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Innovative Roadmap for Smart Water Cities: A Global Perspective †

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Abstract: Globally, cities are feeling the effects of climate change: rising temperatures, droughts, heatwaves, and more extreme storms are impacting water quantity and water quality. Roughly half of the world's population are now living in cities. By the year 2050, that figure is anticipated to rise to as much as 80 per cent. If we want our cities to be sustainable both locally and globally, we need to make sure that we use fewer natural resources and generate less trash. The built environment of a smart city incorporates digital, human, and physical components. It is critical to discover appropriate assessment procedures given the rapid urbanization and wide-ranging innovations. Due to impending scarcity, we must move now to increase water treatment and distribution efficiency while decreasing consumption. Risk assessment, mitigation, warning, and forecasting are all critical components of flood risk management going forward. Institutional and governance measures are also important. By providing fresh insights, this research contributes to the corpus of knowledge on smart city mobility. A smart water city improves the quality of life of citizens by solving existing urban water problems based on various technologies and ICT technologies throughout the urban water cycle. It not only provides individual solutions for conventional water management, such as drainage, water treatment, and wastewater treatment, but also improves comprehensive water management through the restoration of the urban water cycle, waterfront usage, and intelligent water management. Furthermore, in a smart water city, ICT-based intelligent technologies complement and improve existing infrastructure and technologies for water management within the whole urban system. They are a supportive tool for the different functions of water in urban settings. This understanding highlights that smart water cities concern not only the provision of drinking water and sanitation services for urban water users, but also other urban water functions such as urban water restoration, waterfront usage, and integrated water management. This paper examined the use of integrated, real-time information and ICT solutions, such as sensors, monitors, geographic information system (GIS), satellite mapping, and other contactless, intelligent tools in both urban and agriculture water management. The paper presents evidence of how SWM has provided solutions at different scales and across various urban and rural contexts, and how they have impacted the social, economic, environmental, governance, and technological spheres.

Keywords: smart cities; water smart city; urban city; sustainable development

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1. Introduction

Urban planners and politicians are setting the basis for smart cities, which will make use of technology to better serve the needs of citizens and save costs. In the early stages, cities build a "smart" foundation. As linked apps give real-time information to users and providers after around ten years of development, they are now entering a new phase of development [1]. Smart cities, maybe more than any other, require visionary leaders and a collaborative workforce. Several authorities, consultancies, and private businesses monitor the development of smart cities and there are eight commonly recognized themes that combine to make a city smart: mobility, healthcare, security, water, energy, engagement and community, economic development, housing, and waste [2–4]. New approaches to urban water management are needed as a result of urbanization and the effects of climate change. We need to ensure that future generations of urbanites have access to clean freshwater and that the built-up region of the city with its physical assets can withstand a more harsh climate [5]. There are a number of ways that the water smart city strategy may be implemented as shown in Figure 1. Using the water smart city model, urban planning and the urban water cycle are brought together and turned into a profitable venture for the benefit of the whole community [6]. Using this approach, we may better address societal concerns about climate change, resource efficiency, and energy transition, while also improving the aesthetics and recreational value of our water resources [7]. Integrative solutions for environmental, economic, social, and cultural sustainability are developed using this method.

