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REVIEW

Smart Water Systems: Advances in Monitoring, Modeling, and Management of Water Resources in China

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ABSTRACT

Smart water systems are a revolutionary way of utilizing water resources, based on the use of modern technologies (sensors, data analysis, machine learning, and real-time monitoring). Such systems are becoming part and parcel of water management practices in China in order to deal with the fact that the country is facing water scarcity, problems of pollution, and even an unpredictable climate. This article examines the design and deployment of smart waters in China and how monitoring, modeling, and decision-making technologies have been integrated into water management systems in different sectors of water management, such as river basins, urban utilities, agriculture, and groundwater management. We consider how decision support systems (DSS) can be used to improve water allocation, infrastructure management processes, and resilience to floods and droughts. The article, however, also notes that there are various challenges to scaling these systems, such as the lack of technological interoperability, data management concerns, cybersecurity risks, and financial limitations. Moreover, institutional fragmentation and social refusal to accept also complicate the popularisation of smart water technologies. The article wraps up by underscoring the fact that more investment needs to be made in data standards, cross-agency coordination, and capacity building to eliminate these obstacles and to make smart water systems a success in the long term. The activities of China in this respect are a worthy example to other countries that are trying to deal with the challenge of water management, like China.

Keywords: Smart Water Systems; Water Resource Management; Data Integration; Decision Support Systems; China

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1. Introduction

One of the most serious challenges to China is water security, which is the result of the intricate combination of the growing demand, geographical inequality, pollution, and climate change [1,2]. The nation harbors 20% of the population in the world, but just 6% of the fresh water supply. The north, and especially so, is affected by severe water scarcity, whereas the southern ones experience seasonal floods. These problems have been worsened by the rapid urbanization and industrialization that have resulted in over-exploitation of groundwater, pollution of water sources, and a greater likelihood of over-hydrological situations, including floods and droughts. Moreover, there is a never-ending problem of water quality management in which the challenges of pollution by industrial, agricultural, and domestic sources of water severely impact rivers, lakes, and groundwater [3,4].

China has adopted the potential of smart water systems in order to deal with these multifaceted challenges. These digital systems are transforming the process of monitoring, modeling, and management of water resources by integrating digital technologies (the use of sensors, data analytics, modeling, and decision support tools). The smart water solutions are the focus of the attempts of the Chinese to improve the efficiency of water, the distribution of resources, the minimization of environmental impact, and the water security of the population. The promotion of smart water systems also coincides with the further national policies, such as the agenda of ecological civilization and the Water Pollution Prevention and Control Action Plan, where the need to implement technological solutions in protecting the water resources of the country is emphasized [5,6].

The purpose of this review is to offer a detailed analysis of the prevailing situation of smart water systems in China and how they can be used to monitor, model, and manage water resources [7,8]. The review, it will discuss the numerous technological developments that have taken place in the many water sectors, including river basin management, urban utilities, agriculture, and groundwater management. It is against this background that the article seeks to answer many key questions: How has the governance structure in China influenced the formulation and adoption of smart water technologies? What are the major monitoring technologies and data collection measures in use to enhance the management of water resources in China? What is the future of modeling practices, and what contribution can be made to prediction capacities by data assimilation and machine learning? How are smart water systems aiding in the decision-making process, especially in water allocation, emergency response, and environmental protection? What are the most significant scaling impediments to these systems, and what can be done to address them? Through answering these questions, this review will provide insight into how smart water systems are changing the management of water resources in China and make recommendations on how the field should develop in the future.

The article is divided into the following sections. Section 2 focuses on the specifics of governance and institutional environment in China and the way these structures affect the implementation of smart water technologies. The section will delve into national and regional policies, data management, and the institutional coordination that needs to be put in place to deploy the large-scale smart water systems. Section 3 explores the technologies of monitoring that are applied in the smart water systems, including sensor networks, remote sensing technologies, and participatory monitoring platforms. It will discuss the way these technologies are incorporated in national and local water management activities and the issues that are presented by the quality of data and calibration. Section 4 is concerned with the modeling methods that are applied to assist decision-making in smart water systems. In this section, I will discuss the traditional hydrological models, machine learning methods, and a new concept of the digital twins of water systems. It will also test the improvement in model accuracy and reliability with the use of data assimilation. In Section 5, the application of decision support systems (DSS) in China to optimize the water allocation, real-time management of resources, and emergency response has been described. It will discuss methods of optimization and how they can help to enhance the efficiency and resilience of water management. Section 6 outlines the major obstacles to the extensive adoption of smart water systems in China, such as technological incompatibility, technical difficulties, and cybersecurity threats. It will also address the institutional and social aspects, which affect adoption and scaling. Section 7 contains the conclusion and future directions of the smart water systems in China, summarizes the main results of the review, and provides recommendations on the policy, research, and technology development. It is hoped that this review will offer a comprehensive account of how China has been moving towards the digitalization of the management of its water resources and offer a roadmap on how these solutions can be scaled in the next few decades [9–11].

