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ORIGINAL ARTICLE

Analyzing the effects of institutional capacity on sustainable water governance

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Abstract
Sustainable management of water resources is becoming increasingly important in the face of challenges from urbanization, climate change, globalization, and other societal changes. Hong Kong, a water scarce city, is particularly in need of sustainable water management. In this paper, we focus on the key players in Hong Kong's water management and assess their capacities to pick up signals, balance interests, implement policies, and learn and adapt from 1999 to 2018. We find that while the socio-economic and environmental contexts have changed, their capacities to pick up signals and balance interests have remained relatively flat, although they were responsive to public outcry especially over drinking water contamination. Their main attention has been focused on implementation and technical solutions, forgoing opportunities to collaborate with intermediaries in preparing for water stressed scenarios. Thus, we advocate for capacity building and bringing the public and communities into the governance structure for the pursuit of water sustainability in Hong Kong.

Keywords Water policy · Institutional capacity · Water governance

Introduction

Ensuring that freshwater water resources are sustainable, accessible, and equitable by 2030 is the major objective of the United Nations Sustainable Development Goal 6 (UN SDG) (United Nations 2015). However, increasing water stress attributable to growth in both economies and populations, increasing per capita water consumption, and declining water resources due to contamination and climate change have made attaining this goal increasingly challenging (Tortajada and Joshi 2013). It is estimated that the water supplies of major cities, which serve a population of 233 million, will be overextended by 2050, increasing water stress and urban drought risk (Zhang et al. 2019). Insufficient freshwater resources threaten ecosystems and economic growth, affecting food production, health, and energy production, which can lead to displacement, conflict, and migration (United Nations 2018). More efficient and integrated systems for the management of water resources are needed to meet these challenges.

Hong Kong, as a water scarce urban metropolis, is not immune to these issues. Furthermore, Hong Kong is located in the Pearl River Delta (PRD), together with seven other cities, which all rely on the same water source (Dong River) and, thus, faces particular challenges in water management in this complex network. In the early 2000s, the effects of surprise events such as droughts in Guangdong cascaded over Hong Kong, leading to a capping of Hong Kong's annual water imports at 860 million cubic meters (MCM), spurring the need to develop alternative sources and conservation strategies. Seemingly sufficient supplies for meeting local demand coupled with the freeze in water tariffs since 1995 have created the false impression of water security in the Hong Kong public and a lack of culture of water saving (ADM Capital Foundation 2017). Overall, Hong Kong

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scored rather low among global cities on sustainability, despite possessing comparable natural resource endowments and economic growth as Singapore, which was ranked highly on the index. Creating synergies across different agencies and crafting policies incentivizing technological and social innovations have driven Singapore towards increased water sustainability (Shmelev and Shmeleva 2019).

Water resource management has become recognized as a complex multi-disciplinary topic with multiple interdependences (Söderbaum and Tortajada 2011) and inherent complexity. Reconfiguring our current systems to ensure sustainability (Benson et al. 2020) is, therefore, required. Scholars have suggested building structures which enable cooperation and partnerships (Lenihan 2009; Hering and Ingold 2012; Schneider and Buser 2018), and to make the processes more inclusive and robust (Edelenbos et al. 2003; Bourblanc 2010; Akhmouch 2014; Schnegg 2018; Schneider and Buser 2018) accommodating consultation and deliberation among the public, industrial, and academic sectors (Lenihan 2009; Hering and Ingold 2012; Schneider and Buser 2018). These results highlight the importance of capable institutions in sustainable water governance.

A significant amount of attention has been paid to water pollution monitoring and control technologies and ecological conservation in Hong Kong and the PRD region. On freshwater management, scholars have examined the limited local supply that can be attributed to the hydrological features of Hong Kong (Chau 1993; An et al. 2015), the quality of the Dong River water (Ho and Hui 2001; Ho et al. 2003; Kao 2015) and the relationship between Hong Kong and the mainland (Lee 2014; Ng and Kao 2017; Hartley et al. 2018). However, comparatively little attention has been placed on the institutions of Hong Kong's water management system. Our study will fill the gap in the literature by gauging the institutional capacity of Hong Kong's water management system and how it has evolved over time. The assessment will contribute to both SDG 6 (ensure availability and sustainable management of water and sanitation for all) and SDG target 16.6 (develop effective, accountable and transparent institutions at all levels) (United Nations 2015).

We have found that there are significant gaps in the capacity of the various actors, which have led to a reliance on technological solutions, while significant areas affecting water conservation and demand management have been relatively ignored, leading to a failure to control water demand in Hong Kong. Although those results may not directly apply to other global cities, our methodological exploration with constructing an assessment tool for systematically evaluating institutional capacity will offer an analytical framework for diagnosing water governance systems in other contexts.

The remainder of this paper is organized as follows: we first introduce Hong Kong's water management system. Next, we conceptualize institutional capacity for sustainable water governance. The following section operationalizes and contextualizes the assessment tool for Hong Kong and describes methods for data collection and analysis. We then present the results and the following section discusses. The last section concludes the paper.

Hong Kong's water management system

Institutional setup of Hong Kong's water management

The Water Supplies Department (WSD) is the leading agency in charge of overseeing and implementing the Waterworks Ordinance and regulations, including water supply, network maintenance, reservoir construction, and enforcement of violations. Due to the broad nature of its responsibilities and missions, WSD interfaces with a large number of agencies and departments, including the Drainage Services Department (DSD), the Environmental Protection Department (EPD), the Food and Health Bureau, and the Transport and Housing Bureau. Both WSD and DSD are subordinate agencies to the Development Bureau, which is the policy bureau in charge of planning, management, and implementation of public sector infrastructure development.

