



## Different paradigms for dealing with urban water issues, using new technological and governance solutions, learning from Chinese, Indian and European experiences

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### ABSTRACT

Three paradigms to deal with urban water issues are compared. The analysis focuses on their definition and objectives, the role of different stakeholders, the issues they deal with, and the possible solutions suggested. The paradigms differ in scope (from the narrow focus of the sponge city paradigm to the broad goals of eco-city paradigm) and in terms of the governance structures used to coordinate different stakeholders. The smart and sponge paradigms mainly use existing government structures. In the eco-cities approach, the citizens want to be involved through newly created governance structures. Smart and eco-city initiatives emphasize the involvement of stakeholders, while in the sponge cities approach, the initiative is often taken by the local government. Finally, in terms of expected solutions, the paradigms want to create eco- or healthy cities or improve water management to create a more healthy urban environment. After identifying the issue, alternative water-related technologies are available, like generating energy from wastewater or separating grey and brown water. Cities require different governance structures, and managing information flows in an integrated way to solve water and other issues. The experience in Europe, China, and India may help other cities choose the right paradigm.

**Key words:** eco-cities, governance, paradigms, smart cities, sponge cities, water management

### HIGHLIGHTS

- The eco, sponge, or smart cities approaches are three fundamental different paradigms to deal with water issues and to contribute to developing healthy cities.
- Identify issue at stake, choose best-fitting paradigm, and introduce new technological and governance options.
- Modern technology can help to solve urban water issues smartly.
- Governance structures, involving major stakeholders, are important to achieve sustainability.

### INTRODUCTION

Hurricanes have reminded us why the world needs smart cities. They cause catastrophic damage and flooding, sometimes killing hundreds of people and leaving thousands homeless. Monsoon downpours have flooded Mumbai, and 1,000 people were feared dead across South East Asia. At the same time, flooding has forced thousands from their homes in Niger's capital, Niamey. To avoid such problems, more ecologically friendly cities are needed. A number of cities have embarked on different, more sustainable city paradigms, to deal with climate change, leading to issues like flooding, droughts, and water scarcity.

For improved urban water management, one needs to look at the governance structures (defined as different ways to involve stakeholders), different infrastructural options, and different modes of finance and transportation, some of which are more sustainable than others (Litman & Burnell 2006). The choice between them is often conditioned by history, culture, and climate.

Through globalization, cities have become more competitive, but they also want to become greener. The competitive cities, the cultural city, or the Eco<sup>2</sup>cities concept (Suzuki *et al.* 2010) will not be discussed. Green cities as a paradigm means making cities greener, more environmentally friendly, and livable (Lindfield & Steinberg 2012). More and more cities

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have as an objective CO<sub>2</sub> reduction, or even zero emissions, and in particular, in the ‘new urbanism’ in England, CO<sub>2</sub> reduction is important (Smith-Morris 2011). Different initiatives went for zero carbon buildings, and the eco-cities concept broadened its meaning to include the concern for carbon emissions. The use of water for transportation is often at the losing end. Some cities encourage sustainable transportation by introducing shared means of transportation, or encouraging alternative methods of transportation, including the use of existing rivers and canals (Pojani & Stead 2015).

More environmental technologies are available for energy and water management to turn these systems into closed-loop systems (closing the water cycle). Waste water can be considered an asset, because of the potential to generate energy from waste water in the form of heat or bio gas. Creating green, clean, healthy, resilient cities, and promoting the circular economy or vibrant (in economic terms) cities (Lindfield & Steinberg 2012) concepts are not discussed separately. Elements of these approaches come back in the paradigms analyzed.

Take urban resilience or vulnerability as an example. Urban resilience is defined as ‘the ability to learn, plan, and recover from the hazards to which they are exposed’ (De Jong 2016). This definition of resilience can be made more complete by adding that a resilient city should also be able to deal with hazards in a sustainable way (UNISDR 2010), meaning the environment should be taken into account. The activities should also be financially and socially sustainable (Rotterdam Resilience Strategy 2016). Sustainability can be considered an indicator of the ability to absorb changes in an ecosystem. The system should persist and after a disturbance return to its equilibrium.