The close interconnection between institutional governance and technological innovation is also one of the aspects characterizing the smart water systems in China. China does not follow the widely used model in several countries, where water management systems are being developed without any reference to the wider institutional frameworks: China integrates the concept of smart water in its governance systems, which are not only centralized but also decentralized. The national government takes a central position in providing policies and structures on water management, whereas the local authorities are involved in the implementation and execution of water management policies and structures at the regional and municipal levels. Such a dual structure has its advantages and disadvantages in terms of how new technologies can be integrated. As an illustration, national policies, including the Integrated Water Resources Management (IWRM) model and Sponge City popularization, have influenced the implementation of smart water technologies considerably. Nonetheless, data fragmentation across various governmental departments, the absence of standardized work across regions, and higher-level work remain persistent obstacles to the effective operation of smart water systems. It is necessary to learn how China can overcome these obstacles and establish cooperation between the state, academia, industry, and the city population to understand the effectiveness and extent of the Chinese smart water programs [6,9,12].

The innovative themes discernible from this review can be summarized in three interconnected areas: monitoring, modeling, and management. These are the foundations of any smart water system, yet the unique environmental, social, and political factors determine their implementation in China. It has been noted that monitoring technologies, such as those important in responding to the water scarcity and pollution issues in China, predictive modeling, and decision support tools are being put to improve water allocation, leaks, optimization of the treatment procedures, and response to natural disasters. These technologies have just contributed to the efficiency of water resource management through the integration of these technologies in the governance framework, though the challenges of scaling, data integration, and O&M still exist. With China still developing its digital water plans, the adoption of new technology, including AI, the Internet of Things (IoT), and big data analytics, will be the next source of innovation in water resource management. The experience of smart water systems that China had will be relevant both to other nations grappling with the same water predicament and to the water industry in general [13–15].

This review employs a narrative (critical) review methodology to synthesize the current state of smart water systems in China. Unlike systematic reviews, this approach is better suited for integrating diverse evidence types, including peer-reviewed articles, government policy documents, technical reports, and case studies, across multiple water sectors (river basins, urban utilities, agriculture, and groundwater). The literature search was conducted using Web of Science, Scopus, CNKI (China National Knowledge Infrastructure), and Google Scholar for the period 2005–2025. Search keywords included combinations of ‘smart water systems,’ ‘water resource management,’ ‘China,’ ‘Internet of Things (IoT),’ ‘digital twin,’ ‘decision support systems (DSS),’ ‘remote sensing,’ ‘machine learning,’ ‘hydrological modeling,’ and ‘water quality monitoring.’ Inclusion criteria were: (i) peer-reviewed articles, government reports, or credible conference proceedings; (ii) relevance to monitoring, modeling, or management of water resources in China; (iii) English or Chinese language. Exclusion criteria included non-China case studies without comparative value, non-digital water management approaches, and opinion pieces lacking empirical or policy evidence. The analytical framework was thematic, organizing findings into three interconnected domains: (1) monitoring technologies (sensors, remote sensing, crowdsourced data), (2) modeling approaches (hydrological/hydraulic models, machine learning, digital twins), and (3) decision support and management systems (water allocation, real-time control, early warning systems). This framework enabled critical synthesis of technological, institutional, and policy dimensions across the reviewed literature.

2. Governance and Institutional Context for Smart Water Systems in China

2.1. Institutional Landscape

China's water management system is characterized by a complex institutional structure that operates at multiple levels of governance [16]. The central government plays a crucial role in setting overarching policies and regulations that shape water resource management practices across the country. At the provincial and municipal levels, local governments are tasked with the implementation and enforcement of these policies. Local authorities, such as provincial water resource bureaus and municipal water supply and drainage agencies, are responsible for managing water distribution, treatment, and infrastructure maintenance within their respective regions. As shown in **Figure 1**, the conceptual framework of a smart water system integrates various technologies, from sensors and real-time monitoring to decision support systems (DSS). This framework illustrates how data flows from the monitoring phase to predictive modeling and, finally, to management actions that inform resource allocation and system optimization.

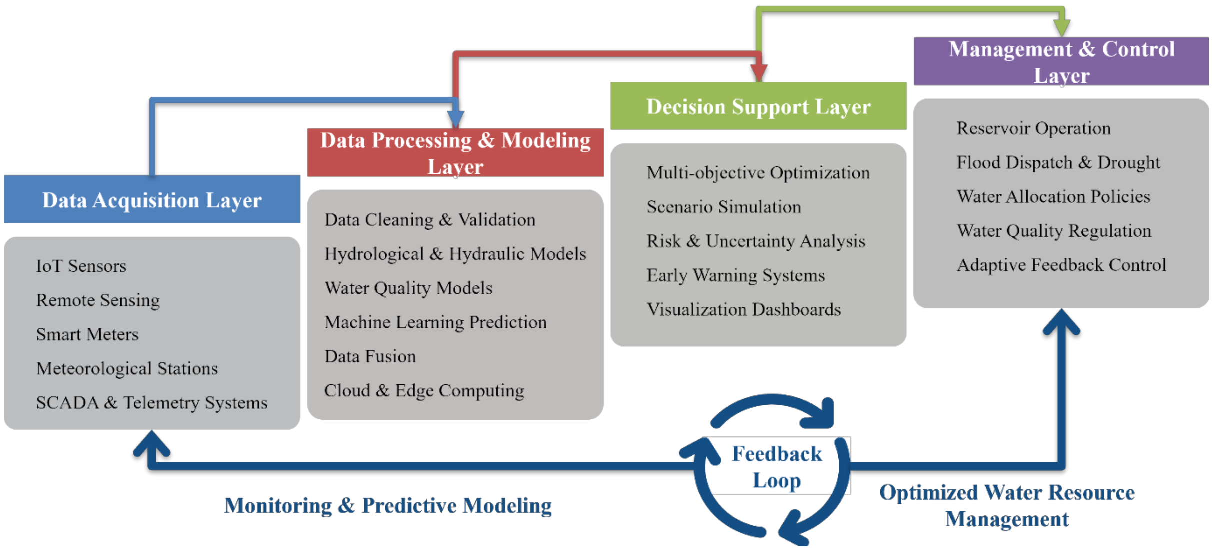

Figure 1. Conceptual Framework of a Smart Water System.