The Advisory Committee on the Quality of Water Supplies (ACQWS) is an independent body, aiming to provide transparency on water issues and increase public involvement in water quality-related issues. WSD's actions are subject to periodic review by the Audit Commission or investigation by the Ombudsman to provide accountability and assurances that WSD is operating efficiently and effectively. WSD must also interface closely with the Legislative Council (LegCo) and its various sub committees as they play a large role in WSD's operations, including fund appropriation, setting tariffs, approving large infrastructure, and setting Hong Kong's policy agenda. A list of agencies actively involved in water resource management decisions and their characteristics is provided in Table 1.

Drinking water supply and consumption

Hong Kong currently has a reliable freshwater water supply of 1050 million cubic meters (MCM), of which 70% is purchased from China through an agreement with Guangdong provincial authorities, which is sufficient to meet projected demand until approximately 2025 (Water Supplies Department 2018). The water purchases began in the 1960s, spurred on by severe droughts and a changing political climate which made water imports an attractive and economical option for the British government (Ho 2001). While this

Table 1 List of agencies involved in water resource management decisions

Type	Name	Composition
Administrative branch	WSD (Water Supplies Department)	Government
	ACQWS (Advisory Committee on the Quality of Water Supplies)	Government, academic, and industry
	Development Bureau	Government
	Audit Commission	Government
	Ombudsman	Government
Legislative branch	Legislative Council Finance Committee	Government, LegCo members are elected individuals from multisector backgrounds who represent local geographical constituencies

has been the predominant arrangement since the 1980s, its sustainability is threatened by increasing rainfall variability both locally and in the Pearl River Delta as a whole due to climate change. Climate change projections predict a 50-MCM reduction in local yield in Hong Kong alone (Water Supplies Department 2018). The flow of the Dong River has been reduced by 30% and the current level of water withdrawals has already exceeded its ecologically safe level (Lee and Moss 2014).

The PRD is one of the most important growth engines of the Chinese economy (generating 10% of GDP while housing 3% of its population in just 0.6% of its land area), in which four cities rely on the Dong River for between 70 and 90% of their water supply. The demand for water is expected to increase under current economic development plans for the area (Hong Kong General Chamber of Commerce 2017). To address this excessive water demand, China has capped water use in the area, making water consumption reduction necessary for Hong Kong (Leung Sze-lun 2007). Despite WSD's efforts to reduce leaks and curb consumption, domestic water use has continued to increase in recent years, to 134.6 L/day per person, which will soon outpace the available local and purchased resources. The changing political climate with China may also have effects on the ability to purchase additional water, as requests for additional supplies during droughts have been refused in the past during the 1967 Labor riots (Lee 2014).

Overall, Hong Kong lacks a comprehensive water policy. The Chief Executive's policy addresses which set the government's policy agenda, have discussed water quality issues (Chief Executive of Hong Kong SAR Government 1999, 2018) and seawater desalination (Chief Executive of Hong Kong SAR Government 2005, 2011) but with no mention of water security. It remains unknown how capable the Hong Kong government is of addressing the water challenges. We will conceptualize and operationalize the concept of institutional capacity and develop an assessment tool for this task.

Conceptualizing institutional capacity for sustainable water governance

Although a fluid concept, sustainable water governance can be defined as various actors such as government agencies, civil society, and transnational organizations working through formal and informal institutions to manage and conserve water resources, control water pollution, and resolve water conflicts (Li 2006). For achieving the purpose of water sustainability, actors devise structures and processes (formal and informal institutions) to reach consensus and/or form collective actions, responding to pressures, changes, and disturbances in the complex water-related social–ecological systems, across different spatial and temporal scales (Dietz et al. 2003; Ostrom 2009; Young 2010).

In state-dominated societies, it is essential for the government to be able to not only exert its will over the objections of dissenting social groups (Skocpol 1990), but also identify problems, develop and evaluate policy alternatives for dealing with them, and operate government programs (Howitt 1977). However, state-centric systems are inherently rigid, and decision makers suffer information deficits (Duit and Galaz 2008). Alternative governance modes that are network based or polycentric have been proven advantageous for forming effective collective actions to manage water and other natural resources (Dietz et al. 2003; Duit and Galaz 2008; Ostrom 2010; Van de Meene et al. 2011; Pahl-Wostl 2019).

Considering the complexity of the social–ecological systems, scholars argue the following capacities to be desirable, "providing information, dealing with conflict, inducing compliance, providing infrastructure, and be prepared for change" (Dietz et al. 2003). Information and signals worth picking up reflect the stocks and flows of water resources as well as human–environment interactions affecting them, such as product price and quality (Dietz et al. 2003). Accessible to stakeholders and decision makers, this information sets the basis for effective diagnosis, problem solving and learning (Li and Li 2012; OECD 2015). In making decisions with important sustainability implications, whose interests are taken into consideration reflects decision makers' understanding of to whom they are held accountable, which have implications for inclusion, conflict, fairness, and equity (OECD 2015; United Nations 2018). Besides balancing different interests, decision makers have to make trade-offs between different policy alternatives such as command-and-control, economic incentive mechanisms, informational incentive mechanisms, and/or voluntary approaches. These different tools involve different implementation and enforcement costs and induce different levels of compliance (Dietz et al. 2003).

To a large extent, choice of policy options and also outputs and outcomes delivered depend on available technologies and social infrastructure such as relationships and norms (North 1991; Dietz et al. 2003; Schnegg 2018). Beyond reacting to external stresses, monitoring and evaluation provide a feedback loop and offer opportunities for stakeholders and decision makers to learn, change proactively, and adapt to emerging new conditions (Green Growth Best Practice 2014; OECD 2015). As the World Development Report 2003 correctly points out, transforming institutions to achieve sustainable development in a dynamic world requires equipping them with the following four capacities: pick up signals, balance interests, implement policies, and learn and adapt (Shalizi 2003). Following the principles of good governance, the decision makers should also be held accountable (United Nations Economic and Social Commission for Asia and the Pacific 2009; OECD 2015).