China has a history of concepts for environmental model cities.<sup>1</sup> The three most important ones discussed briefly as a background to the current paradigms are as follows:

1. The China Environmental Model City Program (EMCP)
2. China Low-Carbon Eco-City Program (LCCEP)
3. China Low-Carbon City Program (LCCP)

The China EMCP, launched by the Ministry of Environmental Protection in 2009, wants to improve urban environmental performance and sustainability through creating and upscaling best practices found elsewhere in the urban environmental sector (China’s Ministry of Environmental Protection 2009).

The Low-Carbon Eco-City Program initiated in 2010, and originally coordinated by the Ministry of Housing, Urban and Regional Development (MoHURD), is building on the experience of this ministry with energy-efficient building. It was followed up by the green building program, which focused on new urban developments. The objective is sustainable development and the improvement of the quality of urban life.

The LCCP began in 2010, which was initiated through the National Development and Reform Commission (NDRC). This program is concerned about carbon production. The program builds on experiences and lessons learnt by the NDRC’s sectoral approaches to carbon emission reduction and more energy efficiency in the energy sector and material-intensive production. LCCP wants to contribute to a low-carbon city.

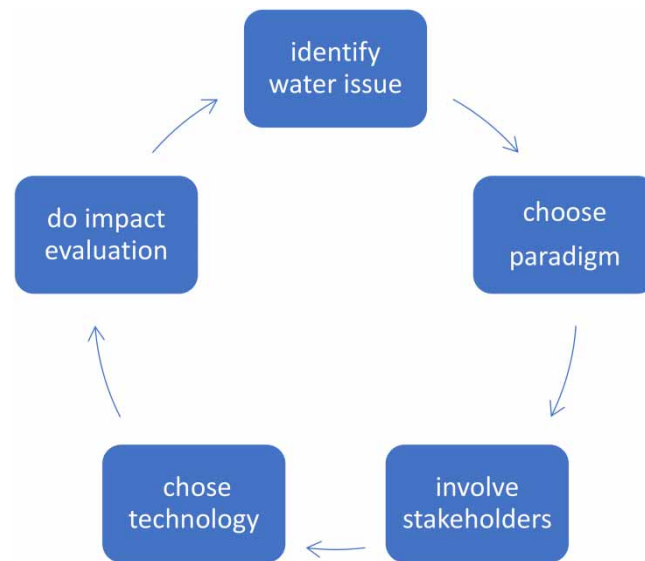
Zhang *et al.* (2019a) used an integrated approach to measure urban vulnerability in Beijing. Vulnerabilities to climatic threats of heat waves, drainage floods, and droughts have increased by 5–15% during the period of 2008–2016 in Beijing. High vulnerabilities to both heat waves and drainage floods have been observed in the urban downtown area, while high vulnerability to droughts has been observed in the outskirts. The developments of threats like flooding and droughts are analyzed separately for 16 districts, and an integrated vulnerability index for all of Beijing is provided. Priority climatic threats in Beijing (in order of priority) are floods, droughts, heat waves, and heavy snow and freezing. In total, 21 variables are used to measure the seriousness of these problems. This vulnerability assessment, which addressed climatic threats, provides a holistic understanding of the susceptibility to climate change. This could facilitate adaptation to it.

The term ‘healthy city’ is used in the WHO sense of a city continuously improving its physical and social environment.<sup>2</sup> If the focus is on urban planning and the impact of urban development on health, we use the broader term ‘healthy urban environment’ (Hall *et al.* 2010). Figure 1 shows the visualization of the paper.

The Government of India has taken the initiative to develop 100 smart cities across the country. This would also require a ‘Water Centric’ thought process and learning from experiences elsewhere in the world. Cities in the Global South suffer from

<sup>1</sup> Data for this section were provided by Dr. Zhang Mingshun of BUCEA Beijing.

<sup>2</sup> World Health Organization [www.who.org](http://www.who.org).



**Figure 1** | Creating a healthy city or a healthy urban environment.

rapid growth, pollution, congestion, water shortages or surpluses, and climate change challenges cities even more. Due to climate change, cities can also expect heat waves (Zhang *et al.* 2019b), more or less rain, and more volatility (IPCC 2018).

Indian cities have developed mitigation and adaptation policies to deal with climate change and environmental policies to reduce pollution. Cities often also introduced programs to become better places to live in. Solutions in China that keep coming back are the technical solutions of the sponge paradigm, initiatives to reduce greenhouse gas emission and to close the water cycle (Butterworth *et al.* 2011), trying to minimize waste and promoting integrated waste management, and development of an integrated infrastructure and different transport policies (Dastabz *et al.* 2018).

