Sustainable Water Management Framework in Urban Areas and Smart Cities in Context of Governance, Infrastructure, Economics and Technology S P Jain School of Global Management

Suresh KUmar Sharma[1], Seetha Raman[2], and K Maddulety[3]

[1]Scholar
[2]Dean-Research
[3]Deputy Director-DBA

November 24, 2022

Abstract

The demand for water supply and sanitation services is growing fast owing to the interactive effects of demographic growth, economic development and improvements in living standards. Increasing urbanisation has been a worldwide trend since the beginning of the twentieth century, and its increase continues. A long-term sustainable water management system (SWMS) is the solution to ensuring the water rights and water security of citizens are met. The concept of an integrated urban water management system (IUWM) guides the utilities in planning the water system at a hydrological cycle level. The input of Information and Communication Technology (ICT) and the Internet of Things (IOT) in water management has added a smart quotient to the entire water management scenario. Smartness in water management has increased the overall performance of the system. The global practice of water management in smart cities is based on IUWM combined with smartness in the system. Financing, technology and infrastructure along with governance-which drives the policies, laws and institutional framework-are key drivers of SWMS and IUWM. There is no uniform definition of governance which can guide the governance of IUWM and SWMS.

Hosted file

`essoar.10503241.1.docx` available at https://authorea.com/users/548596/articles/603168-sustainable-water-management-framework-in-urban-areas-and-smart-cities-in-context-of-governance-infrastructure-economics-and-technology-s-p-jain-school-of-global-management

Sustainable Water Management Framework in Urban Areas and Smart Cities in Context of Governance, Infrastructure, Economics and Technology

Suresh Kumar Sharma-DBA Scholar, suresh.ds19dba003@spjain.org,
Dr. Seetha Raman, Dean-Research, seetha.raman@spjain.org,
Dr. K Maddulety, Deputy Director- DBA, k.maddulety@spjain.org
S P Jain School of Global Management, Dubai, Mumbai, Singapore, Sydney

Abstract

The demand for water supply and sanitation services is growing fast owing to the interactive effects of demographic growth, economic development and improvements in living standards. Increasing urbanisation has been a worldwide trend since the beginning of the twentieth century, and its increase continues. A long-term sustainable water management system (SWMS) is the solution to ensuring the water rights and water security of citizens are met. The concept of an integrated urban water management system (IUWM) guides the utilities in planning the water system at a hydrological cycle level. The input of Information and Communication Technology (ICT) and the Internet of Things (IOT) in water management has added a smart quotient to the entire water management scenario. Smartness in water management has increased the overall performance of the system. The global practice of water management in smart cities is based on IUWM combined with smartness in the system.

Financing, technology and infrastructure along with governance – which drives the policies, laws and institutional framework – are key drivers of SWMS and IUWM. There is no uniform definition of governance which can guide the governance of IUWM and SWMS.

Key Words

Sustainable water management system (SWMS), integrated urban water management system (IUWM), water rights, water security, smart city, governance, infrastructure, financing, economics, smartness, water technology.

1.0 Introduction

The world's population is set to reach 8.5 billion in 2030 and 9.7 billion in 2050. Today, almost 50% of the world's population lives in cities. The growth potential of cities causes migration from rural areas for employment and education (Khatoun, R., & Zeadally, S., 2016). Most cities are places of historical importance and centres of technology developments, start-ups, social networks, cultural heritage, economic growth and political structures. The idea of the citizen originated in cities, and cities have become a symbol of the progress of mankind. They have become the place of markets, offices, industries, malls, residential areas, civil areas, recreational hubs, hotels and all types of socio-politico-economic activities. Cities are perceived by citizens as places of faster life with greater opportunities for leisure and jobs ever since human civilization began. The exponential growth of cities has posed various types of risks and challenges for resource availability, resource quality, public health and basic amenities. The present situation has demanded an urgent, effective and smarter action plan to mitigate these challenges and risks (Anandita Roy Saha and Neha Singh, 2017). Cities are becoming smarter in order to provide better a quality of life to citizens who are under pressure from increasing urbanisation.

Providing clean and adequate water for life and the livelihood of the citizen is an important parameter for cities. Water resources are subject to immense stress from excessive demand and climatic variations (Rockstrom et al. 2009, IPCC 2014). Technology, infrastructure, economics and governance are key attributes in the achievement of sustainability in an urban water supply system. The world over, many types of water management systems are implemented to develop, operate and sustain water systems and resources.

An OECD report on the principles of water governance states that while accessible, fresh and potable water resources are not infinite . The report projected that demand for water would increase by 55% in the next 30 years and stated that 40% of the world's population today lives in water-deficient river basins where they are subjected to severe water scarcity (OECD, 2012a). Excessive extraction and pollutant mixing in ground water all over the world may impact adversely on food production, the environment, the availability of drinking water and an area's geomorphological characteristics. Around 240 million people may be deprived of drinking water facilities and 1.4 billion people may not have access to sanitation by 2050. A huge portion of the water supply's infrastructure in most cities is old and, despite improvements in technology and governance, it is not capable of addressing the sustainability challenges and increasing demand for water. By 2050, investment of 6.7 trillion USD (Rs. 470 trillion) will be required to augment, rejuvenate and create infrastructure for water supply and sanitation (OECD, 2015c). Underground and surface water management is both a global and local challenge, and includes a wide range of stakeholder involvement in decision making, policy framework and project management. The water sector requires huge capital investment and is currently under the monopoly control of states. It has very close links with other sectors of social, infrastructural and economic development plans which address the quality of life in cities. The climatic changes and increasing population of cities has made water a less-available resource to fulfil the demands of the city. With increasing demand, the efficient management of water has become more important for states. Efficient water management will provide water to citizens in adequate, potable quality, at low cost and with minimum use of energy. Inducing smartness and sustainability in the water management system is the prime objective of policy makers nowadays, across the globe. Smart and integrated urban water management is considered an effective solution to fulfilling the increasing demand for water in cities.

2.0 Research Questions

This study aims to understand the global practices of a sustainable water management system in smart cities in regard to governance, technology, infrastructure and economic aspects and in the context of smart cities in India.

a. How the Governance, Infrastructure, Technology and Economics impact the SWM in urban Areas and smart cities in India
b. How is the Governance of water management is related to Economics, Infrastructure and Technology for SWM of urban areas and smart cities in India

3.0 Research Objectives

The water supply system of Indian cities have different type of pressures related to its sustainability, the response of the states to these pressures depends upon many factors, which can be categorized under four major factors likewise Governance, Technology, Infrastructure and economics. This paper assesses the relationship and impact of these factors on sustainability of water management of urban areas and smart cities of India taking reference of IUWM of Singapore. Following are the objective of this paper:

1. To evaluate the sustainability of a water management system in urban areas and smart cities of India.
2. To study the dependency of a sustainable water management system in urban areas and smart cities on governance, technology, infrastructure and economics in India

4.0 Scope of Study

Sustainable water management is absolutely essential in providing water for all. In urban areas, an IUWM has been effectively implemented in cities like Singapore and Hong Kong. IUWM is dependent on variables like governance, technology, infrastructure and economics. There have been renewed initiatives to provide water for all in urban areas by using the sustainability and smartness of the smart city concept. Such global practices will be adapted for India through Smart City Missions. In order to make a comprehensive study, this qualitative research is confined to the sustainable water management of cities for water for life.