The political structure used in the management of water resources is highly dependent on the hierarchical system of governance within the country. Although the national government is offering general policy guidelines, it is often necessary that different local governments collaborate in the implementation process of these guidelines, starting with local governments and environmental and water resources bureaus. The presence of various government bodies can contribute to the difficulty in coordination and information exchange since various bodies can possess other priorities, budgets, and technological capacities. Nonetheless, in the recent past, the Chinese government has been trying to enhance coordination through the formation of cross-sectoral committees and commissions that control the integration of water management activities. Such committees can include representatives of environmental and urban planning and water management departments, which facilitates improved information sharing and policy coordination [17,18].

On the river basin level, the management of water resources at the catchment level is done by basin commissions that deal with water resources at the multi-provincial level. Such commissions possess a great power in making arrangements to allocate water and in establishing a fair allocation of water between various sectors, which include agricultural, industrial, and urban development. Other significant roles are played by the river basin commissions in recording the quality of water and other flood control measures. Considering the high environmental and economic value of their river systems, such commissions are also getting actively involved with an attempt to incorporate smart water technologies in their management systems, including the application of remote sensing to monitor and decision support systems (DSS) for water allocation [19].

2.2. Policy Drivers for Smart Water Solutions

Smart water technologies have been achieved in China due to the national water policies [6,20]. The Water Pollution Prevention and Control Action Plan and the 13th Five-Year Plan of Ecological and Environmental Protection have set high targets to be achieved to improve the water quality, lessen the pollution, and increase the sustainability of water resources. These policies note the importance of technological innovation to meet water scarcity, enhance water quality, and minimize the environmental footprint of water use.

Meanwhile, the Chinese government has also launched various special initiatives that are intended to popularize the application of smart water management. One of such programs is the idea of Sponge Cities, which is aimed at increasing the resilience of cities to floods and better control of stormwater. Through green infrastructure, real-time observation, and information-based decision making, Sponge City programs will mitigate the threat of urban flooding, enhance water saving, and enhance the well-being of urban water systems in general. These programs are in unison with the overall objectives of realizing ecological civilization, that give priority to sustainable environmental practices and the application of digital technologies to aid the environmental long-term mandate [21,22].

Also, the 13th five-year plan of water resources development of China has also recommended the adoption of smart water systems at both the national and regional levels. This involves the implementation of modern monitoring systems like remote sensing, Internet of Things (IoT) systems, and large-scale data analysis to conduct better monitoring of water quality, water distribution efficiency, and better management of water shortage. The focus of the government on smart water solutions is also justified by the investments in research and development, at the same time, the incentive of local governments and private companies to implement innovative water technologies [23,24].

2.3. Data Governance and Interoperability

A major problem of the successful implementation of smart water systems in China is data governance. The disjointed data infrastructure in the country is a major issue with regard to interoperability and sharing of data among different stakeholders, including government agencies, research institutions, private companies, and the local water utilities. The data related to water management is frequently isolated inside the particular agencies, including the Ministry of Water Resources (MWR), the Ministry of Ecology and Environment (MEE), and the local environmental protection bureaus. Such agencies usually gather information associated with water quality, water supply, and water utilization, but due to the absence of standardization of data formats and protocols, it is hard to combine data within systems [25,26].

To overcome these issues, the Chinese government has embarked on ensuring that national and regional data platforms are developed that seek to consolidate and integrate water management information among other sources. The platforms are the central storage of water resource-related information, quality, and utilization, which allows making more effective decisions based on big data analytics and real-time data processing. Nonetheless, the problem of integrating the data through these platforms still exists, especially with regard to the process of integrating the information of various sources, including environmental monitoring stations, water utility systems, and remote sensing through satellites [27,28].

Besides these technical hurdles, institutional and regulatory obstacles to effective data sharing are also huge. Indicatively, issues of data privacy, such as when it comes to using smart meters and data about water consumption, may make some stakeholders not divulge information. Additionally, the absence of a proper structure of governance of data ownership and access may obstruct collaboration between various governmental agencies and commercial parties. Consequently, the development of standardized data types, the protection of sensitive data, and the development of explicit data exchange policies will be crucial to the effective implementation of smart water systems in the whole of China [6,29].

2.4. Funding and Procurement Models

The development of smart water systems in China is affected by the central and local level priorities, and the way in which the water infrastructure development includes the participation of the private sector in the way of its funding and procurement [30]. On the national level, the government programs and funding projects, like the 13th Five-Year Plan on Ecological and Environmental Protection, have contributed substantial resources to the implementation of smart water technologies. Smart water systems are also an area of focus among the local governments in the economically developed regions in the quest to modernize their cities and conserve the environment. Such funding programs are usually directed at the financial support of infrastructure development, implementation of new technologies, and creation of monitoring and data control systems.