The Hong Kong Special Administrative Region has long been striving for a clean and efficient government (Environmental Bureau 2017). In its mission statement, the WSD is particularly concerned about the following features of water services: reliability, adequacy/quantity, quality, and cost-effectiveness (signals worth picking up). Besides positioning the Hong Kong public as its customers and aiming to satisfy their needs, WSD also takes into consideration its "environmental responsibilities" (balancing interests). WSD believes it is important "to maintain and motivate an effective, efficient and committed workforce" for serving the community (implementation). Lastly, WSD emphasizes learning and continuous improvement by making "the best use of resources and technology" (Water Supplies Department 2019). Seemingly attentive to all the four aspects of institutional capacity, there is no systemic assessment on to what extent the WSD and other key players in Hong Kong's water management have actually paid attention to and exhibited those capacities.

Methodology

Operationalizing institutional capacity of Hong Kong's water management system

We measure the level of capacity to pick up signals by the efforts taken and information gathered and communicated on the stock, flow, price and quality of Hong Kong's water resources. The level of capacity to balance interests is measured by actors involved, objectives and interests expressed, and participatory processes installed for interest articulation in managing Hong Kong's water resources. Furthermore, we measure the capacity to implement policies by the policy alternatives or programs chosen, and efforts taken for executing, monitoring, and evaluating those policies and related programs for managing Hong Kong's water. As to the capacity to learn and adapt, we measure it by purposive knowledge accumulation, upgrading of technologies and standards, and/or international lesson learning. Lastly, accountability mechanisms are operationalized as scrutiny and oversight by external bodies on the water management in Hong Kong.

Publicly available official documents offer a solid ground for creating a good understanding of the specificities of the water management system in Hong Kong. Furthermore, reading through the conceptual lens to distil the above elements of institutional capacity from those official documents helps substantiate the indicators in the Hong Kong context. The extracted texts and keywords (methods for content analysis are introduced in "Methods for data analysis") along the following five dimensions, pick up signal (P), balance interests (B), implement policies (I), learn and adapt (L), and accountability mechanisms (A), after robustness checks, become the tailor-made indicators for assessing the institutional capacity of Hong Kong's water management.

To avoid possible omissions and confirm the applicability of the indicators to Hong Kong, we conducted robustness checks on the assessment tool. In focus group discussions with five WSD officials on April 24, 2019, we presented the list of indicators to obtain their feedback on (1) the classification and (2) possible missing items that are relevant for desirable institutional capacities for sustainable water management in Hong Kong. Furthermore, in March and June of 2019, we sent emails to a total of five professors in local universities, with 10 or more years of research experiences in water policy and management in Hong Kong and two replied stating their opinions on the same questions.

Based on the views of both the practitioners and academics, we modified one item (drinking water safety) and added four (energy efficiency, water gathering ground, salt water for flushing, replacement and rehabilitation program of water mains) and finalized indicator list for assessment.

The assessment tool is comprised of a total of 92 indicators with 13 in P, 18 in B, 43 in I, 15 in L, and 3 in A (Table S1 in supplementary information). Level of attention to institutional capacity exhibited is operationalized as the frequency count of the occurrences of each indicator in a document. The processes of theory-guided content analysis, operationalization of institutional capacity and indicator construction are iterative and exploratory in nature.

Methods for data collection

The years 1999 to present were chosen for the study as they reflect the time period after the Legislative Council was put into place and represent Hong Kong's management of the water supply without British influence. Removing this influence allows us to assess the level of attention to, and exhibition of, desirable institutional capacities for sustainable water management by the current stakeholders. We conducted desktop research on online government repositories and library collections to collect official publications generated by relevant government agencies (Table 1) which discuss water management issues.

These documents provide detailed information on what considerations/measures/actions have been taken by those organizations. As both Chinese and English are official languages in Hong Kong, only the English language documents were used to avoid duplication and double counting. Older documents in image format were converted by OCR to Word documents and reviewed for accuracy. This resulted in the collection of approximately 400 publicly available documents, including regulations, annual reports, research briefs, committee questions, policy papers, and meeting minutes published between 1999 and 2018.

Methods for data analysis

We applied content analysis to implement the grounded approach in both indicator construction and assessment of the institutional capacity of Hong Kong's water management system. Bearing in mind the operationalization of institutional capacity for sustainable water management, we manually reviewed each document to extract the words and phrases related to the efforts taken and results demonstrated on the indicative list of institutional capacities (paragraph 1 in "Operationalizing institutional capacity of HongKong's water management system"). The results from the grounded content analysis form a list of keywords and those unduplicated ones were manually classified to form a preliminary indicator list. After cross checking by the three team members and the robustness check by external experts, we finalized the indicator list and adopted computerized content analysis using Nvivo12.

To accurately measure the level of attention to each indicator of institutional capacity by frequency count of its occurrence in a document, we utilized the word frequency query function embedded in Nvivo12. Then, we were able to catch both the exact indicators and similar stem words using the grouping option. Furthermore, we checked the full-page text in which each indicator or equivalent word/phrase appears for excluding non-water-related usages. Following the computerized frequency counting by indicator and document, the results were aggregated for each indicator for understanding its overall magnitude and distribution by agency and by year. Focusing on the top five most frequently appeared indicators of institutional capacity (overall and by agency), we visualized their temporal variations (scatter plot) and matched with major events to uncover the underlying mechanisms of changes in the level of attention to the indicators. Lastly, *t*-test was performed to test whether differences in attention between agencies to the various institutional capacity indicators were significant.

