Developing Towards flood Resilient Cities; Opportunities for Sponge Infrastructure

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Abstract.

The urban flooding disaster is as a result combines with the action of heavy rainfall, degree of urbanization and capacity of drainage systems. Sustainable urban water management is a better alternative to the traditional approaches to managing water systems in urbanizing areas. The urban water runoff management goals are developing gradually beyond flood control and water conveyance, to include pollution control, runoff retention, and control, integrated infrastructure which consider environmental, social, economic and political contexts, providing the required water services for human and ecological uses. This paper seeks to investigate the existing sustainable measure for urban water management practices.

Keywords: Urbanization, Climate change, Sponge city, LID

1. Introduction

Urban floods have increased in recent past as a result of climate change and rapid urbanization. Conventionally, drainage systems have been primarily designed for collection of grey infrastructures that, in many instances, cannot cope with the increased stormwater flows patterns. [1]The urban flooding disaster is as a result combines the action of heavy rainfall, degree of urbanization and capacity of drainage systems. Above all, global climate change and increased rainfall patterns need more close attention to determine a way forward and deciding which is the most sustainable approach to build more floods and sufficient resilient cities.

Sustainable urban water management is a better alternative to the traditional approaches to managing water systems in urbanizing areas.[2] The goals of stormwater management are developing gradually beyond flood control and water conveyance, to include pollution control, runoff retention, and control, integrated infrastructure which considers environmental, social, economic and political contexts, providing water services for human and ecological uses[2, 3].

Developing cities in developing countries are faced with many challenges associated with urban water sustainability issues such as aging and/or outdated infrastructure for water and wastewater, urban flooding, water quality deterioration, combined sewer overflow, water scarcity, and a high frequency of extreme weather. Thus, there is a necessity to incorporate LID sponge flood control measures in the early phases of developments of these cities to ensure livable cities in the future.

2. **Urban Water Management Transitions Framework**

The urban water management benchmarking tool has been put forward to assist planners to identify those cities engaged in progressive transition strategies that can be applied to other cities [4]. The framework identifies six transitions as shown in Figure 1, in Australian cities, the first three transitions are; the 'Water Supply City', 'Sewer City' and 'Drained City', all evolved from the historical research phase; the 'Waterways City' and some part of the 'Water Cycle City'. The current management practices show regime shifts towards the 'Water Cycle City' and 'Water Sensitive City' transitions states.

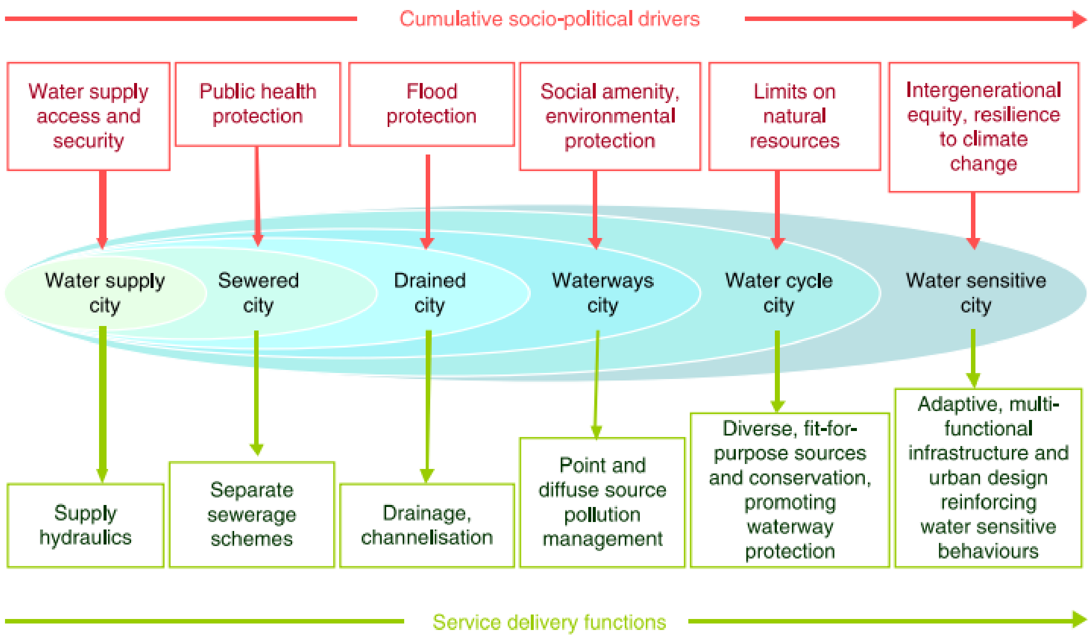

Figure 1: Urban water management transition framework[5]

2. Drivers

2.1 Stormwater Characterization; quality and Quantity

Urban runoff contains pollutants including suspended solid particles, heavy metals, pathogens, and also nutrients [6]. Nonpoint water pollution which results from stormwater runoff has been found as among the leading causes of the degrading quality of receiving waters. The street suspended solids and sewer deposits are the main pollutants in urban runoff. It's noted also that, characteristics of urban runoff are not easy to qualify and quantify than are those of the wastewater.[7] Accurate information on the quantity and quality of stormwater runoff is needed to assess the resultant impacts on the environment and thus to develop relevant mitigation technologies[8].

