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Strategies for building resilience to hazards in water, sanitation and hygiene (WASH) systems: The role of public private partnerships

Åse Johannessen [a,*], Arno Rosemarin [a], Frank Thomalla [b], Åsa Gerger Swartling [a,d], Thor Axel Stenström [c], Gregor Vulturius [a]

[a] Stockholm Environment Institute, Stockholm, Sweden
[b] Stockholm Environment Institute, Bangkok, Thailand
[c] SARChI, Durban University of Technology, Institute for Water and Wastewater Technology, South Africa
[d] Stockholm Resilience Center, Stockholm, Sweden

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ABSTRACT

The aim of this paper is to enhance understanding of how the resilience of water, sanitation and hygiene (WASH) systems to hazards can be improved. In turn, this aims to inform different strategies for public and private partnerships (PPPs). In a new approach, to acknowledge the multi levelled nature of resilience; risk at the relevant levels are taken into account, (regional/river basin, urban area, and individual). For these levels, we first describe the different components of risk, vulnerability and resilience of the WASH system that influence people's exposure to hazards. We illustrate these components using examples from case studies in the literature. Using a social learning lens - a crucial ingredient of resilience - we examine opportunities for reducing risks through improving public–private engagement. These are presented as strategies which could guide investment decisions: As pressures from climate change and development add up, businesses must become aware of the risks involved in operating and investing without considering ecosystem health, both in terms of the services they provide for mitigating floods and droughts, as well as in terms of the development approaches that define how ecosystems are managed (e.g. "making space" for, rather than controlling water). There is a need to develop an institutional culture that strives towards greener and more resilient urban environments with the help of various quality assurance methods. Partnerships must reach the poorer customer base, encourage informal small entrepreneurs, and boost financial mechanisms (e.g. micro-insurance, micro-finance) to support the most vulnerable in society.

1. Introduction

One of the largest risks to people living in urban areas in the developing world is a lack of improved water, sanitation and hygiene (WASH) provision [117]. Access to water and sanitation is an important factor in determining social vulnerability to natural hazards, not only for meeting immediate needs, but also for the wider application of relevant disaster prevention [115]. Especially, the state of sanitation is a global crisis, and addressing the Millenium Development Goal (MDG) for sanitation is lagging significantly behind the other goals [33]. According to

* Corresponding author.
E-mail address: ase.johannessen@sei-international.org (Å. Johannessen).

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GLAAS [33], 83% of countries have fallen significantly behind the national targets they have set for sanitation. Many cities and their peri-urban areas, particularly those in low-income countries experiencing rapid urbanization, are struggling to address basic WASH needs to keep up with service provision due to deficits in financing, capacity and governance. This in turn leads to serious economic, social, and health implications [53]. In other words, even without considering "external" hazards such as floods or droughts, cities can become unsustainable from "internal" health hazards because WASH systems are not properly designed, implemented and maintained.

Despite the apparent urgency of current and future challenges from climate change and development, few studies have explored how the resilience of WASH systems to hazards can be enhanced. Oates et al. [75] provide a recent review of progress and challenges in WASH service provision and explore the potential impacts of climate change on WASH risk assessment and planning. They argue that near-term changes, impacts and the practical needs of decision makers remain poorly understood, while studies have mostly focused on modeling long-term changes. In the context of climate change, recent work on the resilience of water supply and sanitation was conducted by Howard & Bartram, [40]; Howard et al., [41]; Calow et al. [24] and Batchelor et al. [13].

This paper aims to identify strategies for investments by public and private partnerships (PPPs) based on an enhanced understanding of how the resilience of WASH systems to water-related hazards (e.g. floods and water scarcity) can be improved. We argue here that the scope for PPPs has not been explored to its full potential limited by a lack of systems analysis, taking the entire social, economic and environment system in which the WASH system is located into account. We argue that investments must not only focus on access and provision of WASH services through infrastructure development, but should be much more strongly coordinated with the activities of stakeholders across the entire integrated urban and river basin system, even with regional and global influences, with which the WASH system is linked through ecosystem services, such as hydrological flows, purification and waste treatment, flood and drought control, etc. [49]. This includes a stronger emphasis on the non-structural solutions requiring social learning between the involved stakeholders.

The provision of safe and resilient WASH services is intrinsically linked to processes of water management, land use planning, and DRR across the entire river basin and even beyond, as well as to the urban area in which they are located. Many hard won investments in WASH systems can be undone by not taking the entire system processes into account set by boundaries of the river basin and even beyond. Within urban areas, a lack of planning can lead to inappropriate development that in turn can increase people's exposure to flash floods, which heighten risks from inappropriate sanitation options that can result in the contamination of potable water sources [80]. Despite the need to take DRR into consideration in upstream areas connected to the WASH system, such links and feedbacks are seldom considered in investment decisions relating to WASH systems. Similarly, health-related costs are often given little weight in decisions about specific interventions to protect against hazards such as floods. Ahern et al. [3] conclude that one reason for this might be a poor understanding of the downstream health impacts caused by floods. They therefore highlight the need to quantify the degree to which climate change and land use change contribute to flood risk and the resulting health impacts in different settings.