5.0 Literature Review

The Sustainable Development Goals (SDGs) proposed by United Nations call for worldwide accessibility of water and sanitation facilities by 2030 under Goal 6. This SDG adheres to an inclusive development framework, focusing on social, ecological and relational inclusiveness (Schwartz, K., Gupta, J., & Tutusaus, M., 2018). Clean drinking water, hygiene and sanitation play an important part in maintaining survival, health, growth and human development (Background Note on Infrastructure and Investment in Water and Sanitation in India issued by RIS, Ministry of Finance, Government of India , FICCI and MCCIA, 1st June 2018, Pune).

IUWM promises a better approach than the current system, in which water supply, sanitation, storm water and waste water are managed by isolated entities, and all four are separated from land-use planning and economic development (Akica Bahri, TEC Background paper N0. 16, Global water partnership technical committee, 2012). IUWM in Singapore signifies coordination between all types of water sources at the hydrological cycle level. The water sources include underground water, surface water, storm water, recycled water, harvested rain water and desalinated water etc (Olivia Jensen and Sreeja Nair , 2019). An integrated approach of resource management, water treatment, water distribution, waste water collection, waste water treatment and its reuse is envisaged and planned to cater for all types of water demand through all types of water with applicable quality. It will also consider ecological and environmental factors at local and global level. IUWM recognises the importance of water-use efficiency and economic efficiency, without which water operations cannot be sustainable (Akica Bahri, TEC Background paper No. 16, Global water partnership technical committee, 2012).

Water management in European smart cities focuses on efficiency, supply, reduction of losses, progressive tariffs and efforts in education, sanitation and the integral purification of waste water (Andress Molina-Gomez ,2018). Melbourne city scores highly in areas of sustainability such as water efficiency, waste water efficiency i.e. energy recovery, and climate change commitments related to heat and water scarcity (Van Leeuwen, C. J., 2017). Singapore, for example, has created a balance in the governance of water management, rules, policies, institutional framework, infrastructure investment, technology interventions, sustainability, stakeholder participation, economic considerations and service level guarantees etc. (Tortajada, C., 2006).

India, as the world's second most populous country, always inundated with huge religious, social and sectoral diversities, has not been able to demonstrate its potential to the world of high quality of living (Jog, Y., Singhal, T. K., Barot, F., Cardoza, M., & Dave, D., 2017). The Indian Water Mission has started many schemes to meet SDG no. 6 by 2030 (Background Note on Infrastructure and Investment in Water and Sanitation in India issued by RIS, Ministry of Finance, Government of India, FICCI and MCCIA, 1st June 2018, Pune). The Charting Our Water Future economic frameworks to inform decision making by the 2030 Water Resource Group of McKinsey & Company (2016) suggest that with investment of 8.4 billion UDS (Rs. 590 billions) in water for agriculture, the gap of demand and supply can be mitigated by 2030.

According to guidelines from India's Ministry of Urban Development, no single definition can universally define all the world's smart cities. The concept of the smart city is different for each city and each country. It depends upon the level of aspirations of state- and non-state actors in a city to adopt technology, reforms and the sustainability of resources in their city. There is no single definition for smart cities within India. Cities can incrementally add levels of smartness to their services and various types physical, social and economic infrastructure over time.

Smart Solutions	
E Governance and citizen Services	**Energy Management**
Public Information, Grievance Redressal	Smart Meters & Management
Electronic Service Delivery	Renewable Sources of Energy
Citizen Engagement	Energy Efficient & Green Buildings
Citizens-City's Eyes and Ears	**Urban Mobility**
Video Crime Monitoring	Smart Packing
Waste Management	Intelligent Traffic Management
Waste to Energy & fuel	Integrated Multi-Modal Transport
Waste to Compost	**Others**
Waste Water to be Treated	Tele-Medicine and Tele Education
Recycling and Reduction of C&D Waste	Incubation /Trade facilitation Centres
Water Management	Skill Development Centres
Smart Meters & Management	
Leakage Identification, Preventive Maintenance	
Water Quality Monitoring	

Figure 1 below represents the concept of an Indian smart city for the Smart City Mission of India. Water management in Indian smart cities is limited to smart metering, leakage management and water quality monitoring, however it is under the overall umbrella of a smart city governance system.

Figure 1: Guidelines of Smart City Mission, Government of India

Traditional water management technology is hugely dependent on human intervention, which makes the system highly inefficient. Water management is one of the areas where ICT plays a key role in addressing various challenges such leakage detection and dynamic optimisation. While the addition of ICT to critical infrastructure enhances performance, it also leaves the infrastructure vulnerable to cyber-attacks (Nonhlanhla Ntuli, Adnan Abu-Mahfouz, 2016). The recent advent of high resolution smart water meters and advanced data analytics allow for a new era of using the continuous 'big data' generated by these meter fleets to create an intelligent system for urban water management to overcome projected demand design pipeline oversizing problems (Nguyen, K. A., Stewart, R. A., Zhang, H., Sahin, O., & Siriwardene, N., 2018).

With the help of technologies like the creation of District Metering Areas (DMAs) with appropriate water meters and good pricing strategies we can take the first step towards the reduction of non-revenue water (NRW) (Murugan, S. S., & Chandran, S., 2019). Private sector participation is essential to develop state-of-the-art infrastructure and to increase operational efficiencies (Gupta, Mishra, Bokde and Kulet, 2016). Leakages in pipelines are one of the biggest challenges for water utilities in all countries. Water leakages occur due to the aging of the pipeline, high system pressure and physical damage by other agencies of underground utilities (Gupta, Mishra, Bokde and Kulet, 2016).

5.1 Sustainable Water Management System (SWMS)

The challenges of present and future water demand and supply can be met by the integration of sustainability, technology, governance, economics, water infrastructure and social inclusion. Sustainable Develop Goal 6 (SDG 6) for water and sanitation focuses on providing water and sanitation to all. SDG 6 can be achieved through sustainable water management.

IUWM ensures access to water and sanitation infrastructure and services for all and management of rainwater harvesting, waste water reuse and recycling, storm water drainage, runoff pollution, potable water quality including during floods, droughts and landslides and prevention of resource degradation (Akica Bahri, TEC Background paper No. 16, Global water partnership technical committee, 2012). IUWM intends to deliver improved water security, enhanced social, ecological, and economic sustainability at various scales, more resilient systems, environmental quality, resource efficiency, and economic development (Olivia Jensen and Sreeja Nair, 2019). IUWM has some practical constraints like providing guidance for innovation, investment, technology upgradation and dynamic policymaking.

India has moved forward in terms of SWMS by merging various departments handling water, waste water, rain water, water resources etc. under one ministry called Jal Shakti. However, it is just a beginning. Challenges related to governance, policy, administration and investment are yet to be addressed, however India has launched various programmes directed towards IUWM like AMRUT mission and Smart City Mission.