Pathogens are the main cause for impaired surface waters [9], Elevated bacteria levels can lead to economic losses in recreation waters, increased drinking water treatment costs, and potential health concerns [11]. The most serious effect of flooding is the outbreak of water-borne diseases during the rainy season. It is estimated that slums are home two of every three persons in Nairobi's 4 million people. In slums, open sewers overflow quickly and thus get into stormwater. This brings with them Harmful wastes which get washed through the city onto the rivers. Slum-dwellers depend on water in rivers for domestic use, washing clothes, prepare food and use it for irrigation and livestock. Because of such conditions, the city is under persistent threat cholera breakout. For example, In 2017, above 4,000 cases of cholera reported across the nation, of which more than 70% in Nairobi. (WHO report 2017)

2.2 Impacts of climate change and urbanization

The increasing urbanization has an impact on the urban hydrological and environmental conditions.[10] Such impacts are often reflected by an increasing amount of runoff in terms of volume and rate, decreases permeable surfaces for infiltration and consequently reduced groundwater recharge.[11] Africa's urban population is projected to double itself over the coming 20 years, posing an immense water challenge for cities. There is always weather forecasts that there will be heavy rains but no sound plans to Mitigate these challenges.

From the perspective of climate due to climate change, it is expected that there will be increased rainfall events in terms of frequency and intensity leading to increased flash floods at the rainy seasons.[2, 12]

Urbanization results in urban land alterations due to competing for land usage such as construction, pavements, but also to blockage of drainage channels and the diversion of natural flows. [13]The two drivers; Climate change and urbanization thus all combine to produce increased stormwater flows and elevated flood frequencies, magnitude, and duration.

2.3 Challenges to Conventional Drainage Systems

Conventional drainage systems have been in existence for the long term as important city infrastructure. The design of the conventional drainage network was to collect and convey the excess stormwater and used water away from the urban areas.[14] This approach usually treats stormwater as a nuisance that must be removed in the urban area as fast as possible with the only aim of flood avoidance.[15] It has also been noted that conventional drainage systems have minimal capacity and flexibility to adapt to future climate variations and urbanizing world[16].

Conventional methods of centralized urban drainage are ineffective to accommodate and to deal with excessive rainfall and have no mechanism for sustainable water mechanism in urban areas. Adverse impacts of water hydrology in urban areas can be resolved by using sustainable drainage, low impact developments, and best water management practices in urban areas[17].

Formally, responses to increased flood risks in most affected cities have been solely based on expanding the capacity of the sewer systems in place. However, such approaches are associated with high economic and technical constraints, more so in the developing countries where there may be an infrastructure deficit hitherto [18].

The sustainable drainage features are designed as another alternative and/or complement to detain and reduce the stormwater flow, allow infiltration for groundwater recharge, provide water for purposes of irrigation, reduce soil erosion, and aiding elimination pollutants and sediments.

3. Terms and cases of Sustainable drainage systems

As noted earlier, The basic design of a conventional drainage system was to ensure a good flow of stormwater but most factors were not considered, for instance, consider the consequences when extreme rainfall rates occur. Thus when rainfall intensifies and exceeds what can be conveyed by the designed conventional drainage system, floods may occur [19]. The urban planners, scientists have come up with alternative urban designs to complement/replace the conventional drainage systems.
Different countries have adopted various methodologies to deal with urban flooding and restore urban hydrology, for example, China is implementing Sponge City Concept SCC in its Mega Cities.

3.1 Low Impact developments.

Low impact development (LIDS) is an alternative measure to combat stormwater flooding in urban areas. The LIDS aims at controlling floods through decentralized drainage systems, where stormwater is controlled nearly at the source. [20] LID technologies and practices include permeable paving, rainwater harvesting, green roofs, infiltration swales and bio-swales, bio-retention areas and disconnected impervious surfaces.

The goals of LID are to replicate the natural hydrologic landscape as much as possible and generate flow conditions that mimic the natural flow regime through its engineered mechanisms of microscale stormwater retention, storage, increased infiltration and increased runoff time[20].
The reasons for incorporating Natural designs to help control floods at the source rather than infrastructural design. Most infrastructural designs require a lot of finances which cannot be achieved by Most developing countries, and thus low impact developments can compensate as it requires less capital and can restore the natural ecosystem in the urbanized Centres.
The LID approach can suitable compensation to aging and outdated infrastructure in the urbanizing world. This LID infrastructure has a greater opportunity to be applied in developing countries especially in Africa as they are cost-effective and does not necessarily require extra space

3.2 Sponge Cities

A sponge city means that an urban setting can be designed as a sponge with the potential to absorb, infiltrate, purify and store stormwater[21]. This alternative has a greater incentive as it can solve the scarcity of water in the urbanizing world. However, most sponge cities still experiencing urban floods due to high rainfall in some cases [22].