Public Private Partnerships (PPP) are increasingly seen as a way to motivate private sector investment in urban WASH infrastructure projects that lack public funding [53]. PPPs have the potential to expand the range of service providers beyond traditional public sector monopolies and inject a measure of efficiency, dynamism, innovation, increase of access, improvement in quality, cost-recovery and consumer responsiveness [1,61]. Currently, the proportion of private investment in the water and sanitation sectors in developing countries is low, representing only 35% of the market compared to 80% in the developed world [114]. Some authors (e.g. [61]) therefore suggest that private sector participation should be encouraged to increase service efficiency, quality and accountability. However, privatization cannot be seen as a panacea. The wave of privatization of water utilities in the 1990s, for example, has been viewed as a failure by some observers [7]. Privatization has shown to actually reduce competition in the operation and management of water and sewerage services. On the other hand, public–private cooperation can work to everyone's benefit. The key criterion is that public services should remain under public control [44].

PPPs have also recently emerged as important and necessary mechanisms to strengthen DRR efforts in general. This has been motivated by an improved understanding of the vulnerabilities of supply chains and infrastructure assets to hazards. The enormous potential for private sector engagement in building resilience through corporate social responsibility (CSR) and philanthropy has recently been demonstrated by the United Nations Office for Disaster Risk Reduction's Private Sector Partnerships in DRR [119]. However, the areas in which private sector engagement would provide the most appropriate and effective contributions have not yet been well defined, and this study aims to provide some direction.

Resilience is the ability of a system to absorb shocks and to maintain its functionality, structure, identity and feedbacks, while coping and adapting to change, variability and extreme events [122,116,94]. We use the concept of social learning in our analysis, which is an important element of resilience in addressing environmental change [32,113,35]. Social learning is widely argued to have the potential to share knowledge and lessons, both formally and informally, between many levels and across different sectors. As such, insights and knowledge can transfer beyond the individual to organizations or communities of practice [113,89]. Social learning has a great potential in underpinning the strategic innovation needed to radically improve the modus operandi of private sector involvement for more resilient WASH systems. In the context of WASH, social learning has so far only been explored in relation to the governance of WASH systems

[22,121,70,95,83,77,110,71,17]. However, it has not been explored in detail in relation to DRR and WASH system resilience at the river basin level [78].

2. Framing the construction of risk and vulnerability to hazards in WASH systems

2.1. Data collection and analysis

The evidence presented in this paper is based on a review and analysis of the academic and non-academic literature. We conducted a comprehensive search of relevant literature using the electronic databases Science Direct, Google Scholar, and an internet search using Google applying the keywords 'WASH, sanitation, hygiene, disaster risk reduction, resilience, PPPs'. The search identified about 55 documents relevant for the analysis presented in the paper. Selected case studies were analyzed to identify key challenges, gaps and opportunities in building more resilient WASH systems involving social learning relating to the three levels - regional/river basin, urban area, and individual. The study is also based on conversations with private actors (two private philanthropy professionals), and three interviews with representatives of the humanitarian and development sectors (one humanitarian WASH professional, one development WASH professional, and one former Mayor).

We first describe the different components of risk, vulnerability and resilience of the WASH system that influence people's exposure to hazards at different levels. We distinguish between regional/river basin, urban and individual levels to account for different dynamics and processes. Using empirical examples from published case studies we then illustrate these components and examine the resulting increased vulnerabilities and health impacts in communities at risk. Finally, using a social learning lens we examine opportunities for improving public–private engagement and as such resilience at the different levels. These opportunities are presented as strategies which could guide investment decisions through new and innovative approaches and mechanisms that involve social learning and collaborative partnerships between private and public actors, and potentially also urban communities.

2.2. Disaster risk in WASH systems

Disasters are often described as a result of exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences [116]. A disaster can be defined as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources." [116]. A hazard, such as a flood or drought, can lead to a range of secondary hazards. For example, a health hazard might arise through the exposure of people to contaminated water in the WASH system. In the framework presented here, we consider the "disaster of disease" [116] as a consequence of a dysfunctional WASH system. For example, enteric (intestinal) pathogens from infected humans, including symptomless carriers, represent a hazard under the UNISDR definition.

The impact is not exclusively on human health, but will also affect and impact on downstream ecosystems and communities and activities in a river basin context including fisheries and tourism in addition to destruction of water resources heavily polluted by nutrients and organic compounds [30]. As water is very much a driver of economic development, the degradation of this resource will trigger indirect and direct financial impacts on businesses and the public sector with negative implications on long-term economic growth rate, sustainable development and resilience [92,91].

2.3. Vulnerabilities of WASH systems to water-related hazards at different levels

Vulnerability is defined as the capacity of a receptor to experience harm from a specific hazard or a range of hazards [52,19,111,2]. Disasters occurring in WASH systems tend to result from vulnerabilities to a range of hazards impacting upon the system at different geographical levels.

In order to identify all vulnerabilities in the different WASH system components, to understand interdependencies and feedbacks, and to exclude unwanted externalities/surprises [81] it is crucial to consider the entire river basin as the natural boundary of the linked water and WASH system. By selecting this boundary, upstream/downstream processes of the WASH system can be captured and system complexities and uncertainties can be accounted for [79]. We use the term regional to complement the river basin level and relevant influences beyond this, such as migrants and refugees, politics, economic trade systems, pathogens and the hydrological cycle, originating even at global levels. We also distinguish between the urban system and the individual in order to capture the dynamics at these different levels.

2.4. WASH system vulnerabilities at the regional / river basin level

Land use in the river basin, without investment in DRR, can affect the functionality of downstream WASH systems. For example, in 2005 Hurricane Katrina illustrated this very well with about 50% of existing treatment plants and 20% of sewage collection systems needing rehabilitation in the Greater New Orleans area after the storm [25]. Waterborne infectious diseases were of major concern, both due to the physical destruction of the water and sanitation system infrastructure, as well as the impact of the enourmous amounts of floodwater in the city due to the failure of the levees [98].