Limitations of the methodology

Using only publicly available documents, we are unable to confirm, or quantify attention paid to the indicators in internal or classified documents or informal communications that are not accessible by the public. Thus, it is possible that the institutional capacity of the agencies is being underestimated. Additionally, each document or indicator enjoys an equal weight, such that the frequency count may not accurately reflect the level of practical significance of an agency that publishes a small number of documents or an indicator with few mentions. This may not be a concern in this analysis. Based on the focus group discussion, the Development Bureau and the WSD take a consensual approach in decision-making and share common views in official documents; so, it is safe not to analyze separately the publications by the Development Bureau. Furthermore, at the focus group discussion, no particular indicator was pointed out by the WSD officials to be worth of special attention. Only using publicly available documents and avoiding double counting ensure replicability, validity, and reliability of our methodology. Weighting different indicators is another scientific undertaking prone to subjectivity and debate, beyond the scope of this analysis.

Results

The WSD was found to have produced the majority of documents, with LegCO and the ACQWS the 2nd and 3rd most, respectively. Aggregated across all the 92 indicators, the total frequency counts by agency follow the order

Table 2 Indicator definitions

Agency definitions			
WSD	Water Supplies Department		
ACQWS	Advisory Committee on the Quality for Water Supplies		
LegCO	Legislative Council		
Indicator definitions			
p1	AMR/automatic meter reading/smart water/meter/metering	i8	Water quality
p4	Samples/sampling/testing/monitor/monitoring	i9	Salt water/seawater/flushing
p6	Total/per capita consumption/consumption	i29	Staffing
i7	Water supply and demand management	i41	Water safety plan

Table 3 Indicator rankings by agency

Rank	Overall	WSD	LegCo	ACQWS
1	Water sampling and monitoring (p4)	Water quality (i8)	Saltwater/seawater (i9)	Water Quality (i8)
2	Water quality (i8)	Water sampling and monitoring (p4)	Smart metering (p1)	Advisory (l3)
3	Water supply and demand management (i7)	Water supply and demand management (i7)	Water safety plan (i41)	Sampling and monitoring (p4)
4	Saltwater/seawater (i9)	Per capita consumption (p6)	Water supply and demand management (i7)	Amendment/proposed (l4)
5	Smart Metering (p1)	Staffing (i29)	Sampling and monitoring (p4)	Public education (l9)

of the LegCo and its subcommittees, WSD, Audit Commission, ACQWS, Development Bureau, and Ombudsman, from the largest to the smallest (Table S2). While the Audit Commission plays a key advisory role, it was excluded from further analysis as its publications were found to be repeated in LegCo's research briefs, finance committee questions, and other communications between LegCo and WSD. Table 2 contains a list of abbreviations for the indicators referenced in the results.

Key institutions and capacities

Table 3 reports the top five frequently cited indicators, representing capacities to which each organization has paid most attention.

LegCo The top five most frequently referred indicators by LegCo are about policy implementation and picking up signals, i9, p1, i41, i7, p4, in descending order of frequency, focusing on developing freshwater alternatives, water quality, and implementing additional demand management measures. Indicators associated with balancing economic and environmental interests such as household expenditure and purchased water only appear in the 8th and 9th rank, respectively, but water tariffs (310 mentions) and deficits (18 mentions) are rarely discussed. We can see that is LegCo is more concerned with affordability than cost recovery. As LegCo does not have any mandate to follow a user pays principle, there may be little political will to raise prices in lieu of continued subsidization. This may partly explain why the LegCo puts little pressure on WSD to increase tariffs.

Deterioration in the quality of the Dong River water supply (Legislative Council Secretariat 2000) first became a concern for LegCo in 2000 as indicated by the increase in p4 (see Fig. 1). This issue was then quickly addressed by WSD by the construction of a dedicated aqueduct and the establishment of the ACQWS in April 2000 to promote transparency and to encourage public participation in the monitoring of water quality. The attention to water quality had since largely decreased until a spike was again observed in 2015, when lead contamination of drinking water in the Kai Ching public housing Estate occurred in July 2015 (Legislative Council House Committee 2015). If not for the lead in water incidents, the LegCo showed little to no concern about water sampling beyond some questions to WSD regarding required sampling results. This revived attention to water quality issues also led to the creation of water safety plans as a response measure, in reaction to public outcry, which is in line with LegCo being responsible for handling public complaints. This example also shows LegCO's relative sensitivity to societal needs as they quickly responded to this issue, but after