Other technical solutions are heat exchange systems using underground water and rain water harvesting systems. Liang & Van Dijk (2009) analyzed the separation of grey and brown water, which allows the treatment of grey water on the spot, reusing it for flushing the toilets or for irrigating the garden. The remaining brown water needs to be transported to a waste water treatment plant.

We can learn from experiences with these different paradigms, including the sustainable city initiative. UN Habitat has pushed the concept of sustainable cities (UN 2018). Together with the United Nations Environment Program (UNEP), they started a program to ensure environmentally sustainable local development. It is based on recognition of the contributions that urban areas make to economic and social development. This sustainable cities program wants to achieve good environmental governance at different geographical levels. It supports national and local partners to adopt environmental planning and management. It also promotes the integration of good practices into the national legal and policy framework. However, sustainability has many aspects. Besides the technical, the environmental, economic, and financial sustainability, social and institutional sustainability are at stake. It does not just concern water management issues like the three paradigms compared. A methodological section is followed by the theoretical part discussing the different paradigms for urban water management. Then different experiences are compared.

## METHODOLOGICAL APPROACH

Different approaches to achieve healthy cities and environmental sustainability in Chinese, Indian, and European cities will be reviewed to find out to what extent these three paradigms have contributed to the development of livable, healthy, inclusive, and competitive cities. Which policies have contributed to the success of these paradigms? What lessons can be learned from successful eco-cities (cities focusing on the environment), sponge cities (cities managing the quantity and quality of water), or smart cities (cities using digital technology)? Can one draw lessons that can inform other rapidly urbanizing cities and other countries on how to achieve sustainable urban development?

This is a meta-study, drawing from the evaluation studies, which are currently available. The paradigms discussed have social, institutional, economic, and environmental factors as driving factors contributing to a smart, sponge, or an eco-city. For each case, it is necessary to identify:

1. Which policies have been developed to plan for a healthy and clean smart, eco- or sponge city?
2. How are the stakeholders involved, which governance structure has been selected?
3. Which technologies have been selected and which governance structures put in place to manage them?
4. How are these policies evaluated to assess their effectiveness?

By using case studies of Chinese, Indian, and Western cities, the study will look for the driving forces for each dimension of the distinguished paradigms. Each paradigm also has weaknesses. Do they take into account social, economic, environmental, and cultural considerations?

We focus on the challenges provided by flows of water from the rivers, the soil, the rain, and the sea and compare what the different paradigms do to deal with the consequences. A comparison allows us to indicate the strong and weak points of these different paradigms and to show the importance of governance structures, government policies, and actions at different levels of government and at the household level, to implement these policies.

In this article, a framework is developed to compare three recent paradigms to deal with urban water and environmental issues in China and India and the background for these paradigms will be given to better understand their logic. Paradigms are new combinations of solutions recommended for identified water-related urban issues. A paradigm is defined as a specific approach to an issue, implying an underlying analysis of the problem and clear ideas about the solution. The solution usually implies improved water management. However, the supply of drinking water, sanitation services, and water for commercial use should also be assured. If too much water is the problem, it is often necessary to store water to prevent floods and to use the surplus water in times of shortages.

Three paradigms to deal with urban water issues will be compared. The analysis focuses on their definition and objectives, the role of different stakeholders, the issues they deal with, and the possible solutions suggested. The use of these paradigms in different cities is compared on different dimensions to conclude when and where they can be used and for which purpose.

Initiatives can be taken at the national, the regional, the city, the district, the neighborhood, and household levels, each with its own governance structure. Different paradigms have been developed to deal with urban water issues. The ones most often discussed in the literature are building a smart city (OECD 2018), eco-cities (Bhatnagar 2010), or the sponge city paradigm (Liang *et al.* 2020). These paradigms have been analyzed in Table 1, using six indicators (their definition,