In terms of linkages to the regional level and river basin it was concluded that important existing buffers to natural hazards were less functional than anticipated. It is not possible to assess if the breaching of the levees would not have occurred, but the increased exposure of New Orleans to Hurricane Katrina was an important factor. For example, a levee manager in Louisiana said in relation to Hurricane Katrina: "There is no doubt about it that…[the] biggest factor in hurricane risk is land loss. The Gulf of Mexico is,

in effect, probably 29 miles [or 32 km] closer to us than it was in 1965 when Hurricane Betsy hit". Some of these land losses were ironically due to the levees and the dam barriers which were built to protect the city from previous hurricanes [51]. Such influence from structural measures on natural processes, e.g. sedimentation in deltas, which maintain shorelines, is even considered more important than sea-level rise associated with global warming and the global ocean volume increase [107]. New Orleans exemplifies a situation, where the embankments and levees in fact made the populations behind them even more vulnerable to the consequences of a breach by providing a false sense of security. This reliance on infrastructure measures was catastrophic as consequences of failure were not anticipated or planned for.

Not only coastal protection, but also protection from river flooding has a tradition for centuries, especially in high income countries, that the river should be controlled by building dikes to reduce the risk of flooding [45]. But controlling floods has also here showed to have unforeseen consequences, due to the dynamic nature of water systems. Trying to control floods has resulted in the "control paradox", where applying controlling measures creates the need for more control as floods consequently increase [90]. Alternative or complementary measures of non-structural mitigation requires knowledge of such approaches [99], but the choice of hard infrastructure is also more susceptible to corruption [108]. Transparency International's 2005 report highlights 13 different features of infrastructure projects that make them particularly prone to corruption [101]. For example, large complex projects such as hydroelectric dams create ample opportunity for corruption in addition to lack of oversight or insufficient controls [43]. Corruption can also discourage the selection of softer management options. For example, Burra et al. [21] showed how politicians in India were opposed to community-led processes because they did not like working with groups they found difficult to approach for bribes.

Land use such as deforestation at river basin level can also contribute to flooding of downstream WASH systems. For example, in Bangladesh, the 1988 deforestation contributed to flooding resulting in the disruption of the Greater Dhaka's drinking water, sewage and drainage systems and seriously affected the 11 million inhabitants. As a result, diseases such as diarrhea and hepatitis, caused by the polluted water and contaminated food, rapidly spread within poor areas of the capital [73].

2.5. WASH system vulnerabilities at the urban level

A number of processes influence vulnerability of WASH systems at the urban level. The lack of adequate urban WASH facilities and rapid urban development in developing countries combine to increase health risks. Risk-related human exposure grows mainly because of unplanned environments with increasing crowding, inadequate operation and maintenance, dysfunctional facilities and consequently open defecation [34]. In many countries, for example India, large cities do not even have the capacity to treat sewage in an appropriate manner [72].

At the same time the removal of flood mitigating (green) buffers in a city is a slow but steady process. Increasing the impermeable surfaces and encroachment of urban waterways such as rivers and creeks, canals, floodplains, mangrove forests, urban green zones and public parks, that function as a network for stormwater runoff, limit the ground's infiltration capacity and exacerbate urban flash flooding and erosion, and increases the clogging of drainage canals [10,63]. In many cities, structural measures such as flood protection walls, embankments, drainage channels and other efforts to control floodwaters have proliferated. This has created incentives for further development in high risk floodplains, and it has also transferred flood risk downstream. In Bangkok this has had the effect that even a relatively modest river flow can result in damaging floods [55]. In the cities of Bangladesh, diminished water bodies and interrupted river flows are important factors in increasing flood risk [88]. For example, many canals in Dhaka have been filled in to construct settlements and small businesses [87].

Exposure to hazards varies between urban sites and are dependent on the hydrological and morphological characteristics within the river basin. Low-lying floodplains are naturally more exposed and likely to be affected by floods causing inappropriate sanitation systems to leak and contaminate potable water sources [79]. The impact is also dependent on geo-hydrological conditions for groundwater. Both are the case in many cities, and especially low income areas which are often located in flood-prone areas [16]. In spite of this, human settlements continue to develop in risk prone areas [36] through population expansion (e.g. rural-urban migration and city expansion via informal settlements on peri-urban boundaries).

Scarcity of water represents an environmental limit which should rule out options which rely on relatively large amounts of water to function. However, there are examples from Cambodia where school latrines were designed with flush toilets where no water source was available [123]. Alternative options such as simplified or condominial sewerage are, for example, promising low-cost options which have shown to be cost efficient, and can also be retrofitted in unplanned areas [104]. This sanitation option is especially suitable for low-income coastal areas subject to regular annual flooding. The city of Salvador, capital of the Brazilian state of Bahia, has one of the largest simplified sewerage systems in the country [69]. There, an epidemiological investigation revealed that after the system had been introduced, the prevalence in children under five of two types of roundworm and *Giardia* reduced significantly [12].