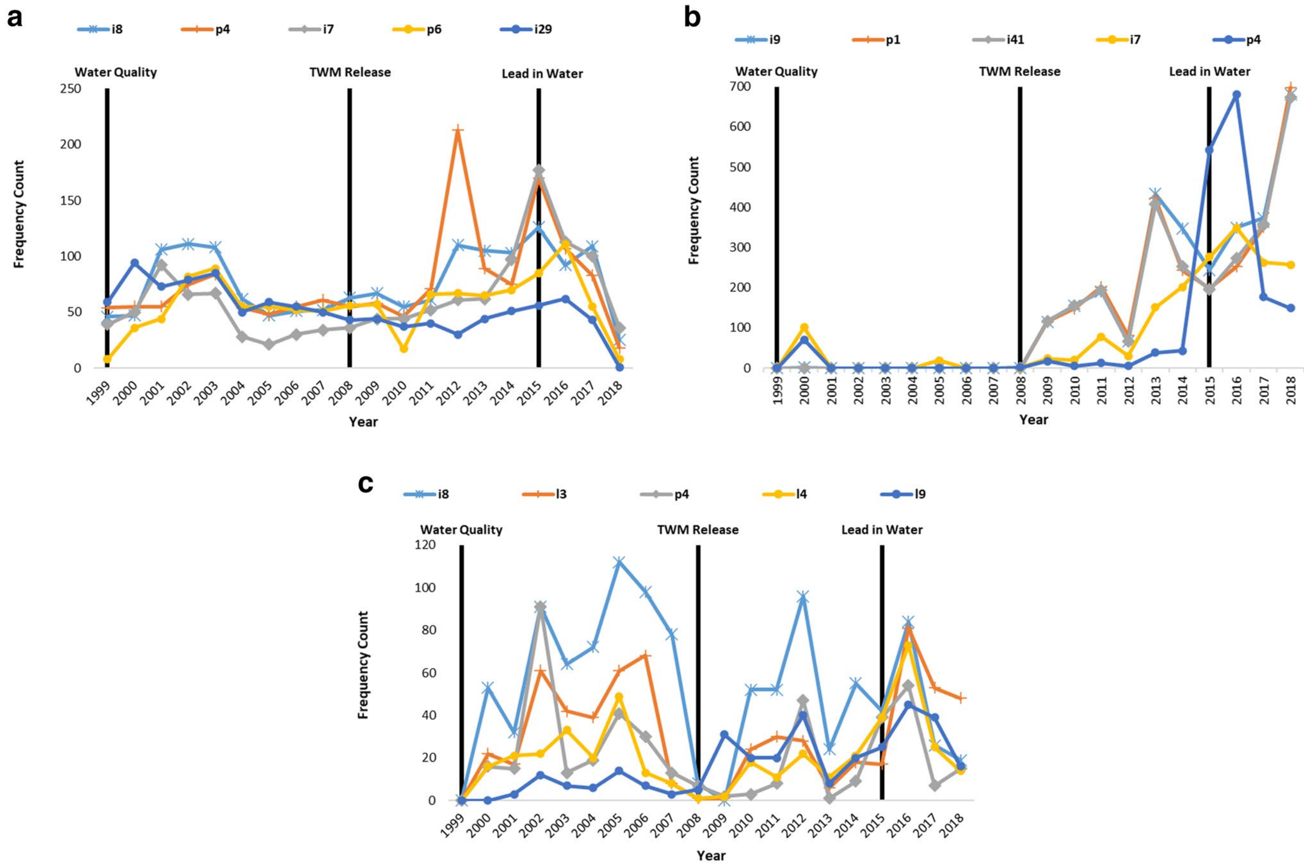

Fig. 1 Time trend of frequency of Top 5 capacity indicators for each agency, (**a**) the Water Supplies Department, (**b**) The Legislative Council, and (**c**) ACQWS

it was fully addressed by late 2016, the discussion had fallen off considerably.

With the implementation of the WSD's Total Water Management (TWM) plan in 2008, we can see a rise in LegCo's attention to (smart) water metering, supply/demand management and seawater, corresponding to the TWM's focuses. As part of this plan, desalination and automated meter reading were put forward as potential solutions, which expanded the definition of seawater beyond flushing and into different potential desalination methods. This led to a series of research papers (Legislative Council Secretariat 2014a, b, c) being produced for LegCo analyzing the cost and appropriateness of these technologies. Discussion of these topics was actually greater within LegCo publications than WSD's, as these topics also advanced several LegCo framework policy initiatives on climate resilience and smart city. Given LegCo votes on government proposals and funding appropriation, it is not surprising that LegCo dominates the discussion on these topics.

ACQWS Another policy-focused actor, the ACQWS' top five are broadly concerned with policy implementation and learning capacities. It routinely reports implementation of education and conservation programs, including "Let's save 10 L" (launched in 2014), number of water-saving device distributed, and number of schools and classes taught. Neither targets for these measures nor evaluation is mentioned in its documents. Thus, it is difficult to determine how they monitor the success of these programs or the long-term impacts such as how many of the distributed devices are still in use and if students retained any conservation behaviors. Although small in magnitude overall, ACQWS's attention to those capacities fluctuated greatly over time (Fig. 1). Based on the spikes in p4 in 2002 and 2016, we can see that the ACQWS was reacting to LegCo's increased interest in water quality and consumer health. However, topics important to water conservation such as water tariff but not paid much attention to by LegCo are equally absent from ACQWS's publications.

WSD As the agency responsible for water supply, WSD is mostly concerned with implementation and monitoring of water quality and consumption, i8, p4, i7, p6, and i29, Except for action plans, the other four of these top five most frequently referred indicators are also related to WSD's regular work. Bringing these actions plans back into context, we found they were created in response to the high levels of public outcry surrounding the lead in water incident, which also caught LegCo's attention and significant media coverage. Besides, the temporal trends of WSD's attention to water quality monitoring and supply/demand management also follow that of LegCo, only with a slight delay in time (Fig. 1). This peak, in 2015, for supply and demand management can be ascribed to WSD's intensive discussion on desalination for supply expansion (which had become a major topic at LegCo) and reclaimed water for flushing as a replacement for seawater. These topics were all also pursued by ACQWS in similar time frames. This reflects the solidarity in water management in Hong Kong but would also suggest that WSD has become a rather reactive than proactive agency, in its management of the water supply, based on the publicly available documents.

Mapping the frequency counts of the capacity indicators against WSD's vision, mission, and value statements, we found that indicators related to balancing interests (economic costs, sustainability, and public participation) are ranked quite low, and none appears in the top 10 (Table S3). Tariffs, deficits and costs have received very few mentions, becoming absent from the main text of the annual reports in 2012 and being replaced with the term low cost water. Deficits are still mentioned in the annual reports, but only in footnotes. Furthermore, there is a lack of attention to capacities associated with implementation (capacity building and setting targets/goals) or learning and adaptation (training and education). These results suggest WSD's focus on meeting the immediate needs of the public as customers with insufficient capacities exhibited for balancing interests and learning, which make proactive policy making more difficult.