5.2 Governance

Governance plays a pivotal role in managing water but has no universally accepted definition. The governance of water management is location-specific and guided by the legal framework of each respective city. Different researchers have different perspectives on the governance of the water management system (De Loë and Kreutzwiser 2007, Woodhouse and Muller, 2017). Water Governance can be defined as a *"system with 'structural features and transient processes at both rule making and operational levels that 'takes into account the different actors and networks that help formulate and implement water policy*" (Pahl-Wostl et al. ,2012). Araral and Yu (Pg: 2, 2013) defined water governance in terms of *"various dimensions of water law, policies, and administration that have been commonly regarded in the literature as determinants of performance. These include water rights, pricing, decentralisation, accountability, integration, private sector participation, user group participation, and organisational basis of water management, among others"*. The World Bank defines governance as the way in which power is exercised in the management of the economic and social resources of any country (Tortajada, C., 2010). Bakker, K., Kooy, M., Shofiani, N. E., & Martijn, E. J. (Pg:1894, 2008) defined water governance as "*the range of political, organisational, and administrative processes through which stakeholders (including citizens and interest groups) articulate their interests, exercise their legal rights, take decisions, meet their obligations, and mediate their differences"*.

The definition of governance by Araral and Yu (2013:5307) is nearer to the SWMS and IUWM concepts. It allows for sustainability, infrastructural upgrades, stakeholder participation, a way forward for investment and financially sustainable operations and water for all, directly or indirectly. To make the governance of water management in smart cities explicit, the following modifications, shown in bold text, are proposed in revised definition of governance by Araral and Yu.

'Various dimensions of water law, policies, and administration that have been commonly regarded in the literature as determinants of ***integrated system*** *performance* ***at hydrological cycle level and smartness****. These include water rights, pricing,* ***financing****, decentralisation, accountability, integration,* ***technology, asset creation and upgradation****, private sector participation, user group participation, and organisational basis of* ***sustainable*** *water management, among others.'*

The above single definition is suitable for the governance of water management of smart cities, SWMS and IUWM simultaneously.

Governments have different motives for starting participatory efforts in water governance, such as increasing support for policies, enhancing problem-solving capacity, breaking deadlocks, avoiding litigation costs or improving the quality of decisions describe public participation by invitation (Van Buuren, A., van Meerkerk, I., & Tortajada, C., 2019). The private sector is a very important stakeholder of IUWM. The involvement of the private sector fills the gap of capabilities in technical, operational, managerial and financial aspects of water management institutions. The private sector is involved in water management through various contract models. The Public Private Partnership (PPP) model is commonly used in water management projects in Asia. More and more countries are adopting the PPP model of contracting services in the water sector, including those countries that rejected this model prior to 2000 (Jensen, O. , 2017).

5.2.1 Smart City Mission of India (SCMI)

In accordance with the guidelines of SCMI, each city selected to become a smart city has institutionalised a special-purpose vehicle (SPV), a public sector company incorporated under the Indian Companies Act, 2013, to implement the smart city project. As per the guidelines of Smart City Mission, the SPV will be the nodal agency to plan, appraise, approve, release funds, implement, manage, operate, monitor and evaluate the smart city development projects. Each SPV will be led by a dedicated CEO and be supported by state and central government representatives. The SPV will have equal equity shareholding up to a maximum of a 50:50 share for state and central governments. The private sector can invest in the company but the joint equity state and central government should be the majority and equal in proportion at all times. Each smart city is funded with USD 1.4 millions (Rs. 1 billion) every year each by state and central government. Most of the government development programmes like AMRUT, Swachh Bharat and many others are connected with Smart City Mission for social, infrastructural and institutional upgrades.

5.3 Technology

Water supply system performance and efficiencies depend upon the condition of the infrastructure assets like pipes, valves, pumps, controllers etc. In addition, they depend on the hydraulics, technology involvement and legal frameworks. Asian cities exercise pricing- and non-pricing strategies to moderate the water demand. Pricing moderation is more closely related to governance and non-pricing mechanisms are more closely related to engineering and technology (Araral, E., & Wang, Y., 2013). This paper will scrutinise the involvement of technology in SWMS, IUWM and smart city water management based on the following parameters.

5.3.1 Non-Revenue Water (NRW)

The International Water Association defines the NRW as the difference between water supplied and consumed by users. Supply of water is measured by bulk-flow meters and consumption is measured by consumer meters (Murugan S. Chandran, 2019). Non-revenue water costs 14 billion USD per year globally. NRW causes dissipation of 45 million cubic meters of water yearly, which is enough to serve 200 billion people and increase the sustainability and quality of water. Reducing 50% of NRW could save 2.9 billion USD , globally (Gupta, Mishra, Bokde and Kulet, 2016).

NRW has three types of components:

a. Physical or real losses caused by leakages and poor operation and maintenance
b. Apparent or commercial losses caused by meter reading errors, faulty meters and water theft
c. Unbilled authorised consumers like fire services, and free water provided to some groups such as unmetered connections in parks etc.

Figure 2 below shows the NRW percentage in different countries (Gupta, Mishra, Bokde and Kulet, 2016).

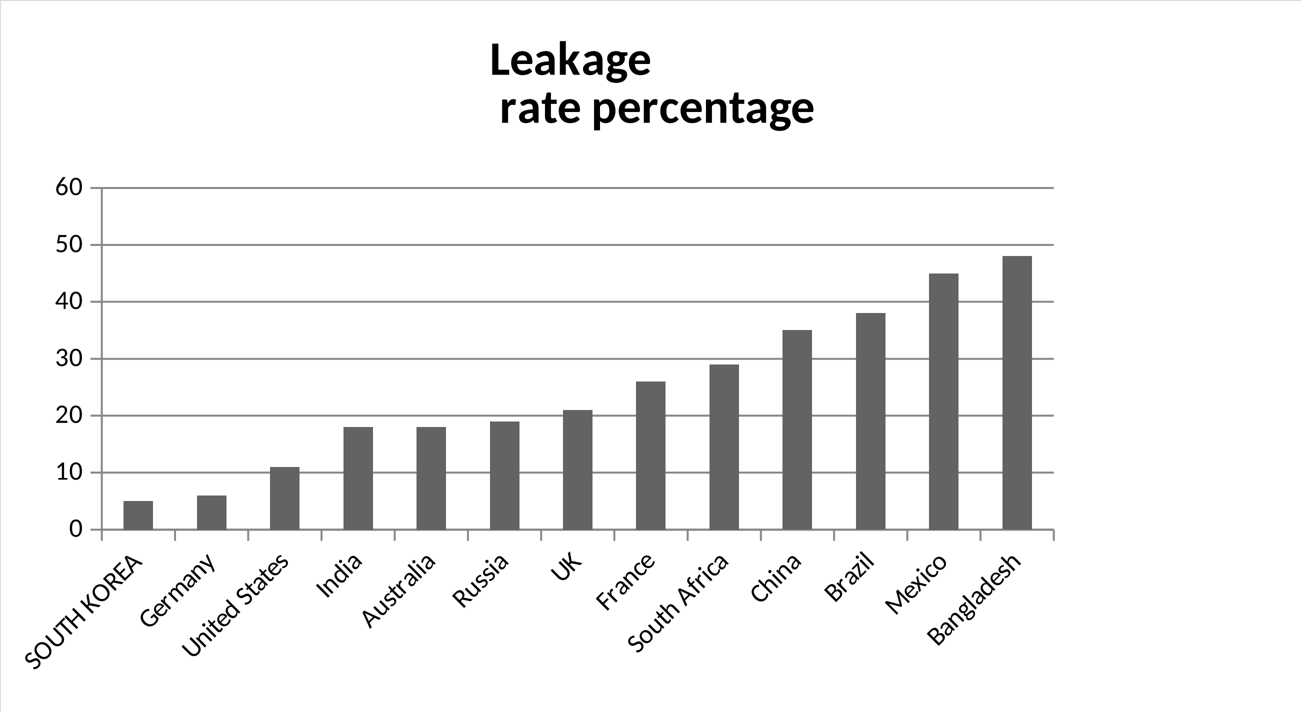

Figure 2 : Leakage percentage in the water distribution system in different countries