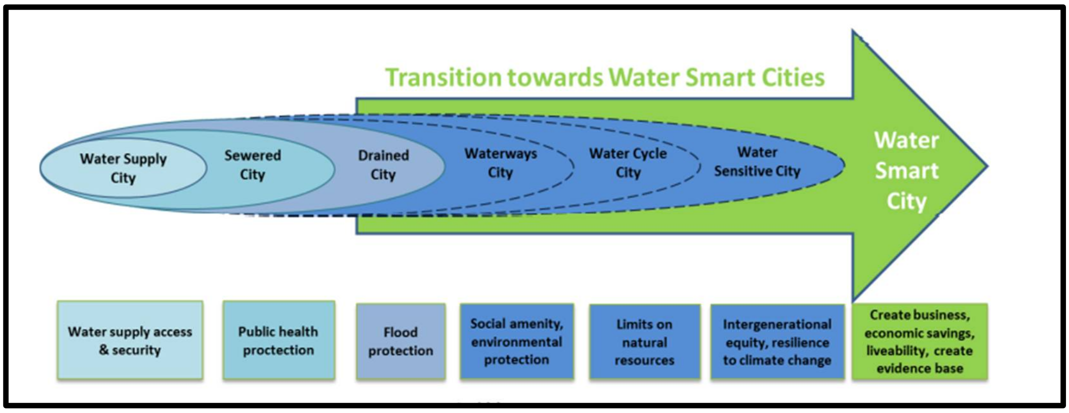

Figure 1. Transition stages in urban cities for the development of smart water cities.

2. Issues in Urban Cities

There are various urban issues which are obstructing in water smart cities: (i) urbanization, (ii) water infrastructure that is undervalued, (iii) living conditions, (iv) strengthening of institutional capability, (v) technological advancement, and (vi) water logging.

2.1. Urbanization

For enterprises, industry, and manufacturing, cities throughout the globe are constantly offering financial and specialized services. Urbanization has been accelerated by the establishment of new markets, which has led to a rise in population. The estimated worldwide urban population is 3.5 billion, and is anticipated to exceed 5 billion by 2030 [8]. Outlying towns are being swallowed up by this fast expansion, generating peri-urban zones, places that are located just outside of official urban limits and municipal authorities and in certain parts of the world, even mega-cities. High demand has resulted in unsustainable water use and over abstraction, and a depletion of groundwater and rivers that has major environmental effects [9–11]. As climate change impacts progressively limit megacities' capacity to offer access to a stable and clean supply of water, these problems may have a devastating effect on megacities in arid and semiarid regions. Many additional difficulties have arisen because the government has been unable to provide residents with the infrastructure essential to meet their needs [12–14]. Since these unofficial networks are so poorly controlled, they put the general public in danger.

2.2. Water Infrastructure That Is Undervalued

Effective urban water management requires a substantial financial commitment to a systemic approach. Increasing urbanization necessitates the construction of new infrastructure to meet the needs of both the present and the future. It has become increasingly difficult to finance urban water services due to the high costs and substantial investment requirements, which has resulted in the shifting of responsibilities between governments and municipalities, governments and industries/businesses (e.g., polluter pay effect), and governments and the public (e.g., underpriced water due to insufficient tariffs) [15].

2.3. Living Condition

Urbanization in certain places is outpacing the capacity of governments (local and national), both of which have a role to play. Unprecedented urban expansion may result in serious inequities in water and sanitation service supply due to the fact that infrastructure design and capacity of water distribution and treatment facilities are based on predicted water consumption and socioeconomic data.

2.4. Strengthening of Institutional Capability

In order to address the issues impacting urban water resources, sustainable policies, strategies, and practices are required. As a result, there is a lack of coordination in the management of urban water resources because of poor regulatory water and sanitation frameworks and overlapping tasks in government agencies and organizations. As a consequence, many cities throughout the world are experiencing inefficient and unsustainable methods to urban water management due to the fragmentation of plans, redundancies, jurisdictional disputes, waste of resources, and conflicts in finance [16].

2.5. Technical Advancement

Smart water management technology has yet to be implemented by city governments. Smart water systems are receiving more and more attention as a way to improve water and wastewater infrastructure assets' efficiency, efficacy, and adaptability. Continuous water resource monitoring, real-time measurement, modelling improvements, and issue diagnostics are a few examples of these approaches, which make it possible to properly maintain and optimize the water network on all levels. A few cities, however, are plagued by a severe data shortage and an inability to use it in conjunction with other modern technologies [17].

2.6. Water Logging

An ever-increasing number of cities throughout the globe are experiencing urban flooding, which presents a major problem to municipal administrators and planners. Urban flooding is a serious issue, and it is only going to become worse as the planet warms and changes its climate, causing precipitation to fluctuate more widely and more unevenly within cities and regions [18].

2.7. Water Smart City Approach

Approaches that combine sustainable urban design with water management are called "water smart cities," and they strive to reduce the environmental implications of urban growth. Three pillars for the integration of urban development and water management exist: cities as water supply catchments, cities as ecosystem services and increased livability, and cities as water-aware communities and establishments as shown in Figure 2.