Overall system capacities and their distribution

Considering the three key players as a whole, Fig. 2 illustrates how the top five frequently referred indicators have changed over time. Again, sampling and monitoring, water quality, supply/demand management, seawater, and (smart) metering were the most referenced capacities for addressing water issues (Table 4). Unsurprisingly, no capacities related to learning and adaptation or balancing interests were among the top 5. It is also clear that levels of importance placed on the above five capacities are not evenly distributed across the three key players, WSD, LegCo and ACQWS.

Prior to 2008, LegCo's role in the water supply policy-making process was predominately relegated to conducting duty visits to Guangzhou and the occasional research brief on purchased water. LegCo's attention to all five capacity issues was relatively static, despite changes occurring in water consumption, purchase water price, and advances in technology during the 10 years. In 2008, the WSD published the TWM, which in itself was a response to a major drought in Guangdong. After 2008, while heightened attention was observed for almost all indicators by all actors, LegCo's tended to be earlier. This yet again demonstrates LegCo's role in publicly driving the discussion and setting priorities for the other actors. This effect is most clear with regards to smart metering, which does not appear in WSD's top 5, but still makes it into the overall top 5 due to the high level of LegCo's interest in recent years. Smart Metering programs are often mentioned in LegCo documents related to general sustainability and smart city, such as the Hong Kong 2030+ documents.

These differences in focus are clearly revealed by the *T*-test results (Table 5). Unsurprisingly, among the three key players, WSD was most concerned with Water supply and demand management, LegCo was most focused on smart metering, and ACQWS was most concerned about water quality. In general, the *T*-test results prove the distinctiveness in priorities and focus areas of these agencies, which reflects differences in their missions or functions.

Trend of institutional capacities by category

Aggregated by capacity category, implementation received the most attention, including water quality, water supply and demand management, and seawater flushing, in descending order of magnitude (Table S4), aiming to ensure water safety and reduce consumption. Structural changes were introduced to enhance implementation. For example, the creation of water safety plans and the associated staffing positions also received significant attention in 2015, in response to the lead in water incident. Furthermore, consumer responsibilities, ranked the 7th most discussed by WSD, were also recognized important for making the implementation successful.

Indicators in the category of picking up signals received the second most total number of mentions. Those indicators performed relatively stable over time, expect for monitoring and smart metering, as previously discussed. Interestingly, the spike in monitoring in 2002 was of a far greater magnitude for the ACQWS, which may be explained by their efforts in international policy analysis for water quality solutions. Attention to pipe burst diverged between WSD (declining) and LegCo (increasing). This may be due to the recent completion of the HK$23.6 billion pipe rehabilitation program in 2015.

The majority of these indicators are related to WSD's ability to gauge the performance of the water infrastructures. In contrast, indicators which would allow it to understand consumer behaviors, such as audits, consumer surveys, and district management areas, received few mentions. These results reveal that the WSD lacks the necessary capacity to pick up signals from the public regarding water consumption and their opinions on water policy issues. This may help to explain why the WSD has not obtained a good understanding