**Table 1** | Characteristics of different paradigms for urban water management

Question	Eco-city	Sponge city	Smart city
What is the definition?	Eco-cities focus on the living environment to defy challenges, like climate change	Technical solutions for a city to slow, spread, sink, and store water runoff	In smart cities, information technology is used to deal with different issues in an integrated way, including water and sanitation
What are the objectives to be achieved?	Building an eco-city with water scaping, as a pleasant place to live	Manage quantity and quality of water to improve the water environment	Increased efficiency, interaction with stakeholders and generating data for urban management
Governance: the role of different stakeholders?	Motivated individuals and project developers	Mainly local government, possibly the private sector	Community involvement is promoted through the use of computers and Internet
Environmental ambition?	More green, less polluted and an integrated approach	Cleaner water, using natural water treatment processes	Not explicit, but information generated can be used to improve urban life
Possible solutions?	A different type of planning is suggested	Technical options and private sector participation	Increased integration of information available digitally would facilitate urban management
A reference to a publication on impact	Bhatnagar (2010) and Wong & Yuen (2011)	Liang (2018) and Liang <i>et al.</i> (2020)	Dastbaz <i>et al.</i> (2018) and Lim (2021)

the objectives, the role of different stakeholders, the environmental ambitions, the possible solution proposed, and relevant references). What are the issues they deal with? Have the objectives and ambitions been achieved?

The three paradigms are compared in Table 1 to find out in what respects they differ. Each paradigm discussed suggests different technologies to be used and a range of activities to be undertaken by the stakeholders, implying the use of different urban water governance structures. Eco-cities focus on the environment, and the sponge paradigm suggests technical solutions, using government structures to achieve the objective of reducing the impact of too much water. Finally, the smart cities concept emphasizes the use of information technology to deal with all kinds of issues, including water and sanitation.

A section on eco-cities, smart cities, and sponge cities paradigms will provide more information for the comparison. The three selected paradigms are compared using experiences in China, India, and the Netherlands to identify when and where the paradigms can be used and for which purpose. The paradigms differ substantially in their scope (from the narrow focus of the sponge city paradigm to the broad goals of eco-city paradigms), the technological solutions, and in terms of the governance mechanisms used to coordinate different actors. We first discuss the three major paradigms studied.

## ECO-CITIES, THE THEORY

Eco-cities are cities that focus on the living environment. Auroville in India is a case in point (Thomas & Thomas 2013). Van Dijk (2010, 2011) compares different experiences with eco-cities in Asia and Europe. A system to measure the characteristics of eco-cities was developed using ten indicators and different subindicators per indicator. It was applied to Beijing (China) and Rotterdam (a major European port in the Netherlands) (Van Dijk 2014).

The brief definition of an eco-city is a city wanting to avoid an ecological or climate disaster and create an attractive living environment. The inhabitants want to create a nature-friendly city and improve the water management. Bhatnagar (2010) has given different definitions for eco-cities. Each author of the book has put his own emphasis and subjective view of what is important to define eco-cities. Kenworthy (2006) stresses the role of transport, while Rombout (2010) emphasizes the importance of green and he also uses the words garden or lobe cities. Raj (2010) stresses that urban development planning should take both the culture and the environment into account. Solid waste management is also often mentioned in the case of eco-cities. How to deal with waste in a different way? Waste can block drains and cause health hazards. Solid waste minimization through an integrated waste management strategy is important (Oduro-Kwarteng & Van Dijk 2017).

The eco-city concept proposes 'an ecological approach to urban design, management and towards a new lifestyle' (Wong & Yuen 2011: 3). The focus is on the urban metabolism. Eco-cities have a different way of dealing with the cycles of energy, water, waste, and pollution. The eco-cities idea can be compared to the Eco<sup>2</sup>cities approach launched by the World Bank. Suzuki *et al.* (2010) emphasize two important ambitions of cities in developing countries to achieve greater ecological and economic sustainability. Justice and equality are important norms, but rarely included. Eco-cities tend to be for the happy few.

Dimensions of eco-city policies, which will be analyzed, are the ecological aspects, water and waste-related aspects, in relation to energy, the role of transport and infrastructure and the implementation of eco-city ideas (Liu *et al.* 2016). It is possible to give eco-labels at these different levels of government (Burnett 2007). Second, the focus tends to be on a new town or neighborhood. There are also ecological buildings, ecological houses, blocks of houses, or apartment buildings. Examples are sharing heating/cooling systems or grey water reuse facilities. Individual initiatives at the household level are also important. They can take place spontaneously or can happen by providing incentives or by reactions to price decreases or price increases: using public transport, if fuel prices increase, or installing double windows to reduce the cost of heating.