2.6. WASH system vulnerabilities at the level of the individual

Ironically, efforts to increase access to improved WASH system services at the household level often do not adequately consider risk reduction to protect public health in the community. Even if household options are implemented, untreated wastewater is frequently discharged into ditches or open storm-water drains (if they exist), which defies the purpose of the household efforts. Children

playing in the streets become exposed when partially treated and pathogen-laden overflow from septic tanks or other sanitary installations are drained to curb-side open channels, or households directly flush their toilet waste into street drains. Such drains are often clogged from silting or the dumping of garbage, thus causing overflows. They are further impacted during heavy rainfall causing further spread of contamination [104]. The drains are often directly accessed for drinking and washing water thus further increasing exposure. Conventional sewerage is not possible when the capital costs and water requirements are too high for the area in question. Other factors hindering such infrastructure investments are the additional costs for operation and maintenance, lack of financial and technical strength within the local administration, and too narrow streets in unplanned settlements. When conventional sewerage is ruled out for poor urban areas, pour flush or pit latrines along with septic tanks seem to be the only remaining option [104]. However these options are not appropriate in flood prone settings because they cause contamination and leakage, especially in areas with high water tables [37,38]. Unfortunately, alternative approaches are not provided. Instead a single technology, often dysfunctional, is often promoted with subsidies attached to it [85].

Access to hand-washing facilities, improved sanitation and safe water, can be an effective barrier against health hazards, as can hygienic behavior [60]. However, if service is only provided for a few hours every day the systems are vulnerable to contaminants that can enter through leaks when pipes are empty or pressure is low. Even where access was once provided, the reported rates of non-functionality of (mainly rural) hand pumps across the sector in 20 of Sub-Saharan countries is as high as 30–40% [58], and provide a strong signal that existing mechanisms for financing capital maintenance are inadequate. Existing systems are failing or have become dysfunctional due to lack of investments in operation and maintenance or upgrading of aging systems, resulting in system failures and wasted donor and government investment, for example in Asia Pacific [123]. Lack of access can also be caused by the inability of service providers' to respond to community motivations, needs and preferences, or to be sensitive to gender issues, disability and the needs of children. Furthermore, in cities in the global south, dysfunctional systems have economic implications, especially for the poor, who often have to rely on less safe water sources or on private water vendors who deliver water from unspecified sources (e.g. small pipe systems, jerry cans or tankers) usually also at a unit cost several times higher that delivered via public water supply systems to the middle and upper classes [11].

3. Strategies for linking investment in PPPs with DRR and building resilience in WASH systems

Any business interested in ensuring the safety of long-term investments will have to start thinking of the adequate strategies for managing disaster risk. While businesses are accustomed to managing business risks, in terms of disaster risk they often focus in on the response and reconstruction phase, and are yet to integrate the long-term risks of development or climate change into their strategies. They are also not preparing to grasp the competitive advantages that will accrue to those taking early action [54]. Consequently, relatively little attention has been given to the extensive partnership possibilities and innovations possible of PPPs for boosting resilient WASH systems beyond traditional ways. Questioning the business as usual approach could improve access to safe WASH services, alongside economic opportunities and security in vulnerable urban communities, which would have positive feedbacks on societies and economies in turn, offering more routes out of poverty [27]. In terms of resilience, this process can be described as transformation, which alters the fundamental attributes, such as paradigms, power systems, goals [47] value systems, regulatory, legislative or bureaucratic regimes, financial institutions, and technological or biological systems [46] which underlies the way decisions and actions are made which shape risk reduction and future risk generation.

In Sections 3.1 to 3.7 we provide insights into some important strategies for investments which also include measures at the urban and river basin/regional levels, as well as involving social learning. These are illustrated in Fig. 1, and could guide investment decisions through PPP initiatives and that could at the same time reduce vulnerability and build resilience of the WASH system at different levels. (Table 1).

3.1. Environmental limits: profitability reexamined

Profitability is one of the main conditions for a business enterprise. However, cost-benefit analyses may now change the way we look at investments if we take into account risks caused by a lack of focus on, or investment in, environmental buffers for floods. Comparisons of losses with investment in ecosystem services are becoming increasingly convincing arguments for private companies to become active in Corporate Social Responsibility (CSR) potentially as part of PPPs. For example, in 2011 Bangkok experienced a serious flood affecting approximately 13.6 million people and costing 1425 billion baht (US$ 45.7 billion) in economic damages and losses as of 1 December, 2011 [124,125]. Most of these were linked to manufacturing industry. This made it the world's fourth costliest disaster as of 2011 – only less than the 2011 earthquake and tsunami in Japan, the 1995 Kobe earthquake, and Hurricane Katrina in 2005. These events may trigger awareness of the need for business to be aware of the risks of a lack of investment in environmental services. It is perhaps too early to say whether the Bangkok floods have triggered such investment. However, this was the case in, for example, coastal mangrove restoration in the Indian Ocean after the tsunami in 2004, where PPPs have been successfully launched in Gujarat [100]. However, the linkages between investments in ecosystem services and actual value of risk mitigation downstream may not be obvious. One method of assessing appropriate measures based on ecosystem services is to do strategic environmental assessments (SEAs). These provide tools for social learning among various partners in the public and private domain around collaborative decision making over investments.