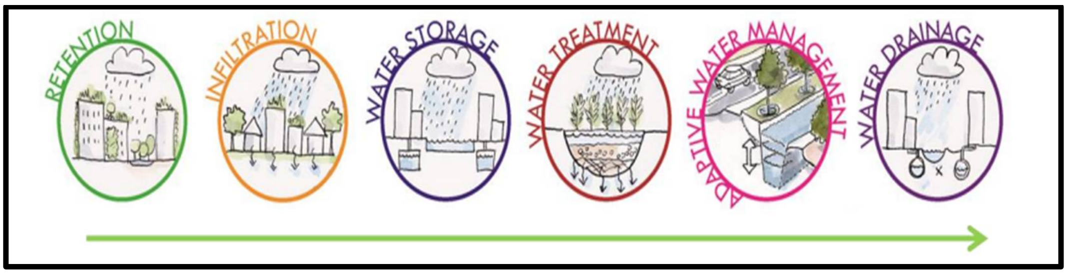

Figure 2. Solution for the water-smart cities.

Water-Smart City Benefits

The infographic below highlights a few of the most significant advantages.

1. Integrating water and green spaces into urban areas to create places where people want to live, work, or play is the first step in creating beautiful locations where people want to live, work, and play.
2. Increase in the value of properties near open water and green space.
3. The goal is to reduce the danger of flooding and to safeguard and enhance the quality of ground and surface water.
4. Reduce the urban heat island effect and noise, and enhance air quality, to create a healthy city.
5. Restoring reduced groundwater levels and improving soil moisture.
6. Promoting and enhancing local biodiversity and natural environments.
7. Give the community a much-needed water supply.
8. Raise public awareness of and enhance knowledge of the management and utilization of runoff from their development.

3. Methodology for Smart Water City

Smart water management covers the various methods and technology. SWM tools as shown in Figure 3, may be broken down into six primary categories, as given below. It is important to highlight that the examples given are not exclusive to these fields of study.

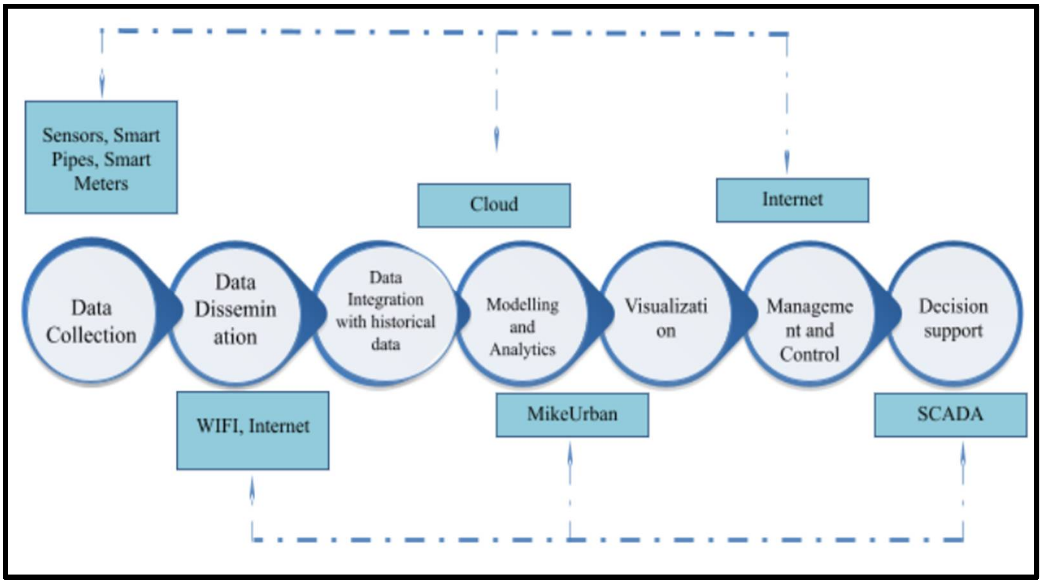

Figure 3. Schematic representation of SWM technologies and tools.