The major aspects of an eco-city, in the context of achieving CO<sub>2</sub> neutrality, are the ecological aspects. Betancourth (2011) emphasizes the importance of nature conservation in eco-cities. More green has been part and parcel of eco-cities. Trees deserve a place, even if they may hinder the traffic. Green and open spaces in an eco-city can have different functions. Uy & Nakagoshi (2007) introduce land suitability analysis to allow cities to maximize the benefits of green spaces. Green space as a percentage of total space gives an estimate of the success of these policies. A last issue is how cities deal with pollution.

Kenworthy (2006) stresses the need to move away from a car-dominated city and to build cities around footpaths, bicycle lanes, and public transportation. Building the right infrastructure is an important step toward an eco-city. It has to do with promoting different means of transportation and with the design of a city. Cars are an important source of air pollution and cause a lot of noise. Choosing the right infrastructure (roads or trains, footpaths, or bicycle paths) is an important

choice made by physical planners and urban managers. Integrated transport policies are necessary. However, often specialized institutions in different parts of the public sector deal with different modes of transportation, and there is not always coordination and cooperation between them. The question should be asked: What can we achieve through physical planning to reduce traffic congestion and travel time? A mass transit system may be introduced, or an alternative type of transportation may be promoted. [Wong & Yuen \(2011\)](#) emphasize the importance of planning and management of eco-cities. The urban planner or manager may take an activist point of view and try to achieve participation of all stakeholders to obtain the desired result.

The largest number of new initiatives for eco-towns can probably be found in China. More than 100 Chinese municipal governments have proposed to build eco-cities or eco-towns ([Wu 2012](#)). They often opt for new towns. Tianjin in the north of China has a flagship eco-city project located 45 km from the city. It is developed in cooperation with Singapore. Financing took place under the Global Environmental Facility (GEF). The objective of the project is to develop an economically sustainable, socially harmonious, environmentally friendly, and resource conserving city. An evaluation of the relation between eco-city development and sustainable tourism has been carried out ([Dunn & Jamieson 2011](#)). [Wu \(2012\)](#) notes that this eco-city is located in 'a newly established district, which is a national strategic location comparable to Pudong in Shanghai' in the 1990s. Total investment for the eco-city near Tianjin is expected to reach 30 billion Yuan. China and Singapore each paid half of this. The neighborhood is located on unusable land. This makes the investment less sensitive to outside critique than when agricultural land would have been used. The story of the Sino-Singapore Tianjin eco-city has been reviewed by [UNDP \(2014\)](#). Did stakeholders build a harmonious and environmentally friendly city? A joint working committee has been established to study the major challenges, and an eco-city management committee has been nominated by the municipal government of Tianjin, a city that has learned from other experiments, such as the economic reforms and resulting business growth in the Binhai New area, also in the coastal area of Tianjin. Technical innovations in water management in Beijing are summarized in [Table 2](#).

The conclusion is that the eco-city concept is very much what [Mollinga \(2023\)](#) calls a Nirvana concept. It suggests an ideal and leaves it to the stakeholder to work in the agreed direction.

## THE SPONGE CITIES PARADIGM

The Chinese authorities introduced the 'sponge city' concept in 2013, to slow, spread, store, and sink runoff. A definition provided by a consultancy firm assisting the city of Wuhan to deal with water is: A sponge city is the collective denominator for a number of smart solutions to capture the water in other parts of the city to prevent flooding of the low-lying parts of the city (NRC, 9 January 2019: S10). Cities in the program are improving the runoff of water and the capacity to store temporarily the surplus rain water.

Many Chinese cities apply the sponge city paradigm. In Tianjin city, the authorities created water absorption beds. Infiltration-by-design in Beijing contributes to the recharge of urban aquifers, and it may mitigate floods and open city surfaces to allow infiltration of water. Cities can choose between cisterns, rooftop gardens, retention ponds, and permeable pavements

**Table 2** | Smart solutions for urban water issues in Beijing as an eco-city

Issue	Smart solution	Reference
Dealing with waste water	Separating grey and brown water and treating them differently	<a href="#">Liang &amp; Van Dijk (2009)</a>
Water shortages	Rain water harvesting and aquifer infiltration techniques	<a href="#">Liang &amp; Van Dijk (2011)</a>
Too much water	Improved water management using electronic sensors	Switch project ( <a href="#">Butterworth et al. 2011</a> )
Improved drainage	Water-Sensitive Urban Design (WSUD in Australia), Low-Impact Development (LID in North America) or Sustainable Urban Drainage Systems (SUDS in Europe)	Switch project ( <a href="#">Butterworth et al. 2011</a> )
Governance of urban water issues	Urban management using information technology	<a href="#">Liang &amp; Van Dijk (2012)</a> <a href="#">Qiu et al. (2014)</a>

Source: [Van Dijk \(2018\)](#).

to reduce half to nearly all runoff. The activities implemented in the sponge city project in Zhuanghe (near Dalian), studied as examples of the sponge city approach, are presented in [Box 1](#).

