear of failure’ for such projects [37]. More specifically, cost burden for correcting a ‘failed’ experiment and potential unintended consequences, personal and organizational reputation as well as political and legal liabilities are major hurdles. On the other hand, a number of success factor for such water sensitive experiments have been identified. For example, Farrelly and Brown [34] highlight that an early engagement of key stakeholders, the sustained involvement of champions and a continuity of engagement from different stakeholder groups as well as mechanisms for defining roles and responsibilities and risk sharing are critical success factors for innovation experiments to be carried out.

4. Australia – Indonesia Research Collaboration: The Urban Water Cluster

A collaborative research program, the “Urban Water Cluster”, has been established between universities in Australia and Indonesia, to support the transition or leapfrogging of Indonesian and Australian cities towards more sustainable, productive, resilient and liveable conditions through mutual learning and rapid uptake of context specific water practices. Funded by the Australian Department of Foreign Affairs and Trade through the Australia Indonesia Centre, this 2 million Australian Dollar investment builds on established research in Australia and Indonesia through a multi-institute research collaboration.

While traditional project delivery involves planning and scheduling activities to achieve outcomes on-time, on budget and with clearly defined performance indicators, the Urban Water Cluster has adopted a framework that better harnesses the momentum that each leapfrogging catalyst creates and delivers focus projects and networks of multi-organizational peer groups to enhance innovative environmental practice [36]. The multi-institutional partnership arrangement shown in Figure 2, and integrated cross-sectoral engagement framework developed by the partners shown in Figure 3, represent a translation of the leapfrogging catalyst described in this paper to an Indonesian context.

Through the involvement of social and political scientists, civil engineers, hydrologists, architects, urban planners and agriculture scientists across six institutes (Figure 2) the Cluster is well presented by transdisciplinary science. The cluster brings together leading researchers in Australia and Indonesia to work together on the issue of SUWM and practice in both countries. The first year of the program has been dedicated to building collaboration agreements to operationalize the research, establish and connect research teams, select case study sites and co-develop research work plans. Time and resources are key enablers of social learning [36] and ensuring a strong foundation for innovation.