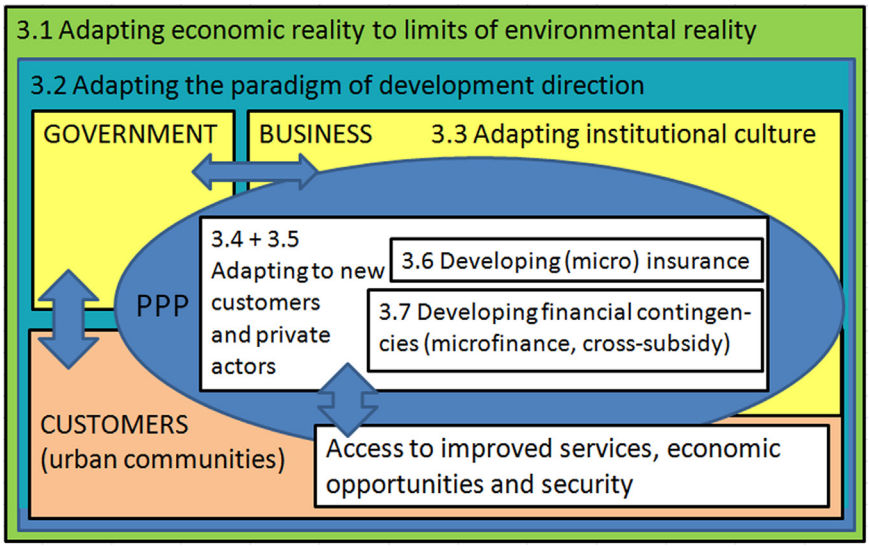

Fig. 1. The relationships and organization of the different strategies for linking investment in PPPs with DRR and building resilience in WASH systems. Note: The government and business form the basic units for the PPP, sometimes also involving the urban communities, and ultimately benefiting customers and the public. Communities can benefit from PPPs in terms of improved access to WASH services, economic opportunities and security, which in turn can have positive feedbacks on society and economy.

Table 1
A list of strategies matched to different levels for which they are most relevant.

Strategy	Level
• 3.1 Adapting economic reality to limits of environmental reality • 3.2 Adapting the paradigm of development direction	River basin level/ regional
• 3.3 Adapting institutional culture • 3.4+3.5 Adapting to new customers and private actors • 3.6 Developing microinsurance • 3.7 Developing financial contingencies (microfinance, cross-subsidy)	Urban level
• Access to improved services, economic opportunities and security	Individual level

These can compare ecosystem investment with alternative investments, so by promoting these tools investment decisions may look very different, particularly because they take into account potential maladaptation and are inclusive of ecosystem services. For example, in the outskirts of Kampala, Uganda, the Nakivubo Swamps provide the important ecosystem service of treating and filtering the biological waste water from much of the city. Ideas to drain the wetland in order to gain agricultural land were dropped when an assessment of this service showed that running a sewage treatment facility with the same capacity as the swamp would cost the city around 2 million US$ annually (TEEB case by [5]). In Belgium, a strategic assessment favored the restoration of approximately 5500 ha of the Scheldt Estuary, alongside dike reinforcement and dredging, instead of a storm surge barrier to meet flood risk. This solution was chosen because it had an estimated payback period of 14 years, compared with the 41-year payback period for the storm surge barrier [26,68,18].

3.2. The paradigm underlying development

Resilience building is ultimately about transformation towards approaches that work over the short term (meeting economic viability objectives), long term (ensuring sustainability) and which can manage change and uncertainty. To ensure that the working strategy of a business can enable progress on these horizons, it is essential to look at the overarching paradigm, worldview and basic principles that underlie its assumptions about socio-economic development. One area where business can add value is in terms of innovation and forward thinking for solutions. In terms of resilient WASH systems, opportunities are offered by adopting the innovative paradigm of 'living with water' as opposed to seeing water as something to shut out, dredge and remove from human economic development activities. This entails more integrated social and technical programmes that incorporate flood preparedness and non-structural mitigation, taking down or relocating dikes, lowering flood plains, creating water storage or removing obstacles [99]. This multifunctional land use approach includes a great effort in design and development, [74] where PPPs has a potential to play a role. Other changes follow from adopting this new paradigm, such as new management measures, new physical interventions in the river basin, uncertainties being addressed, changes in the regulatory framework and the introduction of new norms and values [42]. One result of such a paradigm shift is the Netherlands 'Room for the River' programme, (www.ruimtevoorderivier.nl). A collective learning of the critical and real hazard of flooding

from the sea led to a transformation of the existing approach. This programme now represents the state of the art in flood risk management, governing all other approaches and interventions in the Netherlands.

3.3. Changing business institutional cultures, competitive branding and 'license to operate'

Urban companies are increasingly developing and engaging in branding, programmes and campaigns that include the approach of "resilient" and "green cities", which takes in water risk management [117]. There are a range of different quality assurance approaches and methodologies which can contribute to a company's 'social license to operate', for example corporate citizenship, corporate social responsibility (CSR), good business values and brand reputation. This can be done through a business' own initiative, global standards, for example the Global Reporting Initiative (GRI), the UN Global Compact, ISO-standards, and liaising with programmes such as UNISDR's new programme on risk sensitive business investment [118]. In the same vein, many businesses factor in continuity and long-term reliability and resilience of urban energy, water, and transportation infrastructure into their investment decisions [76]. The city of Miami has used the CITYgreen Tool, a Geographic Information System (GIS) for systematically including green infrastructure, such as parks, urban forests and wetlands, into urban planning. This is done mainly for storm water protection, enhancement of air- and water quality and climate regulation. Using this, a riverine area was rehabilitated that subsequently generated a range of positive side effects (e.g. recreational and property values) [109]. In Sweden, a process of sustainability certification for urban areas is underway. Such tools could be used to mobilize private sector codes of conduct, in integrating DRR with sustainability criteria, such as aspects of drainage and run-off, flood risk, heat absorption, cooling, and ensuring weather-resilient development [50]. The "narrow view" of CSR justifies initiatives when they produce direct and clear links to firm financial performance (e.g. immediate cost savings. The more businesses take a "broad view" of the business case for CSR and similar efforts, the more they can enhance their competitive advantage and create win–win relationships with stakeholders. Support from stakeholders is necessary to create a market for virtue and a business case for CSR in the space where a firm's economic objectives and the social objectives of society converge [23].