The governance structure of sponge city projects in China is that the local government is in charge through its Bureau of Planning. Some projects have been outsourced, which is different from a public-private partnership. In addition, the involvement of the people, community based organizations (CBOs) and non-governmental organizations (NGOs) is limited, and the local government wants to involve the commercial private sector in the last year of the project, when there is no more money, which is not very attractive for the sector. The officials interviewed said they are too busy spending the available money in time to involve other stakeholders. The challenge is to create more participatory governance structures.

The sponge city paradigm has been developed by engineers and embodies a more technical approach to solving water issues. It risks being unsustainable if no more government support is available, while no proper governance structures have been built. It is a challenge to manage urban risks, which are only made explicit in the sponge cities paradigm. Decision-making should be sustainability based, which may be the case if critical stakeholders are really involved, which is not always the case in sponge cities. A recent review of city implementation in China of the sponge city approach has been undertaken by [Chikhi \*et al.\* \(2023\)](#).

## THE SMART CITIES PARADIGM

Besides these two specific water management paradigms, there are alternative concepts, which are not necessarily focusing on water or water-related issues, but are still relevant. In particular, the different types of definitions of smart cities are interesting. Research showed that half of the cities studied recently expressed the ambition to be a smart city as well. Smart means making use of information technology. Criteria used for the Smart Cities Awards given in China each year are as follows: dealing differently with mobility, with IT infrastructure, water management, renewable energy and reuse of waste, safety, cultural development, globalization, and governance. Smart or creative cities emphasize the importance of innovations, such as the digital town hall and using IT for other purposes. There are three types of smart city definitions ([Van Dijk 2018](#)):

- Stressing the role of technology, using the Internet of Things for all kinds of urban and household problems
- Focusing on the transition and adaptation to rapid changes, this is possible by sharing knowledge, learning from best practices, and evaluating different initiatives to tackle the issue at stake ([Table 2](#))
- Pointing to different way of managing cities, focusing on managing physical conditions, or flows of information, and doing it in an integrated way by using information and communication technology and geographical information systems.

Different examples can be given of the use of technology for urban management. Originally, it concerned the relation between citizens and municipal authorities. All kinds of information were provided digitally, and citizens communicated with the municipality through the Internet. [Lim \(2021\)](#) analyzes the South Korean experience and emphasizes the importance of a digital infrastructure. Other examples concern the management of traffic ([Stead 2015](#)) and of waste containers. Also water and waste water flows were monitored, and in smart cities, action is taken on the basis of the information provided by digital sensors about too much or too little water, or the quality of the water.

The eco-city paradigm can be combined with the desire to be a smart city. Such smart eco-cities are about managing flows of information, ideas, money, and so on in an integrated way to create a more healthy urban living environment ([Van Dijk](#)

### Box 1 | Initiatives implemented in the sponge city project in Zhuanghe

- a. Building an underground reservoir of 300 m<sup>3</sup>
- b. Improving drainage in different ways
- c. Natural waste water treatment
- d. Promotion of water penetration in the soil in different ways
- e. Building a wetland
- f. Allowing waste water reuse by separating grey and brown water
- g. Permeable concrete and asphalt
- h. Permeable parking places using plastic to reinforce the ground
- i. Planting grass around the houses
- j. Building roof gardens
- k. Collect rain water from the roof, etc.

2018). The information may concern not only the traffic, the people, pollution, or the number of enterprises moving in and out of the city but also the flows of storm and wastewater are monitored. Developing smart or eco-cities starts with what a city wants to achieve and which flows should be managed better.