All three components listed above can be stopped or minimised by using technology interventions in the following ways:

a. Application of special purpose valves (pressure regulating, pressure reducing, flow control and altitude control valves) would help in managing pressure and flow in the system. Pressure and flow discrepancy is caused due design of assets for the projected period demands of water
b. Distribution network modification by converting the pipeline network into a DMA to enable active leak detection strategies using appropriate technologies like acoustics, tracer gas, robotics etc.
c. Framing policies for telescopic water tariffs, connections, reconnections, disconnections and subsidies
d. Using automatic meter reading technology, (smart) enabled consumer water meters, bulk flow meters and sensors in network and pumping stations
e. System monitoring, using analytical software (GIS compatible) and cloud-based mobile applications

5.3.2 Automation and Smartness in the Water Management System

Technology interventions can make city-wide water supply systems fully smart using sensors, transmitters, loggers, actuators and automatic meters. Information and communication technology is key to delivering smartness in the water management system. Smartness enables continuous monitoring, anomaly finding and optimisation of system efficiencies. Data capturing in integration with sensors or water meters and transmitting these through

WIFI or GSM technology to the cloud for processing and storage makes the water management system smart and capable of real-time monitoring of water parameters and generates the MIS for decision making (K. Mohammed Shahanas and P. Bagavathi Sivakumar, 2016). Following system architecture can be useful smart water management systems (Shahanas, K. M., & Sivakumar, P. B. ,2016) .

Sustainable water management system (SWMS), integrated urban water management system (IUWM), water rights, water security, smart city, governance, infrastructure, financing, economics, smartness, water technology.

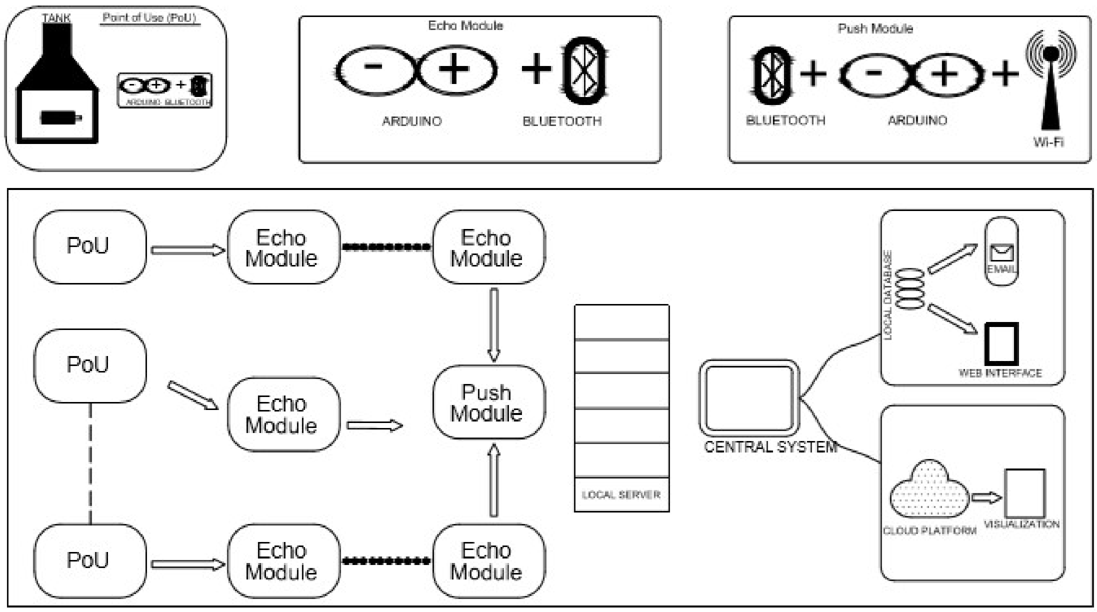

Figure 3: Architecture diagram for a smart water system

A smart city is an urban development vision to integrate multiple ICT, big data and IOT solutions in a secure fashion to manage a city's assets for sustainability, resilience and liveability (Chen, Y., & Han, D., 2018). ICT has the capacity to support in real time the monitoring of underground water, water pollution, waste water treatment plants, water pipeline networks, consumer and bulk water meters, rain water harvesting systems, water demand, hydraulic parameters of water supply, pumping station, electromechanical parameters, valve status, operation maintenance and system performance. ICT brings high performance and high efficiency in SWMS, IUWM and smart city water management.

5.4 Infrastructure

Most of the water supply infrastructure (pipelines, treatment plants, reservoirs etc.) were built between 1930 and 1990 in most of the urban areas in developed and developing countries. This infrastructure is aged and has become hydraulically and conditionally insufficient.

Generally, designers forecast the future water demand based on projected population data. Different countries and their water institutions use different types of mathematical methods for projections of future population. The risk of error in the projection of future demand may create operational, infrastructural, technical and economic problems in water management systems. Overdesign and underdesign are both undesirable for sustainable water management systems (Sarah M. Fletcher, Marco Miott, Jaichander Swaminathan, Magdalena M. Klemun, Kenneth Strzepek and Afreen Siddiqi, 2017). Nowadays, trends of designing water infrastructure with risk and decision methods is increasing. This method causes moderate investment increase, combined with a design of flexible diameter and capacity infrastructure. This method of water infrastructure design reduces the risk of over- and undersize designing (Sarah M. Fletcher, Marco Miott, Jaichander Swaminathan, Magdalena M. Klemun, Kenneth Strzepek and Afreen Siddiqi, 2017).

At present, 163 million people do not have access to safe drinking water and 210 million people lack access to improved basic sanitation in urban India. In urban areas, 96% have access to an improved water source and 54% to improved sanitation (Ali and Dhkar, www.teriin.org, 2018). Quality and quantity of potable water are very important aspects of the infrastructure strategy of any water supply system. These are governed by the World Health Organization (WHO) and the national standards of respective countries. In India quantity and quality of water is standardised by CPHEEO and BIS standards. The water infrastructure should be capable of providing an adequate quality and quantity of water to the citizens.

Deficiency in the water system infrastructure is one of the main hurdles in providing water for all. Smart cities are focusing on upgrading infrastructure to increase the coverage and smart technology. The infrastructure will ensure availability of adequate water of potable quality, 24/7 water supply to each household, smart metering, adequate storage, conveyance, treatment, distribution and controlling assets. IUWM and smart city water management not only deals with an adequate infrastructure for drinking water but they also emphasize adequate infrastructure for waste water collection and its reuse and recycling after treatment. The infrastructure of rain water harvesting, rain water drainage systems and urban rivers restoration and conservation will be part of the infrastructure strategy of smart water management.