3.4. Identifying a new segment of customers

Studies show that there is untapped potential to introduce PPPs in informal areas. In business theory, strategic innovators do something genuinely different that customers like and reward, based on a deep understanding of customers' needs and priorities [62] often overturning and challenging accepted assumptions [102]. To do that, it is for example critical to understand and work with community user preferences. Urban slums are often inhabited by migrants seeking employment [93]. Such people are often temporary tenants and tend to lack incentives to act within the community to reduce the WASH systems hazard. It is important to assess these people's world view, motivations and economic opportunities, because, if the needs, preferences, and buying patterns of these customers at the "bottom of the pyramid" were properly understood, new market opportunities would open up [84].

But there are many challenges to overcome in introducing PPPs for WASH service provision in informal areas. Limited awareness and information contribute to mistrust and a lack of mutual solutions between service providers and their poor constituents (USAID 2006). On the one hand, the urban poor often lack the social, organizational or political skills needed to approach providers or government officials to negotiate access to the services that are so vital to their social and economic well-being [9]. On the other hand, the private sector is risk-averse usually focusing on investment opportunities with wealthy communities, and while avoiding poor urban community service provision since this means operating on narrow margins with poor clients. Businesses are also often ill-prepared to service the low-income market, and their lack of experience with poor clients makes them even more wary of exploring profit-making opportunities in the slums [9]. This lack of experience furthermore creates misconceptions which do not encourage business to engage. For example, the main challenge facing the 'Sanitation as a Business Program' in Uganda (which is based on a pro-poor business model and employs a market-based approach) is dealing with delays in getting bank loans for entrepreneurs. Sanitation entrepreneurs cannot begin operating their businesses until they receive funding through bank loans. It has been observed that banks have limited information on the viability of small businesses in the sanitation sector [120]. This risk aversion is partly based on the lack of awareness that the urban poor are both able and willing to pay for water services, and banks generally do not recognize the potential economic and political benefits of serving the urban poor. For example, poor people living in slums often pay 5 to 10 times more per liter of water than wealthy people living in the same city [121]. But regulation may not provide an enabling environment. For example, there may be challenges in the way publicly or privately operated utilities serve the majority of low-income households [20].

When WASH system innovations become successful, such as low cost options stormwater drainage tailored to the needs of crowded urban environments, these need to be scaled up [82]. To help trigger and scale up innovations, so called 'learning alliances' are networks which are set up to trigger cross-learning to make use of existing knowledge across different levels and segments of society, where the community level also can play a role and provide insights of needs, preferences and pro-poor business models. Some cities have piloted city-wide 'learning alliances' [105] or 'learning and 'action alliances' [8].

3.5. Adapting to new private actors: informal services also count

Experience shows that the lowest-income groups, with the least access to water and sanitation services, receive

the fewest benefits from private provision [61]. Here, PPPs require strategic decisions on financing in order to optimize the public and private capacities to generate funds but also to maintain them. This sort of "reality check" is what has made PPPs a difficult solution for the most needy segments of society in developing countries, including slum communities in peri-urban areas.

However, it is important to acknowledge that the informal sector already delivers WASH services in slum areas. Small-scale independent providers (SSIPs) or non-state provision (NSP) have for a long time provided water supply; not of great quality, and at a high price, but nevertheless providing access and a service appreciated by community members [14]. Small (illegal) operators have been legalized and formalized, for example in Phnom Penh, Cambodia, and in Mozambique. This ensures they provide an adequate service at a regulated price, in return for being able to run a legal business [59] and also enables risk reducing measures by making the business subject to quality control and tasking them with improving the quality of water sources [14].

There are a lot of challenges to empowering and legalizing these informal players and service providers. For example, they lack the benefits of economies of scale, investment capital, long term corporate accountability, and integration of the slums into the larger city – things that are normally pursued by private sector partnerships [9]. In terms of support from the government there are also challenges. While policy now generally supports non-state provision (NSP), it is often repressive and effectively designed to protect established interests [14], and practice is more often unsupportive and relationships are surrounded by mistrust. Government approaches have unfortunately often been trying to replace those informal players rather than assist them [66]. In addition, for larger private companies operating in other areas of a city they represent competitors, even though they are operating in areas where the larger companies have not yet developed coverage [96].

Increasingly, however, formalizing service provision by small-scale independent providers (SSIPs) is practiced in partnership with formal utilities as an alternative model, but little is known about how these partnerships actually function or about their potential to serve as an alternative model for service provision in peri-urban areas. Not only is legalization necessary, but also sustained and non-politicized dialog. The main providers of non-state services—local entrepreneurs, individual practitioners, community organizations and small non-governmental organizations (NGOs)—are largely absent from any dialog with government or city authorities [59]. At the same time, government led processes are also perceived as being very politicized, because persons are replaced after a mandated period, which leads to reduced motivation from other actors, for example NGOs, to cooperate (29). Local government can also be reluctant to get involved [21]. Hesitancy can also be found in communities, possibly due to a mistrust of the efforts of government, politicians and NGOs as a result of past disappointments [112].

Local governments sometimes face the challenge of designing and implementing PPP contracts with private sector partners who may have much greater technical expertise and knowledge of the project requirements. In the case of formalising services provided by the informal sector, community-based organizations (CBOs) and NGOs, power asymmetry play a role. In the Organisation for Economic Co-operation and Development (OECD) there is a suggestion of how to minimize this asymmetry, through technical assistance to cities by national governments. This could take the form of what has been called "dedicated PPP units", specialized public bodies with PPP experts, which already operate at the national level in several OECD countries to increase the capacity of the public sector in engaging in PPPs [76]. Efforts to redesign this support for developing countries would need to include capacity building for pro poor business models, and PPPs tailor-made for collaboration with community groups and local small-scale service providers.