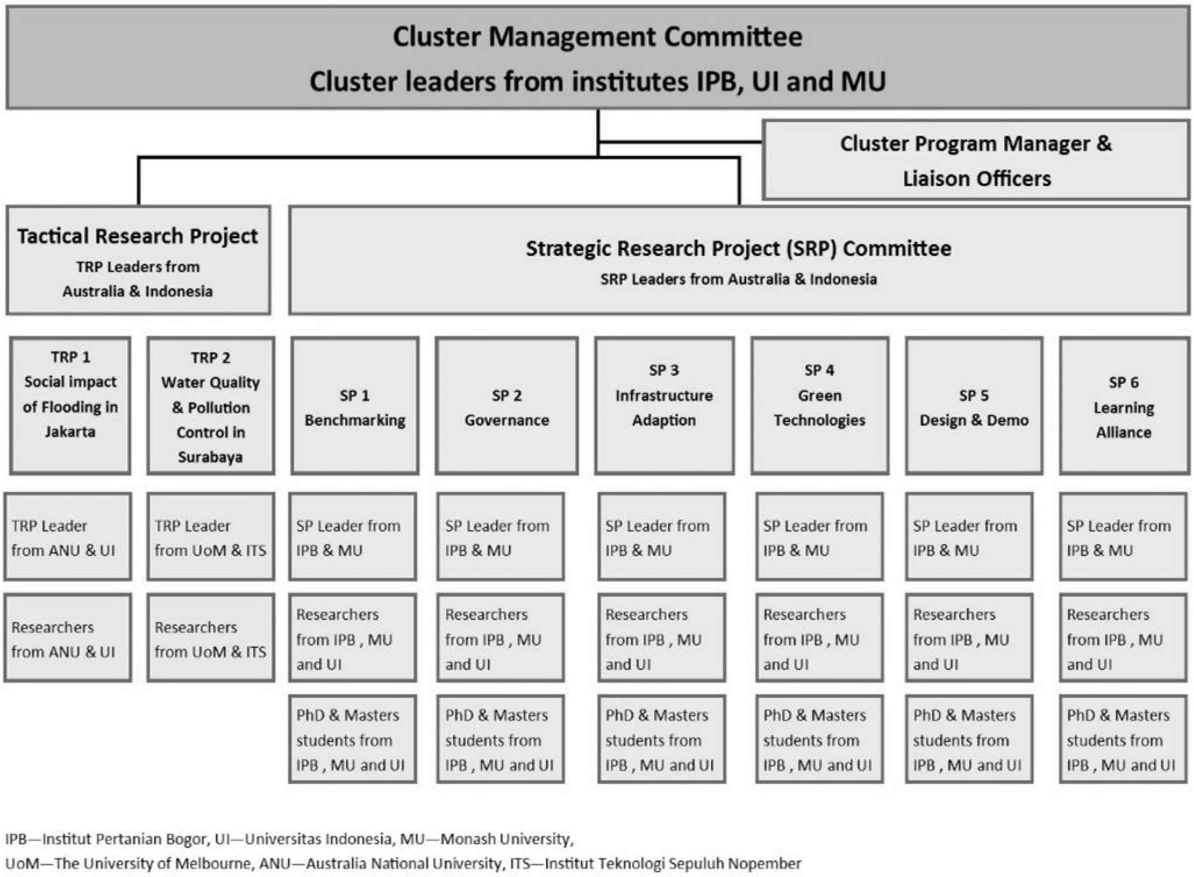

Figure 2. Urban water cluster research collaboration and partnerships.

The urban water innovation experiment includes both strategic and tactical elements. The Strategic Research Program (SRP) aims to deliver a suite of interrelated socio-technical tools to support the leapfrogging of Indonesian cities to a WSC state, including (SP1) city benchmarking, (SP2) transition governance, (SP3) infrastructure adaptation, (SP4) technological innovation, (SP5) urban design, and (SP6) creation of learning alliances (Figure 2). These tools, applied to four case study sites around Bogor and in the Ciliwung and Bekasi river catchments, will inform the leapfrogging strategies for each site. The Tactical Research Projects (TRPs), also have socio and technical elements that broaden the research to other Indonesian cities, including Jakarta and Surabaya. In its entirety, the interdisciplinary collaboration of researchers include 3 Australian Universities and 3 Indonesian Universities, involving 39 academics and 30 higher degree students (PhD and Masters).

Cross-sector collaboration and social learning has been intentionally integrated into the cluster framework throughout the design of the research cluster (Figure 2 & Figure 3) and in particular the creation of a Learning Alliance (SP 6) which will deliver the learning agenda. The learning alliance aims are to ensure the innovative experiments are guided by the experience, expertise and organizational settings relevant to sustainable urban water management practice, and emphasizes sharing socio-technical, organizational and cultural knowledge, understanding the local context at individual and organization levels and across multi-disciplines. Specifically, the alliance brings researchers together to co-design innovation experiments and engage with local, regional and national governments, developers, donors/banks, utilities, communities and Non-Governmental Organizations (NGOs). This engagement of expertise from Indonesia and Australia in water and sanitation, water policy, urban planning, green infrastructure build and management, is achieved through governance arrangements, masterclasses, focus group discussions and workshops.