Smart cities are working towards injecting smartness in the water management system of smart cities through ICT and web-based applications. Metering, real-time monitoring of the quality of water in treatment plants and ground water, realtime monitoring of ground water levels, pressure and flow balancing, asset listing, customer services and NRW management are some aspects of water management that will be made smart in smart cities.

5.5 Economics

India, China and Nigeria lead urbanisation by contributing 35% in urban population. Asian and African countries jointly contribute 90% of urban population in the world due to the high growth of their population and urban migration (Amanda Goksu, Alex Bakalian, Bill

Kingdom, Gustavo Saltiel, Yogita Mumssen, Gerard Soppe, Joel Kolker, and Vicky Delmon, 2019). Around 0.9% of GDP will be invested by lower- and middle-income countries in providing and improving water and sanitation services to their citizens (Rozenberg and Fay 2019). Water supply and sanitation services both involve pipeline and flow-controlling networks but the water supply distributes clean water and sewer system pipelines collect sewage water. Water supply services make better business cases while sanitation services have more challenging social perceptions that impact their pricing and financing. Financing and pricing of the water supply has a peculiar challenge: it is essential for life, which gives rise to ambiguity in the minds of decision makers as to whether it should be considered a social obligation or a natural resource to sell. Most countries claim to provide free water and charge citizens only for operation and maintenance. Such pricing may put utilities at risk of not having enough funds for repair and replacement of underperforming assets.

The water sector is very capital intensive. The lack of regulations and unclear policies make it a less lucrative sector for investment by banks and the private sector. The water utilities are mostly cash starved organisations that are upgrading water infrastructure. These look towards private financing and investment through various types of debting tools and PPP contracting models. The utilities receive revenue from the sources shown below (1) water tariffs (2) transfers of donations and (3) taxes, subsidies and grants.

Sustainable water management system (SWMS), integrated urban water management system (IUWM), water rights, water security, smart city, governance, infrastructure, financing, economics, smartness, water technology.

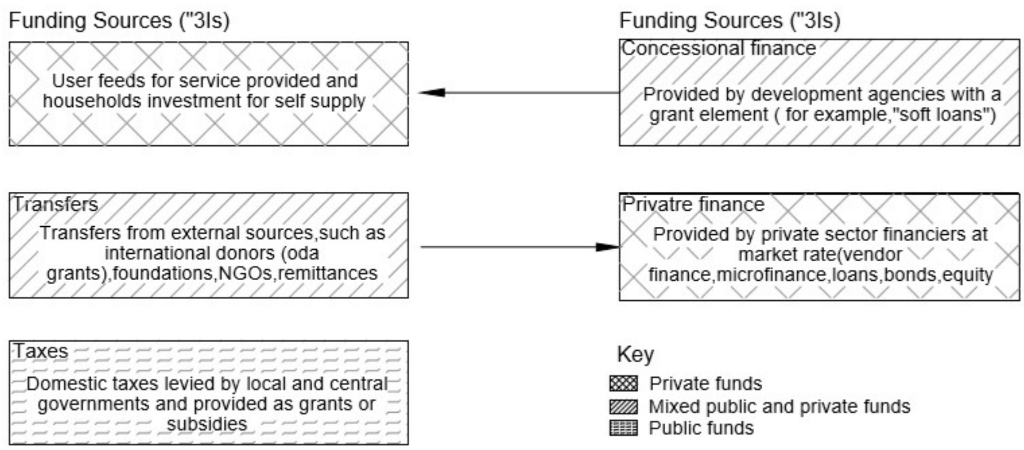

Figure 4: Water sector financing (World Bank Report)

Utilities have lower credit scores than other industries, which affects them when applying for commercial finance. They are mostly dependent on public finance due to the fact that they lack sufficient governance and institutional reforms to attract commercial finance. The creditworthiness of a water utility is directly dependent on its capacity to repay the loans. Utilities' ability to repay loans depends on their operational cash flow and financial reserves.

Generally, lenders consider to be more creditworthy those utilities that recover more than 150% of their cost of operations (Goksu et al., 2017). Figure 5 shows that as the utilities move upwards in financial sustenance, they become worthy of receiving more finance and investment.

ustainable water management system (SWMS), integrated urban water management system (IUWM), water rights, water security, smart city, governance, infrastructure, financing, economics, smartness, water technology.

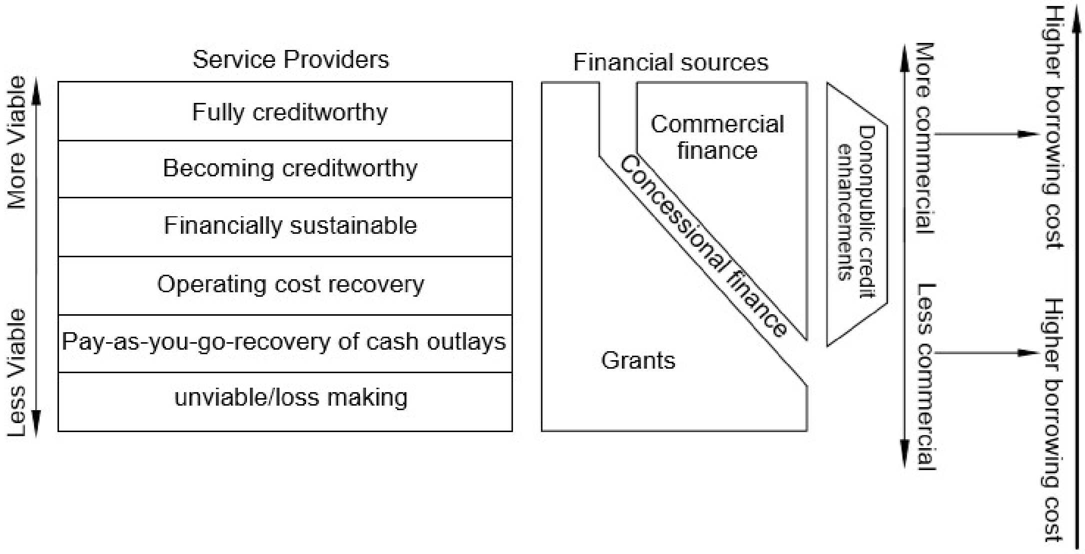

Figure 5: Improved financial performance increases creditworthiness

Smart cities under the Indian Smart City Mission receive USD 6.8 billions (Rs. 480 billions) in five years from central government with equal contribution by states. Most of the smart cities use funds from other governmental programmes to fulfil their fund requirements. Likewise for water management system development, smart cities use funds from the AMRUT scheme and lending from JICA, ADB, the World Bank and other funding agencies.

As per the report of the Seconded European Standardisation of Experts in India, a High Power Expert Committee (HPEC) of the Smart City Mission on investment estimates that a smart city with an average population of one million would require an investment of USD 620 (Rs 43,386) per person in 20 years to improve its infrastructure. In total, an investment of around USD 5 billions (RS 350 billions) would be required in 20 years for Indian smart cities. A PPP contracting model to invite involvement from private parties may be an option in finding this huge amount.