- Acquisition and integration of data is the first step (e.g., sensor networks, smart pipes, and smart meters).
- Radio transmitters, wireless fidelity (WiFi), and the Internet are examples of data delivery methods.
- Geospatial modelling and analytics (either via the use of GIS, Mike Urban, Aquacycle, AISUWRS, or urban groundwater sustainability) is the third part of this section (UGROW).
- This section deals with the actual processing and archiving of data.
- Visualizing and making decisions (e.g., web-based communication and information systems tools).
- Data and information return to cities' technological services and end users (e.g., tools for sharing information on water and on services).

3.1. Smart Meters

It is common for smart meters to include an integrated controller that communicates with sensors, a wireless transmitter, and an extension cable, since there is no mains power source accessible for water meters [19,20]. The 10-to-15-years-lifetime battery is commonly used because there is no mains power supply. A two-way connection between meters and a central system is possible because of the smart meter's ability to transfer data, which may be performed through several channels (e.g., radiocommunication, power line, Internet, or telephone) as shown in Figure 4.

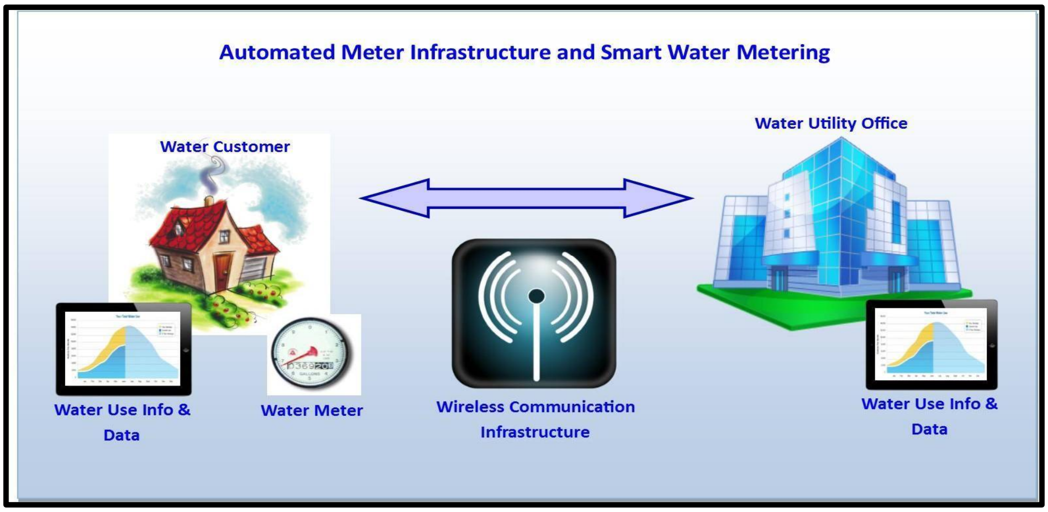

Figure 4. Concept of Smart meter technology.

It is common for smart meters to gather consumption information and then transfer it to a gateway that connects to the local and residential networks (WAN). The meter's metrology or measuring function is on the LAN, while the customer's network is on the HAN.

3.2. Communication Modems

In addition to Bluetooth and Wireless M-Bus, additional options for data transmission include GSM/GPRS, Ethernet, and the worldwide system for mobile communications (GSM). A utility or water authority's central management system may receive real-time or time-stamped data from sensors and metres using these technologies. CIS, GIS, cloud computing, or supervisory and data management tools may then use the data to make better decisions inside the system, which is why the data are made accessible online.

3.3. Information Systems Based on Geographic Data (GIS)

GIS may be used to capture, organise, analyse, and display geographical data for the description and decision making of underground assets. GIS may be utilised in a wide range of applications. Their integration enhances data management in large-scale projects because they provide high-quality results presentation (particularly in hydraulic simulation modelling), allowing for further analysis to better decision making [21].

GIS can cover extensive river basins populated by certain towns by incorporating information from resource satellites. With local rainfall patterns, meteorological and hydrological data, drainage systems, and spatial information and interfaces, urban storm water management may be improved by improving drainage management and boosting rainwater reuse, thereby reducing the frequency of urban floods.