## THE IMPORTANCE OF POLICIES, TECHNOLOGY, AND INVOLVING STAKEHOLDERS

There are five types of policies used to implement the different paradigms discussed:

1. At the national level, general policies can be formulated to promote water quality and conservation and to avoid flooding and drought by introducing the water cycle approach (no water gets lost).
2. At the city level, the focus may be on improving urban drainage, water storage, and infiltration. Singapore is the example of managing a closed water cycle.
3. Subsidies are possible at the local and the national levels. They may raise awareness for particular issues, subsidize the adaptation of buildings, and help in introducing the innovations mentioned at the neighborhood level (separating grey and brown water and rain water harvesting) or at the city level (decentralized treatment of grey water and water storage ponds).
4. Planning requirements, usually formulated at the national level, can force cities to close the water cycle, or make clear that building permits will not be given for construction in lower lying flood-prone areas of the city.
5. Demand management policies can be developed at the national level (Baumann *et al.* 1998). These policies are necessary for reducing the consumption of water and energy and local authorities can help to make available the necessary information and devices.

In practice, the sponge city paradigm turns out to be a very technical, one sector, and government-initiated approach. Table 3 shows that also for the other paradigms, there is a trend of focusing on certain activities or sectors. Sectoral interventions have the advantage of allowing comparison or benchmarking. It is important to choose the relevant dimensions and to use the right indicators to measure the performance. Chinese cities are compared continuously on a number of dimensions such as pollution, per capita water resources and consumption, areas in cities available for recreational purposes, etc. (China Daily 4-4-2014).

Tables 2 and 3 show that the initiatives can come from different stakeholders and do not have to come from governments. Project developers and private individuals also take initiatives and incentives can be provided for these stakeholders. The different paradigms deal differently with water issues, and only the sponge city paradigm follows the classical integrated water resources management approach. The smart city paradigm is more in favor of an adaptive water management approach, which mean trying to focus on the most important issues and solving them together with the relevant stakeholders, rather than going for a government-led top-down integrated water resources management approach.

**Table 3** | Different paradigms for urban water management, characteristic of each type

Criterion	Eco-cities	Sponge cities	Smart cities
Achieving the objectives	Broad-based approach, more or less successful	Successful in its technical achievements	Objectives like better urban water management
Governance, stakeholder participation	More space for local and nongovernmental initiatives	Major role for local government, no time for private sector participation	Still very (local) government centered
The approach to water issues	Eco adaptive water management and water an asset in landscape	The focus is on traditional integrated water management	Based on local challenges: too much or too little water, or poor quality water
Policy support	Policies can provide incentives to isolate, to use solar energy, store water, etc.	Emphasis is on spending the available budgets in time	Emphasis is on measurement and, policies preventing disaster
Evaluations	Bhatnagar (2010), Liu <i>et al.</i> (2016)	Liang <i>et al.</i> (2020), Liang (2018), Chikhi <i>et al.</i> (2023)	De Jong (2016), Lim (2021)



## DISCUSSION: THE COMPARISON BETWEEN THE THREE PARADIGMS

Eco-cities can be seen as a new life style. They also require a different type of management, which promotes harmony with the natural environment and long-term sustainability. It may lead to closing the water cycle. The eco-city concept translates a vision what a city should be like in practice. The eco-city paradigm implies an ethical issue of how to deal with poorer people, who cannot afford the additional efforts. The sponge city concept is a more defensive concept, trying to avoid certain negative developments.

A major lesson learned from looking at smart and eco-cities is that both require managing information flows in an integrated way and being smart. The idea of a smart approach is to use technology as much as possible in urban management and apply it to solving solid waste and waste water (Van Dijk 2018).

The paradigms differ substantially in their scope and in terms of the governance mechanisms used to coordinate between different actors. The smart and sponge paradigms mainly use government structures to achieve their objectives, while the idea is to also involve the private sector (certainly in the case of the sponge city paradigm). This has not happened most of the times because project money, made available by higher levels of government, had to be spent in time. In the eco-cities approach, the citizens want to be involved through newly created governance structures. In smart cities, potential victims of environmental disasters may be involved. Smart and eco-city initiatives emphasize the involvement of stakeholders, while in the sponge cities approach, the initiative is often taken by the local government. Finally, in terms of expected solutions, the paradigms want to create an eco-city or improve water management and create a more healthy urban environment. In the case of smart eco-cities, there is space for introducing different water management practices and new technologies. Water-related technologies are available, for example, generating energy from wastewater or using underground water for heating or cooling.

The eco and sponge city paradigm has a narrow scope, while the green and sustainable city concepts are very broad in what they want to change. At the local level, the focus of the authorities is often on one aspect, managing water, or cleaning it. The different paradigms may lead to sectoral approaches, for example, concerning sustainable drinking water supply. The issue is how to stimulate adaptation policies in the concerned cities, given the projected changes in water supply?