6.0 Research Methodology

Research information was collected through a literature survey using Google Scholar. The key words were as follows:

Sustainable water management, integrated urban water management, smart city, water management, water governance, governance in smart cities, Smart City Mission in India, technology in water management, smart water management, smart technology in water management, infrastructure for water supply, water supply finance and investment in water supply schemes.

The data was collected online from secondary data sources. Most data was collected from online searches using Google Scholar and Google. The data was mostly retrieved from research papers of indexed journals, World Bank reports, industry reports and OECD reports, government of India reports and reference books etc. The research methodology lists the variables identified through an exhaustive literature survey. A direct relationship between four main variables – governance, technology, infrastructure and economics – was considered for evaluation of the research objective.

7.0 Research Framework

The literature review supported my proposal to use the research framework shown in figure 6 below. IUWM is the dependent variable and governance, infrastructure, technology and economics are independent variables.

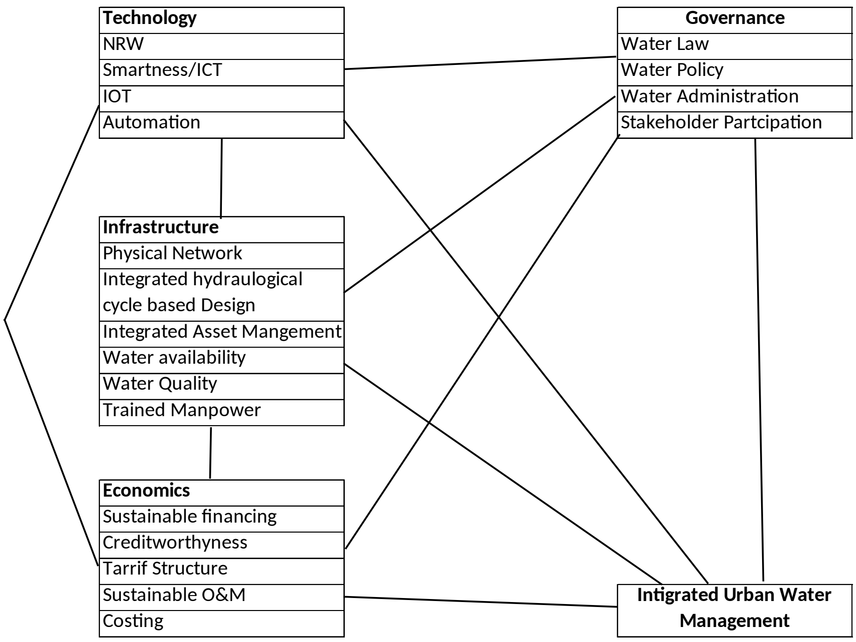

Figure 6 Research Framework

Governance is the key variable for IUWM. Water governance has moved from twentieth-century water-resource management to participative governance to ensure adherence to laws, policy, institutional frameworks, stakeholder roles and responsibility, economic considerations, skills development, water usage guidelines, quality criteria, and NRW standards etc. As per the proposed definition of governance for IUWM and smart cities, it has a correlation with economics, technology, infrastructure, stakeholder participation, water laws, water policies and water administration (institutional framework).

Economics plays a very crucial role in IUWM. It is a mammoth task for utilities to arrange funds for the creation and upgrading of infrastructure. Figure 5 shows that reforms carried out by utilities increase their creditworthiness. The performance of utilities also depends upon their tariff structure and their ability to recover costs that are a direct function of governance. Technology interventions and infrastructure upgrades are dependent on finance and investment to make the city water supply system integrated and sustainable.

Infrastructure is an independent variable for IUWM and a dependent variable of governance. It has a correlation with technology. In an IUWM environment, the infrastructure is created for the entire hydrological cycle, which requires funds and policy direction. The long-term sustainable source of bulk water (rivers, desalination, lakes, ground water, canal systems etc.), water supply coverage, supply criteria, quality of water and type of distribution network are also variables of infrastructure.

Technological advancement in the water sector has played a very important role in making the system sustainable and automated. The smart components through ICT, IOT and active leak detection programmes are part of technology interventions in IUWM and smart city water management systems. They have increased the system performance through reduction in NRW. Technology is a dependent variable of governance and economics and correlates with infrastructure.

8.0 Results and Analysis

Sustainable water management is capable of fulfilling the needs of present and future generations, and involves environmental considerations, agility of governance to mitigate the challenges in real time, long-term economic considerations, modern physical infrastructure and state-of-the-art futuristic technology. The IUWM concept takes care of from natural sources. Like SWMS, IUWM takes care of present and future demand, high efficiencies in all aspects of water management systems and it promotes the reuse, recycling and reduction concept wherever possible (Akica Bahri, TEC Background paper No. 16, Global water partnership technical committee, 2012). IUWM is SWMS in the urban context and smart city context.

Singapore and Hong Kong are world-class smart cities and both ensure their citizens of water security. In both cases, the adoption of IUWM was supported by high-level political commitment and clear allocation of responsibility for strategy design and implementation to a single agency: PUB in Singapore and WSD in Hong Kong (Jensen, O., & Nair, S., 2019).

Governance played a major role in making the system sustainable in Singapore. An all-round approach and institutional framework supported by other inter- and intra-level institutions responsible for sustainable development like finance, environment, irrigation, land development, municipal services, housing etc. jointly worked on delivering water security for Singapore through policies, rules and an institutional framework. PUB, the agency responsible for the water system in Singapore has overall responsibility for managing water in Singapore. Figure 6, below, shows the IUWM structure in Singapore.

Sustainable water management system (SWMS), integrated urban water management system (IUWM), water rights, water security, smart city, governance, infrastructure, financing, economics, smartness, water technology.

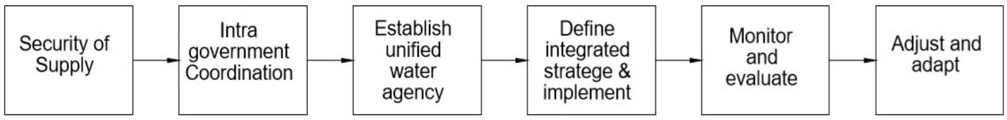

Figure: 7 IUWM Structure of Singapore

The low cost of water has given utilities a governance challenge in expanding their infrastructure (Zhong, H., Taylor, M. H., Rollins, K. S., Manning, D. T., & Goemans, C. G., 2019). The research framework includes a regulated water utility, capable of recovering the cost of operations and future expansion. Cheaper finance is available for the utilities that are capable of recovering their costs without compromising the water rights and water security that are the components of governance. The sustainability of the water system requires huge investment in the continual upgrading of technology and infrastructure. Access to commercial finance does not equate to privatising the water utilities. Utilities across the world, irrespective of the income standards of countries with state-owned utilities such as SABESP (Brazil), Phnom Penh Water Supply Authority (Cambodia), and privately-owned Manila Water (Philippines) are high-standard service providers, thanks to their ability to access commercial finances (Amanda Goksu, Alex Bakalian, Bill Kingdom, Gustavo Saltiel, Yogita Mumssen, Gerard Soppe, Joel Kolker, and Vicky Delmon, 2019). Each country has their own governance system and framework, within which utilities have the opportunity to leverage private finance. Economics plays a very important role in SWMS and IUWM; it is driven by governance and drives infrastructure and technology, which are the main components of IUWM and smart city water management systems.