3.4. Computing in the Cloud

Using a cloud computing service, an application or program may be run outside of the user's own infrastructure. Some of the functionalities of cloud environments include monitoring and managing computing without human intervention, broad network access to allow computing services to be delivered, access across multiple networks and heterogeneous devices, technological ability to scale up or down computational resources quickly and as needed, ability to share across multiple applications, and tracking applications/tenants for billing purposes.

- Data gathering and monitoring (SCADA)

SCADA (supervisory regulate and data acquisition) is a computer-controlled system that can monitor and control water treatment and distribution, as well as wastewater collection and treatment, when integrated with water management systems Figure 5. It is possible to monitor the system via the collection and administration of data, as well as the processing and transmission of instructions inside the system itself. Radio, cable connections, or telemetry may all be used in the communication system [22]. SCADA systems have long been used by utilities to manage real-time alerts and run facilities and networks more effectively.

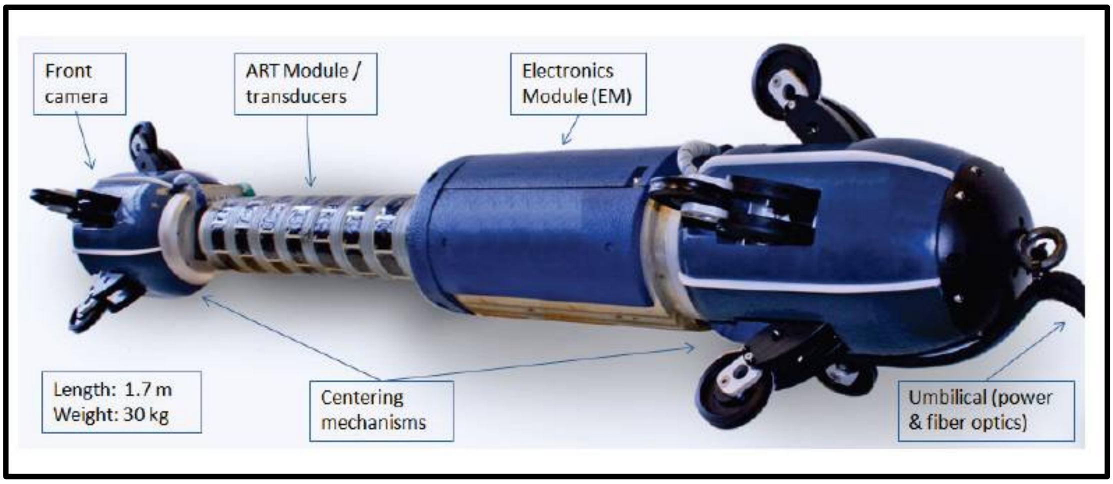

Figure 5. Smart monitoring using Pipe Scanner.

- Integrating SWM: Improving Water Management in Cities

Worldwide, a variety of smart water management programs are spurring technological advancements and providing new solutions at various sizes. Smart grid integration, web-based communication, and urban water management technologies, models, and systems are some of the rising urban efforts. An overview of urban water, wastewater, and flood control programs is provided in this part, all of which are critical to SSC's smooth operation. Examples of these initiatives may be found throughout this document. Cities may be able to use this technology to obtain trustworthy information on the status of their water pipes, as well as data for modeling purposes, in the future. To further reduce expenses and improve administration, this technology may be used to connect up with other intelligent infrastructures.

4. Results and Discussion—Global Case Study

There are very few water-smart cities in the world. In India, there is no city which is a water-smart city. So, here is the case study of the various water-smart cities from around the world.

4.1. The Netherlands—Amsterdam

Climate change poses a serious threat to the Netherlands. Over a third of the Netherlands is located at or below sea level. Coastal flooding will become more common as sea levels rise. The Netherlands is a densely populated nation. Climate change will raise the danger of urban floods and heat waves, which are already a problem in metropolitan areas.