The technology providers, as well as water service operators, are other companies that have become more engaged in the acquisition of smart water solutions within the context of private corporations. In most situations, the so-called public-private partnerships (PPPs) have been developed to assist in the distribution of the financial load in introducing smart water systems. Through these alliances, the private sector is able to bring in experience in technology and innovation, whereas the government sector is able to supply the regulations and funds to execute the operation. Nevertheless, the use of commercial organizations to purchase the smart water technologies may bring up the issues of vendor lock-in and the absence of competition. In addition, the smart water systems can be expensive to maintain and operate on a long-term basis, which could be a monetary burden on the already less economically developed areas [31,32].

The technical and regulatory demands imposed by the local governments also affect the procurement of the smart water systems [33]. Such requirements normally determine the kind of technologies to be employed, the procedures of procurement, and the timelines of the project. It will be essential to make sure that the process of procurement is transparent and competitive and, at the same time, facilitate innovation to enhance the further success of smart water projects in China.

In short, the system of water management in China is determined by the governance and institutional environment based on the mixture of a nation policy, regional interests, and the participation of various stakeholders at the different government levels [34,35]. Although adoption of smart water technologies has achieved tremendous improvement, issues of data governance, interoperability and funding are still present. The adoption of the concept of smart water systems into the current water management facilities in China will involve a further cooperation between the government agencies, the business, and society. In addition, it will be essential to overcome the obstacles to the data sharing, standardization, and long-term funding to scale such systems and ensure water security in the country. With the ever-increasing application of digital technologies in water management, lessons gained out of the experiences will be crucial in not only to other countries with similar predicaments but also to the global community which is striving to ensure sustainable water management activities.

3. Monitoring Systems for Smart Water Management

3.1. Sensor Technologies and Data Collection

The key to any smart water system is its effective monitoring since it gives the background information needed to make decisions, predictive models, and optimize the system. Sensors are also widely used in China, where sensor technologies are currently being utilized to detect water quantity, water quality, and the health of the infrastructure in various water management sectors, such as river basins, urban utilities, and agricultural lands. **Table 1** reveals a summary of the key water management industries in China and the smart water technologies that have been adopted in these industries. Such technologies include remote sensing of river basins and smart meters of urban utilities, and are critical in the solution to the issues of water monitoring and management in the country. Such sensor networks collect important real-time measurements of several parameters, including water flow, pressure, temperature, turbidity, pH, dissolved oxygen, and contaminant concentrations [36,37]. As illustrated in **Figure 2**, various smart water technologies are applied across different water sectors in China. These technologies, such as IoT sensors in urban utilities and remote sensing in river basin management, are tailored to address sector-specific water management challenges, enhancing both operational efficiency and environmental sustainability.

Table 1. Essential water management sectors and smart water technologies in China.

Water Management Sector	Technologies	Primary Applications
River Basins	Remote Sensing, Sensors (water quality/quantity)	Monitoring flood risks, water quality, and reservoir levels
Urban Utilities	Smart Meters, Pressure/Flow Sensors	Leak detection, real-time monitoring, demand forecasting
Agriculture	Soil Moisture Sensors, IoT-based Irrigation Systems	Precision irrigation, water-saving measures
Groundwater	Groundwater Sensors, Remote Sensing	Monitoring groundwater levels and quality

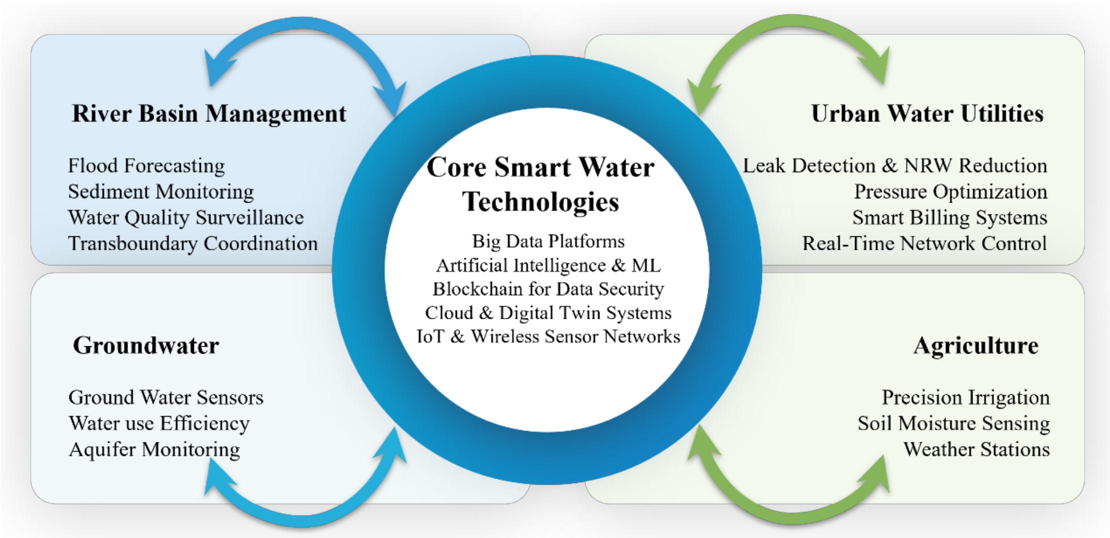

Figure 2. Smart water technologies and their applications in different water sectors.