The sponge city concept entails enhancing the city's capacity to absorb, allow water to infiltrate, storage and manage rainwater and thus "regulating" the water cycle as much as possible to resemble the natural hydrologic water cycle. Thus, a "Sponge City" is a city that has the larger potential to mainstream its urban flood risk control into its decentralized urban plans and designs [23].
The sponge city thus has the capacity not only to deal with excess water runoff but also to help mitigate challenges of water shortage especially in times of drought.

Figure 3: Sponge urban design[24]

3.3 Available green sustainable alternatives

Permeable pavements

Natural ground surfaces can let water to freely infiltrate and percolate. This can help to stabilize and balance between surface and underground water. However, with rapid urbanization in the world, it has replaced the natural land cover surfaces with impervious parking lots, streets and sidewalks. This explains why Most urban areas get flooded during rainy seasons thus disrupting the transportation and general economy of the urban area[25].

To Mitigate this, the permeable pavement has been developed and applied in many parts of the world. Permeable pavement is designed with pores to let the surface runoff to infiltrate and percolate through it and thus can suffice to create a natural ecosystem[26]. Studies indicate that permeable pavement can reduce the rainfall peak flow by 95% and can lower the total rainfall by 95% in an event of 5mm rainfall and have the ability to curb flooding as less runoff will flow[27].

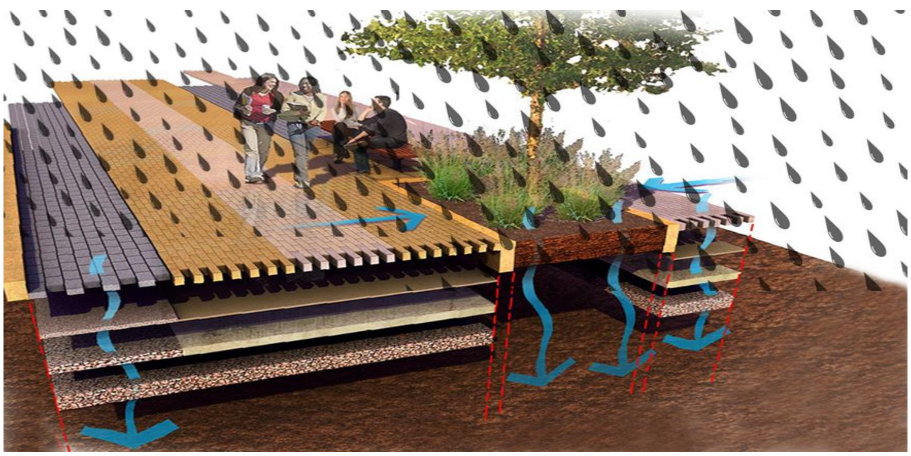

Figure 3: Section showing how permeable paving and landscape collects rainwater and disseminates stormwater (Cred: Smart Cities Dive)

Permeable pavement also can regulate the climate of a place and thus often referred to as ‘’cool road.’’ [28]

Green Roofs

Green roofs are the current most common stormwater management practice in the urbanizing world. This is more convenient as it requires minimal space and can well fit into the existing space. Green roofs technologies are very effective in improving the urban environment through stormwater attenuation, water quality enhancement, noise reduction, air pollution[29] and can considerably reduce the temperatures in the building by absorbing heat radiation[30]

Figure 4: showing a green roof. Adapted [36]

Swales and Bioswales

swales are shallow stormwater conveyance vegetated channels which are either triangular or trapezoidal cross-sections. Also, bioswale combines the conveyance system of grassed traditional swale and filtration and biological water treatment mechanisms of Bio-retention. Pollutant removal employed by standard bioswale includes sedimentation, infiltration and significant amounts of biological and chemicals reduction due to reactions in the soil [9, 31].

Bio retention employs a soil engineered medium below the vegetation. The media is underlain by coarse gravel drainage layers surrounding a perforated underlain to facilitate filtration and infiltration.

Figure 5: Swales, Author

Stormwater detention and biological treatment

4. Conclusions

With urbanization resulting in hotter temperatures, deforestation and increased cases of urban floods, there should now be a high sensitivity of the urban policymakers to the valuable environmental, social and economic roles of trees, gardens, parks, fields, and grasslands. Having towns lined with trees, gardens, and adapting this as a priority in urban planning, should not only be an aesthetic goal but also recognized as a vital part of environmental, economic and social development.

It's worth noting that, there has been an improvement towards advanced technologies for sustainable water management in urban areas in the recent past, but still, the transition to actual implementation is hindered. A more significant change in terms of governance processes when compared to governance structures. More options should still be explored, the monetary cost associated with each as this will determine the adoption by countries. Furthermore, people's interest, willingness to pay, social and cultural values should be taken into account in planning as well as implementation.

Sustainable drainage systems should be further explored: reflections and discussions are thus suggested by the developing countries. They should be recognized in an environmental and economic sense, as well as improved social conditions, especially as floods get worse due to climate change.

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