The recent floods and droughts in major cities, as well as the recent heat waves, have helped to raise awareness. Cities such as Amsterdam and Arnhem were devastated by significant rainfall (>100 mm) in 2014. Over EUR 500 million in damage was suffered in the southeast of the Netherlands in 2016 as a result of severe rainfall during storm occurrences.

Wet-Proofed City of Amsterdam

Amsterdam Rainproof is the city's approach for dealing with severe rainfall. The city of Amsterdam is ill-equipped to deal with all the rain. Because of the city's dense population and extensive network of streets and sidewalks, rainfall has nowhere to go in Amsterdam. Flooding and substantial damage to homes, businesses, and other structures occur as a consequence of this. More and more water is being pumped into the public sewage system. Increasing its capacity indefinitely is not the answer. The city of Amsterdam is rethinking its outdoor urban areas in order to capture and store rainfall before it runs out into the streets. Amsterdam Rainproof's goal is to raise awareness and make Amsterdam rainproof for rain events of up to 60 mm. It is the goal of the Amsterdam Rainproof network to get people involved, to link them with each other and to encourage them to make their city more rainproof through building an influential, wide-ranging and long-lasting Rainproof platform of people or organizations. Politicians and people will be aware of Rainproof's efforts when they hear about it. Water conservation and value creation initiatives must be implemented by all stakeholders in order to protect private gardens and public spaces from rainwater runoff. Amsterdam seeks to incorporate rainproof measures with existing planned projects, if feasible.

4.2. Denmark—Copenhagen

The rising danger of pluvial floods and storm surges provide the greatest obstacle to Denmark's efforts to adapt to climate change. Cities near the long Danish coastline, where the drainage capacity of sewage systems cannot deal with the increasing intensities and durations of precipitation events, are particularly vulnerable. Annual precipitation is expected to rise by 30 percent in Denmark by the end of this century, with more intense rain events occurring in the summer months and a greater frequency of storm surges depending on the particular neighboring oceans. Aquifers in Denmark are numerous and of high quality, and with an expected increase in precipitation rather than a decrease, water supply is not an issue. However, there is some worry about saltwater intrusion due to rising sea levels. In the face of climate change, people are speaking up. After a 2008 statement from Denmark's government, municipalities were obligated to submit a climate adaptation plan by 1 January 2015, which specified how much climate adaptation was required in their area. Research and innovation initiatives on how to adapt to climate change have been carried out parallel to the formulation of these strategies, and networks for the exchange of ideas and discoveries have also emerged. There are two large cities in Denmark: Copenhagen and Frederiksberg, plus two smaller cities in the country, Aarhus and Odense. Other cities, such as Gladsaxe, Middelfart, and Vejle, also have a proactive approach to climate change adaptation.

More than 90% of Copenhagen is served by a combined sewage system, and all of the city's stormwater runs to one of the city's two treatment facilities. The majority of the city's water comes from wells in towns that are between 50 and 100 km outside of the city limits. Frederiksberg Municipality has two-thirds of its water taken from beyond its borders while just one-third comes from inside them.

Additional underground tunnel pipes are being constructed for more significant obstacles, such as low-lying trains, the metro, and utility pipelines. All stormwater runoff from the 350 projects is meant to be handled without the use of the sewage system, i.e., a complete disconnection of all stormwater from the sewer system.

5. Conclusions

Increasing climate resilience and adding value for people are the goals of the water-smart city strategy. Cities need to shift from being water-starved to water-rich. Effective use of information and communication technologies (ICTs) by residents and social institutions may contribute significantly to the cognitive capacity of a city. Smart water cities use ICT-based intelligent solutions to supplement and enhance current infrastructure and technology for water management in the whole metropolitan system. This article examines the most recent improvements in GIS integration procedures and their benefits for smart-city advancements. This study contends that geographic information systems (GIS) have been a significant platform for enhancing the efficiency and smartness of municipal administration, which can reduce future investment and enrich common databases. This must ultimately be developed into a uniform database and platform for cooperation across numerous stakeholders from the public and commercial sectors at all SDI levels, including urban, regional, and national. As a consequence, environmental changes caused by urbanization may be examined, monitored, and managed in a consistent worldwide way.

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