Modern sensors are used to supplement traditional hydrometric stations in river basin management to better measure the water quality and flow patterns [38]. This is because autonomous sensors can be used on remote or inaccessible sites, and this will provide real-time data that will be essential in forecasting floods, monitoring water quality, and the health of ecosystems. As an example, measuring sensors of water temperature, oxygen levels, and other nutrients, such as nitrates and phosphates, are used to monitor the pollution level and determine the ecological condition. Besides the sensors that are located on-site, remote sensing systems, such as satellites and unmanned aerial vehicles (UAVs), have been incorporated in an increasing number into monitoring systems. These technologies are especially efficient when used in large-scale applications, e.g., when it comes to keeping track of the surface water bodies, the amount of water in the reservoirs, and the amount of precipitation over a vast geographical area.

Another example of Smart meters, pressure sensors, and leakage detection systems is also used by urban water utilities in China [39]. The smart water meters fitted in residential and industrial locations present useful information on water consumption habits, leaks, and efficiency of the systems. These systems allow utility operators to identify inefficiency in the water distribution systems, detect anomalies, and monitor consumption in real time. The sensors in the distribution network are used to streamline the operations and maintenance cycles and minimize water wastage as a result of burst pipes or leaks. Moreover, more sophisticated sensors are being implemented to check the quality of water in drinking water distribution networks and to make sure that the accepted norms and the health of people are not violated [40].

3.2. Remote Sensing Technologies and Their Applications

Remote sensing has proved to be one of the most effective weapons in the monitoring of water resources in China [23]. Due to the fast evolution of satellite and UAV-based technologies, remote sensing has become a part of the national and regional water monitoring. These technologies permit the acquisition of large-scale and high-resolution data on several parameters in water without physical access to water bodies. The sensors on satellites, including the Gaofen series made by China, can detect precipitation, soil moisture, evapotranspiration as well as water quality indicators like chlorophyll-a concentration and turbidity.

Remote sensing using satellites is notably applicable in the surveillance of surface water resources in China in the expansive and usually remote areas. As an illustration, the water level of the Yangtze River and its tributaries have been monitored through remote sensing information of the Gaofen satellites to give an early warning of possible floods. Besides that, remotely sensed data have been utilized to monitor the level of droughts, evaluate the availability of water, and enhance the control of agricultural irrigation. UAVs can also be significant in providing high-resolution information in small-scale usage, including reservoirs, lakes, and wetlands monitoring [41–44].

The ecological restoration activities in China are also assisted by remote sensing technologies, especially in solving water quality issues, which are brought about by eutrophication, agricultural runoffs, and industrial releases [45]. The possibility of monitoring water quality in large areas in real time makes the idea of pollution sources more credible, which will help the authorities to achieve the targeted mitigation measures. By combining the data of remote sensing and in-situ measurements, and models, a deeper understanding of the trends of water quality and evidence-based decision-making is achieved.

3.3. Crowdsourced and Participatory Monitoring

Besides the traditional and remote degree of monitoring, crowdsourced and participatory monitoring has become an increasingly useful instrument and can be used to improve the water resources management in China [46]. Especially the urban areas and major rivers have been particularly successful in citizen science programs where the general population participates in data gathering. Through the use of mobile applications, sensors, and social media, communities can report water quality challenges, including pollution events, algal events, and illegal discharges in real time. The official monitoring systems are usually combined with these reports, forming a more all-around and responsive monitoring network.

A famous case of crowdsourced monitoring in China is the implementation of mobile applications to monitor the quality of water in rural regions and peri-urban locations [47]. In other place citizens also utilize smartphones with built-in water testing kits to test such parameters as pH level, turbidity, and temperature, and report them to local governments or water management agencies. These donations may assist in filling the gaps in the data in those regions where there is a lack of official monitoring infrastructures or their absence. The information that is produced with the help of these efforts can be applied to their complementary to the traditional monitoring data, so that the water quality assessment could be carried out more locally and responsively.

As much as the prospect of crowdsourced monitoring is enormous, there are issues that relate to the accuracy and quality of the data [48]. Crowdsourcing can be damaged by inconsistent reporting standards, calibration, and insufficient public awareness regarding the problem of water quality. As a solution to these challenges, there are some efforts to create systems that will validate and verify the crowdsourced data with official monitoring systems and expert analysis in order to solve the challenges in China.

3.4. Data Quality and Calibration

The quality of data is one of the basic elements of any monitoring system, and the quality and accuracy of the data gathered by the sensors are vital in the smooth functioning of smart water systems [49]. In China, just like in other nations, sensor drift, calibration errors, and non-measured data are a problem in ensuring high-quality monitoring networks. Calibration of sensors is necessary to ensure that the data obtained is accurate and useful in decision-making, and the maintenance of the sensors is done regularly. In order to make monitoring data reliable, **Table 2** provides the general data quality assurance and control (QA/QC) processes used in the Smart water systems in China. These processes play a significant role in ensuring that sensor networks are accurate and that real-time information can be used in the decision-making process effectively.

To solve these problems, the Chinese water management agencies have established effective data quality assurance and control (QA/QC) processes [50]. These involve the regular calibration of sensors, especially in areas of critical monitoring like drinking water plants, reservoirs, and also industrial discharge points. Also, calibration data may be compared with ground-truth tests that are provided by independent sources or tests in labs to confirm the precision of sensors.

Table 2. Data Quality Assurance and Control (QA/QC) Procedures for Smart Water Systems.