Futuristic infrastructure is the main concept of the IUWM theory. Water rights, water security and sustainability can be ensured by futuristically adequate infrastructure driven by an institutional framework, rules and policies with adequate funding. Efficiently-designed infrastructure for water management at the hydrological-cycle level and an optimum asset lifecycle combined with the technological and operational inputs of software and electronic hardware enhances system performance multi-fold. IOT and ICT technology has eased the planning and monitoring of the water system. NRW is one of the main parameters of measured performance of any water supply system. Realtime monitoring of pressure and flow has helped utility managers. Leakages in pipelines are a direct result of pressure in the system which can be controlled by structural methods (capital investment) and non-structural methods (operation management) (Gupta, Mishra, Bokde and Kulet, 2016). Pressure-reducing valves, flow-control valves, altitude-control valves and AMR meters along with the use of ICT and IOT systems are structural interventions to control leakages and reduce NRW. Technology and infrastructure are interdependent and jointly drive the SWMS or IUWM and smart city water management. Governance is a guiding variable of infrastructure and technology.

8.1 Strategy for a Sustainable Water Management System for Urban areas and Smart Cities of India

India's geopolitical status is very different to that of other countries. India has a federal system of governance. It is the responsibility of each state to manage their water resources. In the Indian federal system, central government provides finance for water projects of national importance and shares the developmental costs of these projects under various schemes; states then implement these projects within their jurisdiction (Masood Ahmad, Eduardo Araral, 2019). Multilevel governance systems pose challenges in the implementation of projects which lead to delays and cost overruns of projects (Purbo, R. K., Smith, C., & Bianchi, R. J., 2020).

In urban areas, the municipal water utilities are governed by political public representatives and bureaucratic hierarchy. These bodies lack but are responsible for technical, operational, financial and managerial expertise. The capability gap will be filled by private sector participation. Some of India's megacities have the institutional framework of a dedicated organisation for managing water in an integrated manner. Delhi Jal Board (DJB), BWSSB for Bangalore and CMWSSG for Chennai are examples. Aral and Ratra (2016) states that it is very difficult to construct a dam in India because states responsible for building the infrastructure lag in capacity and political will, the Indian democratic system has too many players with a veto and conflict between various state and non-state stakeholders makes the institutional framework ineffective.

India can adapt to technological and infrastructural interventions directly from other world cities but it has to develop its own model of governance and financing for sustainable water management in urban areas or IUWM within its constitutional arrangements. PUB-type institutions may be a solution for India's megacities but they do not consult effectively with stakeholders while implementing projects (Jensen and Nair, 2019). It should be kept in mind that Delhi is dependent on other states' responses for its water security and this situation exists in many parts of India where states have disputes over the sharing of water. Some of India's rivers, which extinguish the thirst of large populations, pass through other countries also. Considering all the geopolitical facts and constitutional arrangements, India should plan its own version of IUWM to fit into its own scenarios.

The Indian Smart City Mission was launched with the aims of improving the quality of life of its citizens and achieving sustainability in its services. Kandpal, Kaur and Tyagi (2017) argue that in India, given its demographics and diversity, unique challenges and opportunities exist for developing ‘smarter’ cities that attract increased investment, employ innovative technology, create environmentally sustainable solutions, grow operational efficiencies and change the lives of urban citizens. Governance is a central concern in achieving sustainability in Indian smart cities.

Although the special-purpose vehicle of the smart city is responsible for the implementation of infrastructure projects, multiple agencies are still working with less coordination than required and different performance parameters are in evident across water supply projects. For example, in the smart city of Agra, the SPV is rejuvenating the water supply system of some areas with 24/7 water supply objectives and reduction of NRW to 20%. (A tender document to provide a 24/7 water supply to the ABD area with water meters and a SCADA system under the Smart City Mission. Jal Nigam, the state agency responsible for water supply in Uttar Pradesh, is also implementing two projects in Agra with different objectives (tender document for Agra water supply phases II and IV under the AMRUT scheme). Such governance failures are present in each smart city: multiple agencies are carrying out similar work with dissimilar objectives.

The convergence of schemes should be limited to financial arrangements only. Technology, infrastructure, sustainability and the governance model of water management should be similar in a city. It can be concluded that India should learn from other countries to form an institutional framework to achieve the Smart City Mission objective of providing a sustainable and smart water management system. The mission is placing too much focus on achieving smartness in the water supply system but placing sustainability on the back seat.

9.0 Conclusion and Limitations

According to the 2011 Indian census report, cities are home to 31% of Indians and make up 63% of Indian GDP. Urban migration from rural areas is inspired by the aspirations to have a better quality of life, more job opportunities and take part in growth story of the country. It is expected that around 40% of Indian citizens will live in urban areas and generate 75% of GDP by 2030 (Shanas, Shivkumar, 2016). The increasing urbanisation increases the urgency to develop service infrastructure, including water management, to cater for the demand. It requires huge investment through public and private financing. The tools and means of public and private financing should be explored by cities to provide sustainable, long-term water rights and water security to its citizens.

Research conducted by the Third World Centre for Water Management reveals that the water crisis is not caused by scarcity of water but by errors in managing it in terms of governance, long-term sustainability and an integrated approach to infrastructure, technology and economics. However, the world will most certainly face a water crisis in the future if previous and current poor to very poor governance practices continue to be used in nearly all developing and developed countries (Biswas, A. K., & Tortajada, C., 2010). Like many other researchers and academicians, Araral and Ratra (2016) argue that governance holds the key to achieving water security in the developing countries, when combined with suitable policies, laws, institutional frameworks, standards, technology and infrastructure. An OECD report on the principles of water governance states that the water crisis is a governance crisis. Few cities have achieved excellence in SWMS. The governance definition proposed in this paper may support utilities in creating an institutional framework for achieving SWMS. The need for universally-accepted measurable indicators of IUWM, SWMS and smart-city water management is opening the doors for future research. The indicators that are derived may be accepted by all countries as SDGs. It should be the prerogative of cities to declare the minimum value of these indicators, and on achievement of these they can be considered to be providing sustainable water management.