3.6. *Develop insurance mechanisms for the most vulnerable people*

Commercial insurance companies rank among the most resourceful actors in the private sector for sharing and redistributing financial risks from extreme events. Insurers make disasters insurable by pooling risks across time, space and large numbers of policyholders who differ in their exposure to risks [64]. Private life, health and property insurance is an important complement to welfare state risk-sharing mechanisms in developed countries. In many high-income countries, private insurers cover a large proportion of the financial burden from natural disasters. In developing countries, on the other hand, market penetration of private insurance is usually low, and governments often rely on humanitarian assistance and financial aid to respond to disasters. Furthermore, limited availability of non-life insurance in these countries means that private insurers shoulder little to none of the losses [124,125]. A healthy domestic insurance market can be a conduit into the international reinsurance market, allowing countries to tap into a pool of over US$400 billion of capital to aid recovery in the aftermath of a disaster. One explanation why Chile proved to be resilient in face of the February 2010 earthquake was that domestic carriers passed on 95 percent of the insured losses to the international reinsurance market. Worldwide, the fraction of insured losses coming from the reinsurance market over the last ten years is around 35 percent [124,125]. Aside from conventional insurance, catastrophe bonds and contingent credit contracts are two potential alternative instruments that can help developing countries to finance disaster risk management [103]. United Kingdom water utilities sign mutual help agreements to prepare for disaster events. This allows water service providers to request assistance from other water companies in case of a low key event, a major event or an emergency. The assistance ranges from the provision of bottled water supplies, tankers, equipment or specialist staff. Such sectoral self-insurance has further scope for replication and adaptation in developing countries [127].

3.7. Microinsurance

Microinsurance schemes are mechanisms that can help vulnerable populations in developing countries to deal with the financial risks from disasters. They are increasingly seen as a way forward in spreading and transferring risk. Microinsurance could help many of the poorest people—2.4 billion people live on less than US$2 per day in 2010 [126]—to escape poverty and fill gaps in risk management. There is a large scope for improvements. In an assessment of 121 local governments progress in DRR this area scores almost lowest of all areas in the 'Making Cities Resilient' campaign (run by the United Nations Office for Disaster Risk Reduction), [48].

Microinsurance schemes normally involve a number of partners from the private sector, governments, NGOs and other actors. These schemes are particularly important in places where people are not bankable. In many developing countries, less than half the population has access to formal financial services, and in most of Africa less than one in five households has access [15]. Microinsurance for health, in some African cases [65], seems to have a much greater chance of becoming a growing market than insurance for WASH systems per se. However, indirectly, microinsurance can play a key role for WASH systems. Risk of eviction is one of the biggest barriers for infrastructure development in slums, and microinsurance in housing could help to manage this risk better. For example, in slum areas of Dhaka, Bangladesh, people managing 'water houses' that provide WASH services would see insurance as an incentive to improve the facilities, which often are of poorest quality and very unhygienic [127].

For insurance to target poor people it is important to, for example, conduct demand studies, in order to understand the customer base and what type of insurance low-income people want to buy. Health insurance is the top priority for low-income households, as one big risk is hospitalization, which often happens suddenly and in most cases requires cash for service. A challenge is that very few companies reach out to develop the kind of relationship of trust and direct contact (both physical and psychological) with potential clients that is necessary for entering the low-income market directly. A challenge in terms of health insurance is that the poor are very much aware of the burden of diseases which mean small costs but which occur often, but these are difficult for a health insurer to cover. The claim process is high cost because it is difficult and expensive to obtain the information needed to verify claims. For a viable health insurance scheme, it is therefore recommended that policyholders and the community be involved in the business process, thus mobilizing their social capital: The greater the degree of convergence of the interests of insured and insurer, the more viable the arrangement will be [86].

3.8. Build (micro) financial contingencies

In high-income countries, governments are typically equipped with financial reserves and quick budget reallocations to cover their legal and social post-disaster responsibilities. There are also directly supporting instruments, for example social funds and livelihoods programmes, which can enable communities to make investments that are vital for building resilience and to transition to new livelihoods, often in new sectors and in urban areas where they may need temporary support. The financial implications of impacts from disasters on WASH are shared to varying extent in existing social welfare state arrangements [97]. The European Union Solidarity Fund, launched in 2002 may become a benchmark example of how risks from disasters can be pooled on a regional level across different sovereign countries.

In developing countries, supporting instruments such as social funds and livelihood programmes can enable communities to make investments that are vital for building the resilience needed to make transitions to new livelihoods. This can be combined with safety nets in the form of cash transfers (both conditional and unconditional), workforce programs and in-kind transfers. In the context of social protection instruments, several countries, including Malawi, have explored productivity-enhancing safety nets, direct welfare transfers and appropriate market interventions [28]. But experience in these has not migrated into the WASH sector as much as it has in food, health, shelter, or transportation. However, cross-subsidies exist in some cases, usually where utilities working across richer and poorer urban neighborhoods agree to government conditions for PPP service contracts that combine profitable projects with unprofitable ones to benefit poorer communities [53]. Creative solutions such as cross subsidies, social funds and livelihood programmes are necessary in order to generate interest from both public and private investors. There is, however, a large gap between the more typical PPPs involving utilities, when a private company is partnering with a public authority to provide a service, and the social protection or social safety activities that are needed to build resilience in poor communities [28]. A recent model which promises to fill this gap is the Asian Development Bank's introduction of a technical and financial toolkit and framework to support urban septage and sewerage management, which involves a range of actors from the sector [6]. Such constructs could lead to more private sector engagement.