Data Quality Issue	Method of Resolution	Implementation Area
Sensor Drift	Regular calibration, cross-validation with external data	Remote sensors, urban water quality sensors
Missing Data	Backup local storage, interpolation using machine learning	Remote sensing, groundwater monitoring
Outliers/Errors	Real-time data validation algorithms, manual checks	All sensor-based networks, especially flood forecasting
Data Gaps	Use of crowdsourced data, integration with official data	Rural and remote water quality monitoring

The completeness of data is another important aspect of data quality that is critical [49]. In most parts of China, remote or rural areas can have connectivity problems; therefore, transmitting data in real time can be problematic. To reduce the effects of the data gaps, there are smart water systems that have backup storage systems enabling data to be recorded and preserved locally until the restoration of connection, which will transmit the data to the central databases. Also, machine learning algorithms are being increasingly employed to detect and fix outliers or gaps live to enhance the strength of monitoring systems in general.

3.5. The Role of Data Fusion and Integration

The process of data fusion or the use of multiple sources to build up on data is an emerging important aspect of smart water systems in China [6,51]. By combining in-situ data, remote sensing data, and crowdsourced data, it is possible to have a more comprehensive view of water resources and environmental conditions. Integrating all these different data streams will enable water managers to have a clearer image of the present situation, anticipate the trends that will likely happen in the future and make better decisions.

An example is the case where data fusion may be applied to integrate estimates of precipitation and soil moisture that are provided by satellites with hydrometric measurements of a specific region, to give a more precise evaluation of the water availability that is available in a particular area. On the same note, where other remote senses are combined with in-situ real-time water quality sensors, the pollution can be tracked and managed even more effectively. In other applications, the data fusion process may be automated with the help of machine learning models, providing the opportunity to analyze and make decisions in real time [52,53].

Big data analytics, cloud computing, and machine learning contribute to the creation of data fusion capabilities [54,55]. These technologies might allow processing and analyzing large volumes of data based on various sources in close real-time, which would ultimately provide water managers with information that is easy to act upon to enhance decision-making and reaction times. Nevertheless, the difficulties are in the areas of guaranteeing data interoperability, responding to the difference in data quality in the diverse sources, and creating standardized protocols to integrate data.

The factor of monitoring is of paramount importance to the smart water systems in China, and the nation has gone a long way in embracing new technologies to enhance water resource management. The use of sensor networks, remote sensing, and crowdsourced monitoring have all helped to achieve better monitoring of water quantity, water quality, and health of water infrastructure. With the current developments, there are still difficulties associated with the quality of the data, calibration of the sensors, and the combination of data provided by various sources. To continue, the successful introduction of the smart water systems at the national and regional levels will require improvement of the reliability and scalability of the monitoring systems. Through these issues and by encouraging the government agencies, technology providers, and the local communities to work together, China can proceed to develop a more resilient and sustainable system in its water management [6,56].

4. Modeling Approaches for Smart Water Systems

4.1. Hydrological and Hydraulic Modeling

The decision-making process in smart water systems should be modeled, as it offers a scientific estimation of the anticipated water availability, water quality, and flood risks, among other water resource variables [57]. Hydrological and hydraulic models are widely applied in China to simulate and predict the water conditions of diverse areas of the country, both small stream catchments and large river basins. These models are normally based on a combination of meteorological, hydrological, and infrastructure data to model the flow and distribution of water in the environment.

The movement of water in the river basins is estimated using hydrological models in China, which incorporate the factors of precipitation, runoff, soil infiltration, and evapotranspiration. The models are especially applicable in flood forecasting and management as they can estimate the amount of water that would run into rivers and reservoirs with the occurrence of heavy rainfalls. Depending on hydrological models, hydraulic models are usually used to model the movement of water within channels, reservoirs, and drainage systems of cities. These models assist water managers to estimate the impacts of different hydraulic interventions, including dam releases, levee constructions, or floodplain management, and how the water will respond to the diversity of functioning conditions [58,59].

Along with these classical models, China is also starting to implement more modernized methods in modeling, which also involve the usage of real-time data from monitoring systems, which include sensors and satellite images. These models that are based on data are being utilized to enhance the level of accuracy in the predictions, particularly where it comes to extreme weather conditions such as floods and drought. It can be used to create more accurate predictions that could be used to make proactive water management plans by incorporating observed data in model simulations [23,60]. **Figure 3** illustrates the integration of various models within a smart water system, demonstrating how data from monitoring technologies is processed through hydrological, water quality, and machine learning models before feeding into decision support systems for actionable insights.