10.0 References

1. Ahmed, M., & Araral, E. (2019). Water Governance in India: Evidence on Water Law, Policy, and Administration from Eight Indian States. *Water*, 11(10), 2071.
2. Araral, E., & David, J. Y. (2013). Comparative water law, policies and administration in Asia: Evidence from seventeen countries (No. 2013, p. 0010). *CSID Working Paper Series.*
3. Araral, E., & Wang, Y. (2013). Water demand management: Review of literature and comparison in South-East Asia. *International Journal of Water Resources Development*, 29(3), 434-450.
4. Aartsen, M., Koop, S., Hegger, D., Goswami, B., Oost, J., & Van Leeuwen, K. (2018). *Connecting water science and policy in India: lessons from a systematic water governance assessment in the city of Ahmedabad. Regional environmental change*, 18(8), 2445-2457.
5. Background note for Infrastructure and Investments in Water and Sanitation in India issued by *Mr. Parameswaran Iyer, Secretary, Ministry of Drinking Water and Sanitation, Government of India*.
6. Bakker, K., Kooy, M., Shofiani, N. E., & Martijn, E. J. (2008). *Governance failure: rethinking the institutional dimensions of urban water supply to poor households. World Development,* 36(10), 1891-1915.
7. Biswas, A. K., & Tortajada, C. (2010). Future water governance: problems and perspectives. *International Journal of Water Resources Development*, 26(2), 129-139.
8. Brown, R. R., Sharp, L., & Ashley, R. M. (2006). Implementation impediments to institutionalising the practice of sustainable urban water management. *Water Science and Technology*, 54(6-7), 415-422.
9. Chen, Y., & Han, D. (2018). Water quality monitoring in smart city: A pilot project. *Automation in Construction*, *89*, 307-316.
10. Falconer, G., & Mitchell, S. (2012). Smart city framework. *Cisco Internet Business Solutions Group (IBSG)*, 1-11.
11. Fletcher, S. M., Miotti, M., Swaminathan, J., Klemun, M. M., Strzepek, K., & Siddiqi, A. (2017). Water supply infrastructure planning: decision-making framework to classify multiple uncertainties and evaluate flexible design. *Journal of Water Resources Planning and Management*, *143*(10), 04017061.
12. Goksu, A., Bakalian, A., Kingdom, B., Saltiel, G., Mumssen, Y., Soppe, G., ... & Delmon, V. (2019). *Reform and Finance for the Urban Water Supply and Sanitation Sector*. World Bank.
13. Grassini, L. (2019). Participatory water governance between theories and practices: learning from a community-based initiative in India. *International Journal of Water Resources Development*, 35(3), 404-429.

14. Himanshu Shekhar, Chandan Bhavnani, Anirban Chatterjee, April, 2016, *A report on Water - the Next Sustainability Frontier , published by YES Bank*
15. Jensen, O., & Nair, S. (2019). Integrated Urban Water Management and Water Security: A Comparison of Singapore and Hong Kong. *Water*, *11*(4), 785.
16. Jensen, O. (2017). Public–private partnerships for water in Asia: a review of two decades of experience. *International journal of water resources development*, 33(1), 4-30.
17. Jog, Y., Singhal, T. K., Barot, F., Cardoza, M., & Dave, D. (2017). Need & Gap Analysis of Converting a City into Smart City. *International Journal of Smart Home*, *11*(3), 9-26.
18. Karwot, J., Kaźmierczak, J., Wyczółkowski, R., Paszkowski, W., & Przystałka, P. (2016). „Smart Water in Smart City: A Case Study". In *Proceedings of SGEM 16th International Scientific Conference on EARTH&GEOSCIENCES, book* (Vol. 3, pp. 851-858).
19. Khatoun, R., & Zeadally, S. (2016). Smart cities: concepts, architectures, research opportunities. *Communications of the ACM*, *59*(8), 46-57.
20. Kumar V Pratap Economic Adviser Ministry of Urban Development Government of India, *Financing of Smart Cities, a presentation on* www.smartcities.gov.in
21. Kumari, O., & Kumar, M. (2020). Water governance: a pragmatic debate of 21st century; an Indian perspective. *In Emerging Issues in the Water Environment during Anthropocene, book* (pp. 355-365). Springer, Singapore.
22. Molina-Giménez, A. N. D. R. É. S. (2018). Water governance in the smart city. *Proceedings of Urban Growth and the Circular Economy*, *179*, 13-22.
23. Mr Qazi Syed Wamiq Ali and Mr. Nathaniel B Dhakar , 2nd December 2019*, an article on India's rampant urban water issues and challenges. (www.* www.teriin.org*)*
24. Murugan, S. S., & Chandran, S. (2019). Assessment of Non-Revenue Water in a Water Distribution System and Strategies to Manage the Water Supply. *Assessment*, *6*(04).
25. Narain, V. (2000). India's water crisis: the challenges of governance. *Water Policy*, 2(6), 433-444.
26. Nguyen, K. A., Stewart, R. A., Zhang, H., Sahin, O., & Siriwardene, N. (2018). Re-engineering traditional urban water management practices with smart metering and informatics. *Environmental modelling & software*, *101*, 256-267.
27. Ntuli, N., & Abu-Mahfouz, A. (2016). A simple security architecture for smart water management system. *Procedia Computer Science*, *83*, 1164-1169.
28. Ozerol, G., Vinke-de-Kruijf, J., Brisbois, M., Casiano Flores, C., Deekshit, P., Girard, C., ... & Schröder, N. J. (2018). Comparative studies on water governance: A systematic review. *Ecology and society*, 23(4),
29. Pahl-Wostl, C. (2015). Water governance in the face of global change. *Springer International Publishing: Switzerland. doi*, *10*, 978-3.
30. Parra, L., Sendra, S., Lloret, J., & Bosch, I. (2015). Development of a conductivity sensor for monitoring groundwater resources to optimize water management in smart city environments. *Sensors*, *15*(9), 20990-21015.
31. Purbo, R. K., Smith, C., & Bianchi, R. J. (2019). Local government and public–private partnerships: experiencing multilevel governance issues in Indonesian water supply provision. *International Journal of Water Resources Development*, 1-23.
32. Sahu, S. (2016). sustainable Urban Water supply in India: some Issues of Governance. *Journal of Governance & Public Policy*, *6*(2), 105.
33. Schwartz, K., Gupta, J., & Tutusaus, M. (2018). Inclusive development and urban water services. *Habitat International*, *73*, 96-100.

34. Shahanas, K. M., & Sivakumar, P. B. (2016). Framework for a smart water management system in the context of smart city initiatives in India. *Procedia Computer Science*, *92*, 142-147.
35. Smart city Mission Statement and guidelines issued *by Ministry of Urban Development, June 2015, (www.smartcities.gov.in)*
36. Tender document issued by Agra Smart City Limited (ASCL), Office of Nagar Nigam, Agra, UP-282001 for *Providing 24x7 water supply to ABD area with water meter and SCADA system under Smart city Mission*
37. Tender Document issued by Office of the General Manager, Ganga Jal Project Unit, U.P. Jal Nigam, *Agra for the project of Agra Water Supply Scheme (Phase-III) in AMRUT Programme*
38. Tender Document issued by Office of the General Manager, Ganga Jal Project Unit, U.P. Jal Nigam, *Agra for the project of Agra Water Supply Scheme (Phase-IV) in AMRUT Programme*
39. Tortajada, C. (2006). Water management in Singapore. *Water Resources Development*, *22*(2), 227-240.
40. Tortajada, C. (2010). Water governance: a research agenda. *International Journal of Water Resources Development*, 26(2), 309-316.
41. Tortajada, C. (2010). Water governance: Some critical issues. *International Journal of Water Resources Development*, 26(2), 297-307.
42. Van Buuren, A., van Meerkerk, I., & Tortajada, C. (2019). Understanding emergent participation practices in water governance
43. Van Leeuwen, C. J. (2017). Water governance and the quality of water services in the city of Melbourne. *Urban Water Journal*, *14*(3), 247-254.
44. Zhong, H., Taylor, M. H., Rollins, K. S., Manning, D. T., & Goemans, C. G. (2019). Who pays for water scarcity? Evaluating the welfare implications of water infrastructure investments for cities. *The Annals of Regional Science*, *63*(3), 559-600.