As far as the governance of the initiatives is concerned, the concepts remain relatively vague. The smart and sponge city paradigms think mainly in terms of using government structures, while in the eco-cities paradigm, the citizens and their organizations want to be involved through newly created governance structures. In the smart cities paradigm, the citizens and the potential victims may be involved, while in the sponge city paradigm, the idea is to involve the private sector, although this has not happened in most Chinese cities (Liang 2018). In governance terms, eco- and sponge city emphasize the involvement of stakeholders, while in the smart cities paradigm, the initiative is often put at the local government level.

Evidence has been collected for the three paradigms using different variables to show that the approach is often not integrated. Rarely, the implementation is based on a strategic planning document, prepared with stakeholders who could implement the results. Urban management is facilitating such initiatives of stakeholders in the city or neighborhoods. Many initiatives are taken at the neighborhood level, for example, information dissemination activities to enable these initiatives, while the households then implement the ideas.

## CONCLUSIONS

Experiences to create healthy cities were analyzed. To what extent have cities that followed a certain paradigm been successful? In terms of achieving the cited objectives, most paradigms were quite successful, but often looked at the government to take the initiative. Only in eco-cities is more space usually available from the beginning for the involvement of all kinds of stakeholders. There is a need for more awareness concerning what other stakeholders and in particular households can do to achieve a more sustainable and healthy city and a more healthy urban environment and how to create new governance structures to deal with the more important water issues, where other state stakeholders than the state can play a role.

Finance is an issue, but usually not the biggest one. Lindfield & Steinberg (2012) note that 'financing sustainable cities' can be defined as helping cities moving toward long-term environmental sustainability by 'maximizing the amount of revenue derived from existing sources, identifying new sources of revenue, leveraging additional resources from the private sector and accessing international and local funding that supports green investments.'

Research on eco, sponge, and smart cities in Europe, India, and China is relevant for developing a new approach to water issues, which needs to be adapted to the local conditions. The paradigm to choose largely depends on the issues a city is facing

and the objectives a city wants to achieve. If the issue is too much or too little water, the sponge city paradigm may be used. If the emphasis is on healthy environment eco-cities may be the paradigm, if the emphasis is on eliminating inefficiencies, the use of IT and smart city may be more appropriate. It is concluded that different stakeholders and several policy instruments are needed to achieve smart eco-cities.

Given climate change and other issues cities are facing, government and stakeholders need to think in terms of closing energy and water cycles where nothing gets lost! The smart eco-city of the future pays attention to managing flows smartly, taking interactions like between water and energy, and infrastructure and means of transportation, into account. Smart ecological cities require the integration of different approaches or sectors. This desirable integration could take place in the framework of strategic planning. One can argue in favor of smart eco-cities starting with a vision of what to achieve. Then there is the option of the possibility to use the right technology to drive the desired change, for example, a reduction of the dependence on fossil energy by using technologies like temperature exchange equipment and getting energy out of waste water.

It is a challenge to pay special attention to the role of poor people in all these paradigms. The conclusion is that implementing the paradigms is easier if the governance structures are more decentralized. Different actors can then play a role; for example, the project developers can sign for a certain approach and the relevant people can receive subsidies for specific environment-friendly activities. Stakeholders can be incentivized to engage in rain water harvesting projects or to build facilities for the separation of grey and brown water. Similarly, demand management can be introduced to limit the consumption of water and electricity.

The question was asked whether all ambitions of these paradigms can be achieved. Cities often focus on one or two elements of the paradigm and do not really follow an integrated approach. Second, some cities wanted to be eco-cities in the 1990s and are trying to become sponge cities now (Zhuanghe) or smart cities (Shenzhen and Beijing), where they were an eco-city before (both). This has to do with the support received from the national level. The impression is that Chinese cities move from one government-supported paradigm to another, without bothering too much about the sustainability of their investments after the end of the projects.

The main elements of a different approach to the problems of water in cities are as follows:

- A. Promoting the use of advanced technologies like the Internet or sensors (Lim 2021).
- B. Using different governance structures with key stakeholders (Van Dijk *et al.* 2017).
- C. Apply different paradigms or different ways of financing (Bongwa & Van Dijk 2021).

## DATA AVAILABILITY STATEMENT

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

## CONFLICT OF INTEREST

The authors declare there is no conflict.

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