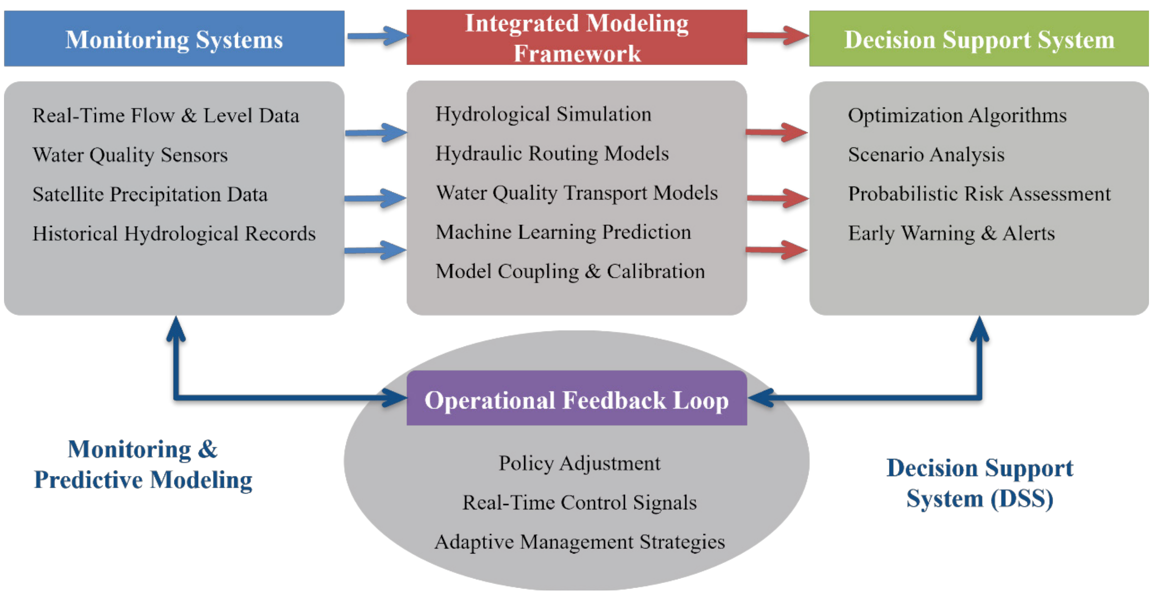

Figure 3. Model integration and data flow in smart water systems.

4.2. Machine Learning and Artificial Intelligence in Water Modeling

Machine learning (ML) and artificial intelligence (AI) have started to become more and more significant in water resource modeling in China in recent years [61]. These technologies hold the possibility of improving the predictive accuracy, increasing the efficiency of models, and automating the process of model calibration and optimization. The classical hydrological and hydraulic models are often founded upon some set of pre-determined physical equations, which involve specific knowledge of catchment features and hydrodynamics. Although these models have been useful in most of the applications, they have many challenges with non-linearity, high variability, and complex systems that cannot be easily modeled using conventional models.

Artificial neural networks (ANNs), support vector machines (SVMs), and decision trees are some machine learning methods that have been used to estimate different parameters of water, including streamflow, water quality, and flood risks. These are data-driven models that are based on historical data and statistical learning in order to establish patterns and relations within the water systems. Specifically, ML models can be useful in detecting complicated nonlinear relationships within water systems that can be hard to model through conventional techniques [62,63]. **Table 3** offers a summary of machine learning methods used in the Chinese smart water systems. The techniques have been adopted to enhance predictive powers, such as forecasting the river discharge to identifying abnormalities in the water distribution system, so that better management can be exercised in the water resources.

Table 3. Machine Learning Techniques Applied to Smart Water Systems in China.

Application	Machine Learning Technique	Purpose/Use Case
Flood Prediction	Support Vector Machines (SVM), Neural Networks	Predicting river discharge, flood risk in urban areas
Water Quality Forecasting	Random Forest, K-Nearest Neighbors (KNN)	Forecasting pollutant levels (nitrates, phosphates)
Leakage Detection	Anomaly Detection (Autoencoders, Isolation Forest)	Identifying leaks and inefficiencies in distribution systems
Demand Forecasting	Time-Series Forecasting (LSTM)	Predicting water demand for urban and industrial users

As an example, in China, ML-based models have been applied to forecast the river discharge and water quality at different monitoring points, particularly in river systems that are highly controlled. These models apply time-series sensor-based data to real-time forecasts on water flow and water quality that can be incorporated into decision support systems to manage the dynamic water resources. The applications of machine learning are also being used to enhance the model of flood forecasting, in which the traditional hydrological model may fail due to the issue of high-frequency data or data gaps. The ability to predict floods on a bigger scale and considering a wider set of variables, such as land-use changes, urbanization, and extreme weather events, is possible with the help of ML algorithms, which are trained on a larger scale of historical and real-time data [64,65].

Besides predictive applications, AI is also being employed in the optimization of the calibration of already existing hydrological models [66]. The conventional methods of calibration usually need the skills of professionals or considerable computation time. Through machine learning algorithms that can be used to automate the process of calibration, one can decrease the time and effort needed to adapt models to particular catchment features and environmental conditions.

4.3. Digital Twins and Data Assimilation

The use of digital twins, which are virtual models of physical systems, has become one of the technologies that are important in water resource management in China [67]. A digital twin is a dynamic and real-time model that is constantly updated with measurements from sensors, satellites, and other surveillance devices. Digital twins enable water managers to predict, optimize, and simulate the behavior of the water systems in real-time by integrating the real-time data into the model.

Digital twins are under development in a variety of applications, such as flood prediction, reservoir control, and urban drainage [68]. An example can be described as simulating the flow and storage of water in a river basin on the digital twin to optimize dam releases and use flood control methods in weather of varying conditions. On the same note, water distribution networks are also being digitalized in cities to emulate the actions of pipes, pumps, and valves, enabling utilities to keep track of how their systems are performing, how they will fail, and when and how to schedule maintenance.

The capability to combine data assimilation methods is one of the strongest capabilities of digital twins. Assimilation of data is the method of combining real-time measurements and model forecasts to enhance more accurate forecasts. Data assimilation can be used in water systems where the models can be continuously updated when new data is made available, so that the simulation can be based on the most up-to-date conditions. This is especially significant in dynamic environments, e.g., during the event of flood or drought, when conditions can change very quickly, and the latest information is paramount to the decision-making process [69].