Investments at the 'bottom of the pyramid' might seem like an obvious route forward because of the size of the potential market and the enormous need among such customers for facilities and services. However, several important hurdles will need to be overcome for such investments to increase because of the nature of informal settlements that require broad-based upgrades in infrastructure, housing and services, among other things [106]. Finding incentives for businesses to invest in this segment of society is part of the challenge of making river basins and urban areas and hence local WASH systems resilient to hazards. For business to do so, some sort of return on investments is necessary within a reasonable turn-around time, but without appropriate governance structures the investments are not forthcoming. If 'bottom of the pyramid' investments are to succeed, a positive investment climate and the governance capacity to build and maintain both simple and complex infrastructure systems is required.

There are many moral hazards involved. Where subsidies are too great it can create the perception that WASH

services are a free commodity. There can also be disincentives to maintenance, for example communities often do not find it worthwhile to invest in operations and maintenance for DRR if they know that when there is a breakdown, governments or NGOs will come to the rescue [31]. Donor support in times of emergencies can also risk crowding out existing private actors [57], and after a humanitarian intervention residents suddenly need to start paying for services that were free and of much better quality (29).

Also, when social security nets are being introduced it is important that already informal systems are not destroyed—a lesson learned from European social history [56]. Developing countries have a long history of informal systems, for example reliance on neighbors and families during disasters, which are important for strengthening resilience to water-related disasters. In Bangladesh, for example, people who have lost their homes due to flooding are in some cases allowed to rebuild on other people's land, under the assumption that the favor will one day be returned [39].

3.9. Microfinance

A review of microfinance programs for water and sanitation suggests that there is a large potential demand. However, while there are many pilot projects, very few have achieved scale. Microfinance institutes still show a low interest in the water and sanitation sector, especially urban sanitation, for it continues to be relatively unknown and is perceived as high risk [67]. In the Philippines, community-level microfinancing exists for both DRR and WASH [117]. Members of a so called Purok system, a micro-governance system at community level, voluntarily contribute to a bank used by those in need of emergency funds after a disaster. Private sector actors also have a role to play in supporting such community microfinance. In the Philippines, a real estate company in the city of Cebu has taken the initiative to transfer the Purok system to a peri urban area. This is motivated by legislation, which prescribes a certain percentage for CSR, as well as by a wish to leave a legacy. Financial capital is built up in a system of co-finance, where the community delivers its part, such as setting up an organization and activities, and then receives incentives accordingly (4).

4. Conclusions

We have described in this paper the different ways in which risk, vulnerability, and resilience to water-related hazards is constructed in WASH systems, how dysfunctional systems result in health impacts for communities at risk, and why these problems should be of grave concern to the global community.

Investments in WASH systems are often narrowly framed. They tend to focus on the provision of access to safe water and sanitation facilities and services at the level of the city at the most or at the community or individual level. Because of a lack of integrated WASH investments, the cost-effectiveness of existing investment decisions can be questioned. We argue in this paper that building the resilience of WASH systems to water-related hazards and resulting health risks requires a broader set of investments across the entire socio-economic system to which the WASH system is linked. This system includes the river basin (and sometimes beyond it) and the wider urban area in which the WASH system is located, right down to the point of access for the individual user. Building resilience to hazards consequently requires better coordination and collaboration between stakeholders engaged in a broad range of different sectors who influence the way in which land and water resources are used at different areas, such as agriculture, energy provision, natural resource extraction, conservation, housing and infrastructure development, industrial development, and disaster risk management. Profound changes or transformations in the way we manage natural resources will ultimately be needed as urbanization and development in river basins increasingly constrain systems.

Central to our examination of resilient WASH systems is the role of Public Private Partnerships (PPPs) and social learning, and the opportunities that exist for strengthening investments that are based on a more integrated view of the different elements of the WASH system and how they interact.

Business strategies

We identified a number of business strategies that could help to reduce the vulnerability of people and businesses to water-related hazards in urban areas, and that have direct and indirect positive impacts on enhancing the resilience of urban WASH systems, emphasizing the important role of social learning. These strategies are summarized below.

1. Reexamine the profitability of existing WASH investments in light of expected losses and damages caused by water-related hazards. Cost-benefit analysis and strategic environmental assessment tools can help raise awareness of the benefits of investing in ecosystems.
2. Replicate and upscale approaches that acknowledge that water needs to have adequate space. This entails more integrated social and technical programmes that incorporate flood preparedness and non-structural mitigation, and a multifunctional land use approach.
3. Create an institutional culture for private sector investment based on accountability, facilitated by quality assurance approaches and methods. Strive towards a more green and resilient city environment, and promote concerns about the continuity and long-term reliability of investments.
4. Develop a better understanding of the customer base, including worldviews, needs and preferences, motivations, and purchasing power. Find out how the 'Bottom of the pyramid' investments can become profitable through strategic innovation, especially in poor urban communities.
5. Support a new segment of private entrepreneurs through legislation, as well as empowerment of and

dialog with (informal) small private actors. Create an enabling policy, and a supportine practice in building trust, capacity and dialog.

6. Develop micro-insurance mechanisms in dialog with vulnerable communities to help them cope with financial risks. The most needed insurance is likely to be for health risks.
7. Build (micro) financial opportunities which can enable vulnerable people to make a transition into new livelihoods and reduce poverty. Consider how to reduce moral hazards when a service is provided for free or at a subsidized price.

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