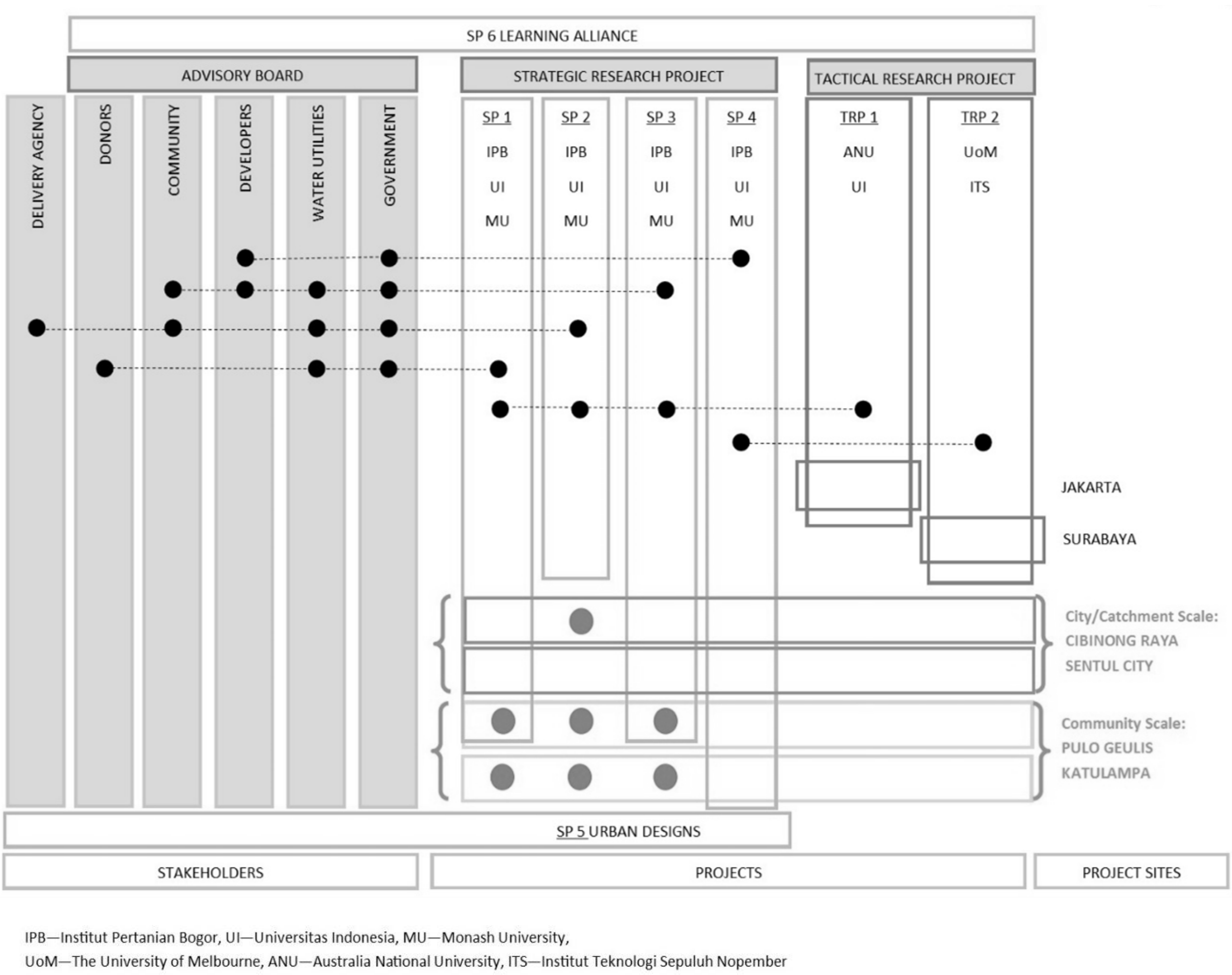

Figure 3. Integrated research framework for the urban water cluster.

Governance of the overall program is provided by an advisory board comprised of champions from each country, discipline and sector. Endorsement of the board and research program by Indonesian Bogor city and regency mayors and the Australian Department of Foreign Affairs and Trade (donor), develops "political capital and commitment" for change and provides legitimacy for the framework [36]. Program governance by the cluster management committee and SP Leaders from Indonesia and Australian leaders, ensures each institute have balanced input into the research program (Figure 2). Cluster leadership and institutional partnership is viewed as crucial to leveraging and strengthening relationships and provide the impetus to lead conceptual thinking in all areas of urban water management and city development. Coordination of the program by a project manager and two liaison officers, strengthens cross-institute relationships and collaboration efforts and ensures governance and administration of the program is well resourced.

Outside of the governance arrangements, cross-sector engagement is achieved through meetings, masterclasses, symposiums, workshops and focus group discussions, that aim to create, share, synthesize and disseminate knowledge in water sensitive design and practices. Consistent with the leapfrogging catalysts, the cluster engagement strategy has been carefully designed to actively create collaboration opportunities between Indonesian and Australian academic, government and industries, through the learning alliance network. The integrated framework (Figure 3) provides a holistic platform to understand urban water and WSC from the perspectives of different actors and deliver practice-based urban design and demonstration forums. These two activities will assure that the cluster achieves on ground practice change.

5. Concluding Remarks

This paper set out to describe catalysts for leapfrogging and to explain their potential role for achieving a water sensitive city in a developing country context. It drew on leapfrogging literature to define leapfrogging towards a water sensitive city and to highlight two key prerequisites. Building on this understanding the paper synthesized key insights from the transformative change and sustainable urban water management literature to describe three catalysts for leapfrogging (transdisciplinary science, cross sector partnerships and innovation experiments) which support the development of both prerequisites simultaneously. The paper also introduced a joint research project between Australian and Indonesian universities that represents a strategic translation of these catalysts into practice.

How the project, its processes and outcomes will facilitate leapfrogging of Indonesian cities towards a Water Sensitivity City remains subject to ongoing research. Nevertheless, two important points for leapfrogging towards water sensitivity in a developing country context can already be made based on this paper and the projects current implementation phase. First, the transformative change and SUWM literature provides a promising scholarly basis for future research on leapfrogging towards water sensitivity. Both bodies of literature with their shared normative basis for sustainable development, their focus on systemic change processes as well as their view on achieving real-world impact make them particularly well suited from a research and practice change perspective. Second, the role of international collaboration between developed and developing country research institutions provides a strong basis for robust leapfrogging research, the development of leapfrogging strategies and their implementation. None of these challenging tasks could be achieved by any side on its own and it is through this type of work that cultural exchange and mutual learning emerges from which both countries benefit.

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