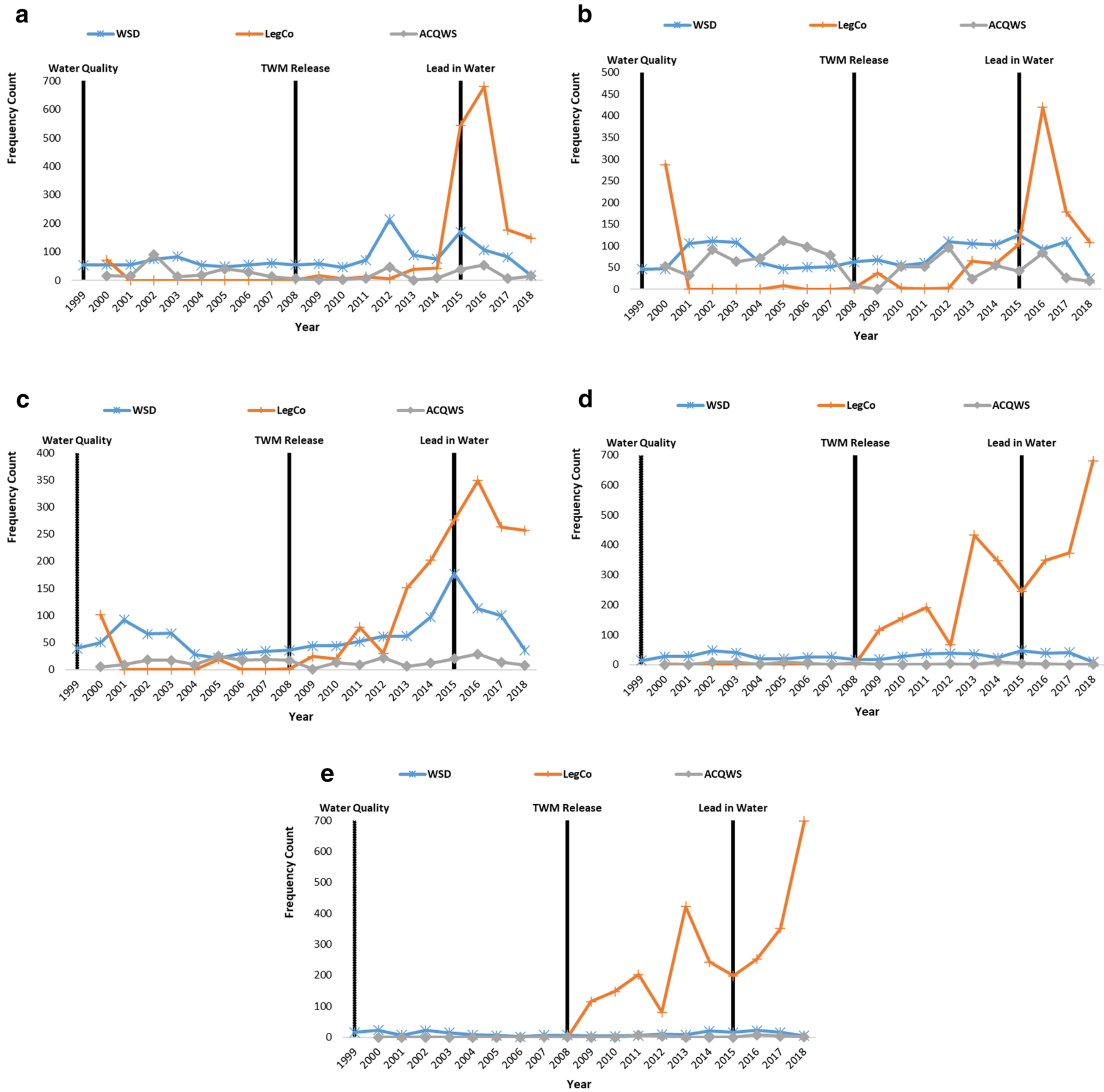

Fig. 2 Trends in the overall top 5 capacity indicators by agency over time, (**a**) Sampling and Monitoring - P4, (**b**) Water Quality - i8, (**c**) Water Supply and Demand Management - i7, (**d**) Salt Water/Seawater -i9, and (**e**) Smart Metering -P1

Table 4 Most frequently referenced capacity indicator

Indicator	Capacity	No. of references	Ref. by WSD	Ref. by LegCo	Ref. by ACQWS
p4	Samples/sampling/testing/monitor/monitoring	4740	1527	1744	430
i8	Water quality/quality	4348	146	1277	1058
i7	Water supply/demand management/demand and supply management	3847	1249	1771	270
i9	Saltwater for flushing/sea water/seawater	3729	578	2957	57
p1	AMR/automatic meter reading/smart water/meter/metering	3213	225	2710	27

Table 5 Inter-agency *T*-test results

Rank	Indicator	Definition	WSD–LegCo		WSD–ACQWS		LegCo–ACQWS	
			diff.	(*t*-statistic)	diff.	(*t*-statistic)	diff.	(*t*-statistic)
1	p4	Sampling, monitoring	– 10.33	– 0.25	8.76	4.65***	62.57	1.55
2	i8	Water quality	2.81	1.67	– 44.52	– 5.75***	– 47.33	– 6.14***
3	i7	Supply/demand management	21.38	5.49***	11.28	2.71**	– 10.09	– 4.97***
4	i9	Seawater flushing	– 10.85	– 1.45	2.0	1.29	12.86	1.74
5	p1	Smart metering	– 118.33	– 2.9***	9.43	5.814***	127.7	3.17***

***Significant at 1%, **significant at 5%, *significant at 10%

of the patterns of water consumption or reasons for non-revenue water.

Balancing interests have been primarily paid attention to by WSD and LegCo, with the ACQWS contributing approximately 10% of the total references. The focus issues for WSD were the Dong River water and water conservation and household income and expenditure levels for LegCo. Discussion concerning purchased water and water conservation have been increasing since 2008 for all agencies. Surprisingly, despite having "keeping costs low" as one of its missions, economic cost of water and cost recovery registered rather low attention from WSD. In contrast, LegCo has been increasingly focused on expenditure, which may be reflective of increasing water purchase prices and the high level of subsidies it pays to WSD to cover free water allocations and the tariff freeze.

While the learning and adapting capacity category has received the lowest level of overall attention, it has also been the most volatile, undergoing significant changes over time. In contrast with the other capacity categories, the ACQWS led the discussion on almost all indicators in this category, except for adoption of the 1999 WHO water standard, which predates its founding. Mentions of the ACQWS also increased in WSD's and LegCo's documents post 2008, and spiked in 2013–2016, which can be explained by its role in advising WSD on policy decisions, and its public education efforts. While the discussion surrounding most topics remained relatively flat, we can see an increase in Education/Schools/Public education (l09) for all agencies, starting in 2008 and spiking in 2015. Prior to 2015, the majority of discussion was focused on ACQWS's efforts to set up education programs for younger students to encourage water conservation, while the 2015 pike coincides with efforts to educate the public on lead in water issues. Additionally, following the 2015 lead in water incident, learning, and updating standards/rules were observed. Amending the plumbing code and Enhancement of the General Acceptance System to strengthen plumbing material control and the WSD's adoption of the WHO standards created spikes in 2016–17.

Discussion

Water management institutions in Hong Kong have demonstrated their capacities in managing the water supply and its physio-chemical features. Interest in water governance was primarily flat for all actors until 2003, as the level of demand placed on the Dong River begun to exceed the ecologically safe level (Guangdong Water Authority 2015), and WSD began to formulate its Total Water Management (TWM) strategy, which was formally released in 2008. WSD formulated the TWM to be a catch-all solution, which laid out its plan to diversify the water supply, manage water loss and consumer demand, and showed that Hong Kong was a "Good Partner" in the PRD network by demonstrating its water stewardship. The TWM, which contains a wish list of desirable water management practices, aimed to save 236 mcm/year by 2030 through a combination of conservation, leak control, increased seawater flushing, and water reclamation and desalination.

Furthermore, both the Hong Kong 2030+ and Total Water Management continue to rely on technical solutions for expanding local supply by desalination and water reclamation. The goal of these strategies is to ensure that local water resources are sufficient to meet predicted water demand until 2040, based on climate change scenarios. Of course, the TWM also plans to shift the water efficiency labeling (WELs) scheme from voluntary to mandatory in stages, to strengthen public education programs by extending them to lower grades, and to develop the Cherish Water ambassador scheme for secondary and tertiary institutions.[1] Without clear signals on the true cost of water production/consumption sent to the Hong Kong public, the LegCo, WSD and other agencies, it is hard to build shared understanding of the urgency of water sustainability and also the ecological and economic costs of water consumption in Hong Kong.

Governance for sustainable resource management demands institutions and capacities for managing both the social and ecological components. Societal consensus on

[1] The updated TWM has not yet been publicly published.

objectives and measures to take sometimes can be inconvenient or even at individuals' costs. Guided by social norms favoring sustainability, the public makes decisions and takes actions according to their specific situations, but all contribute to the common good (Ostrom 2009). In Hong Kong, important issues for water consumption reduction, such as tariffs, are off the agenda of the Legislative Council, which has led to a failure to create a shared conversation space in which citizens can contribute to the decision-making processes or forming desirable social norms.

According to the latest annual report, the average monthly water bill paid by a Hong Kong household is HKD$48 dollars (equivalent to 6 US$), well below 1% of the median income level,[2] with 14% of customers paying nothing due to the free allocation. Due to the tariff freeze enacted in 1985, rates and fees only finance approximately 30% of the WSD's operations. In 2015 alone, the WSD received government subsidies of HK$5,584 million on its rates, which limits the WSD's ability to finance initiatives of its own choice. Furthermore, the low cost also contributes to Hong Kong's excessive per capita water use (ADM Capital Foundation 2017) due to the public's perception of water as plentiful and cheap. Instead of actively shaping public discourses on water sustainability, both the LegCo and WSD responded to public outcries and took immediate measures for addressing the water quality crisis for satisfying customer demand. Although the ACQWS implemented educational programs in schools, there is no advocate in Hong Kong society for building societal consensus on sustainable water consumption.

All the non-technical measures proposed in the updated TWM have already appeared in the government documents analyzed in this study. WSD's most significant effort to date is the "Let's Save 10 L campaign" which provides domestic registrants who register for the program with a pair of flow controllers for sinks. Additionally, several ambitious public education campaigns and other programs aimed at educating students and youths have been established and a number of schools have invited WSD in to teach their students. However, WSD and the ACQWS have not established measurable targets or goals by which to allocate responsibilities to participants or to judge the overall success of these programs and lack any ability to track those in the programs to see if they practice water saving over a long period of time. Thus, the Hong Kong government's capability of setting up the organizational basis for managing the social components of the water governance system cannot be taken for granted.

Overall, tools and efforts associated with interest articulation, collaboration, evaluation, social learning are not well developed in Hong Kong's water management system. By focusing on these areas and including actors from societal and industrial sectors as key players, the WSD can begin to practice participatory planning, implementation, and evaluation of water management (Benson et al. 2020). This approach would allow for the consideration of both sectoral and basin-wide issues, such as effects on transboundary water resources that have been previously neglected, balancing local societal needs with broader environmental limitations through more holistic planning and policy development.

Inducing sustainability, particularly when highly diverse sets of actors are involved, requires high degrees of stakeholder participation to ensure shared systems are developed, different perspectives and concerns are balanced, and effective collaborations can be created and maintained (Schneider and Buser 2018). Similar efforts have been used in Manilla, where a 45% decrease (Teo 2012) in water loss was accomplished without technical measures but by directly engaging community leaders.

In the first step, the Water Authority appointed territorial managers to oversee a 3–5 district management areas, which are treated as their own business unit. Territorial managers were empowered to invest, set profitability targets, and establish cost-recovery measures. This community-led form of governance allows them to pick up signals associated with issues like leakages and water theft, by interfacing directly with customers and community leaders, not technological means (Robins et al. 2017). This approach may suggest inter-agency partnerships with actors currently outside of the water sector, such as district councillors and citizens groups, would provide significant capacity benefits to WSD.

Conclusions

The key players in Hong Kong's water management system have been mainly taking a managerial and technical approach but it has not been sufficient for achieving water sustainability. Frozen water prices distorted the true cost of water, failing to incentivize water conservation efforts. Combined with a lack of ability to detect consumer behaviors, a feedback loop cannot be created for upgrading implementation and adapting to emergent situations in water supply and usage. The existing top-down mode of water policy making has foregone the opportunities to reconcile different interests and tap into knowledge and efforts from civil society. Constrained by the administrative boundaries in the government structure, there is a lack of cross-agency consultation and joint decision-making in Hong Kong's water management system, which further diminishes its capacity to learn and adapt.

[2] Wages and Labour Earnings https://www.censtatd.gov.hk/hkstat/sub/so210.jsp Accessed September, 2019.

Thus, to enhance water sustainability of Hong Kong, a governance approach is needed which involves non-state actors and communities and builds institutional capacity for the network of players. The capacity to pick up signals can be enhanced by collecting information on the true cost of water, public willingness to pay for drinking water, and water usage patterns. Based on this, public engagement, and participation exercises with different sectors at different scales, neighborhood, district, city wide can create the venues for interest articulation, deliberation, consensus building, target setting, social learning and solution finding.

Structural reform within the Hong Kong government such as setting up a steering committee staffed by directors and main decision makers from the Chief Executive Office, Development Bureau, WSD, DSD, EPD and ACQWS can not only elevate the importance of water sustainability but also institutionalize joint decision-making and collaboration across agencies. This can increase both the legitimacy and implementation of water policies and programs and creates opportunities for innovation. With better social infrastructure and increased institutional capacity, responsibilities are shared by actors in the water governance system and accountability can be enhanced through greater transparency, participation, implementation, and monitoring and evaluation. Subsequently, Hong Kong could possibly move from a technocratic regime of water management to a more decentralized and sustainable form of water governance.

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Compliance with ethical standards

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