Application of digital twins in water management practices in China remains at the initial phase, as most applications are restricted to pilot projects or specific urban regions. Nonetheless, with the further development of data integration technologies, computing force, and modeling techniques, digital twins will become a component of the national water management system [70].

4.4. Uncertainty and Model Validation

The existence of uncertainty is inherent in water resource modeling, particularly when it comes to large and complicated systems of factors affected by a variety of dynamics. In China, the challenge of correct and credible models of water resources is increased by a large and heterogeneous nation, and the increased frequency of extreme weather events promoted by a changing climate. Managing uncertainty and validation of the models are, therefore, major parts of the water modeling process [71].

Within the context of hydrological and hydraulic modeling, uncertainty could be caused by different factors such as data quality, assumptions of the model, and variability in the input [72]. An example of this is when there is uncertainty in the measurements of rainfalls, soil properties, or changes in land use, this may have an effect on the model. The modelers in China are now resorting to the ensemble forecasting method in order to solve these problems, in which several model runs are conducted with different inputs in order to come up with a pathway of the possible results. This way of modeling allows more thorough consideration of the variability of the behavior of water systems and prepares the decision-makers in advance for a variety of possible events.

Model validation is also a very essential procedure in making sure that the model is accurate and reliable [73]. Model validation is common in China, whereby model predictions are compared to real data in monitoring stations or historical records. In others, the models can be tested with real-time data of sensors placed in the field. Through frequent model validation, water managers will be able to detect differences in model predictions and observations and make changes to their models. This looping allows the enhancement of predictive abilities of the models and is the reason why they can be trusted to make important water management choices.

In China, modeling is very important in the water resource management, as it assists in the decision-making regarding water distribution, flood management, water quality, and infrastructural preservation [74]. Although the traditional hydrological and hydraulic models are still popular, the intelligent use of machine learning, artificial intelligence, and digital twins is reshaping the modeling environment. Highly developed modeling processes are used to make predictions more accurate, support real-time decisions and the control of complex water systems. Nevertheless, there is still a problem with the quality of data, calibration of the model, quantification of uncertainty and incorporation of real-time data. The next step to more efficient, resilient, and sustainable water resource management will be model development, as China grows to create larger and more sophisticated smart water systems.

5. Decision Support and Management of Water Resources

5.1. Optimizing Water Resource Allocation

One of the most important features of water management in China is the water resource allocation, which is particularly important considering that there are geographical differences in the availability of water in the country. The dilemma is not only how to have enough water to meet the demands of the different sectors, including agriculture, industry, and use by the municipalities, but also to balance between the demands of conservation and protection of the environment. The capacity to optimize the allocation of water, based on the advanced decision support systems (DSS), the integration of real-time data, predictive models, and optimization methods, has been boosted with the adoption of smart water systems [75].

DSS is becoming popular at the regional and basin levels in China to optimize the distribution and allocation of water. These systems are based on hydrological models that mimic the movement of water across the catchments, which assists in determining the most efficient utilization of water resources. As an illustration, in times of drought or the lack of water, DSS might help to optimize the usage of the water for both short-term requirements and sustainable usage of water resources. Mathematical programming methods, including linear programming or mixed-integer programming, may be used to find the optimal allocation strategy using different constraints and goals in such optimization systems [76].

On the river basin level, DSS are used to balance the competing water requirements between the upstream and downstream users, which may include agriculture, urban population, and industries [77]. In other areas such as the Yellow River basin, DSS have also been applied to distribute water more fairly and efficiently in consideration of the economic, environmental, and social effects of water usage. These systems are also becoming more intertwined with real-time information from monitoring networks and remote sensing using satellites, and allowing more dynamic and adaptable water management approaches that can address the evolving environmental conditions.

5.2. Real-Time Monitoring and Control Systems

Besides allocation of resources, other important roles of real-time monitoring and control systems are the effective management of water infrastructure, including reservoirs, treatment plants, distribution networks, and wastewater systems [78]. The systems combine sensors, automation, and decision-making algorithms to optimize the functioning of water systems in real time, which would make water distribution efficient and reliable, and ensure that water quality is in compliance with regulatory requirements.

In city water supply systems, such as in the urban water supply network, real-time monitoring of water flow, pressures, and quality is followed in the distribution network [79]. The leakage and energy consumption are minimized with the usage of advanced pressure management systems, which adjust the pressure in the pipes depending on the demand patterns. With constant monitoring of flow rates and pressures, the utilities are able to immediately identify the aberrations, including bursting and leakages in pipes, and send repair personnel to fix the damage before much of the water is wasted. Real-time monitoring in regions where non-revenue water (NRW) is common is used to detect and control water losses to make the water distribution system more efficient and sustainable.

Likewise, at the wastewater treatment stage, real-time monitoring and control systems are employed in order to streamline the activities of the treatment facility and sewer network [80]. These systems are used to check the critical parameters of chemical dosage, biological treatment procedures, and the work of pumps and valves. Control algorithms that are executed automatically modify the process of treatment, depending on real-time data, to make sure that wastewater is treated to the necessary level and less energy is used. Smart systems are also implemented in the management and control of stormwater drainage in selected cities in China so that the effects of urban floods in cases of heavy rainfall can be simplified.

Real-time monitoring and control systems are also integrated with predictive models, which improves their performance [78]. The predictive models can, as an example, predict the future behavior of water demand, quality, or supply so that water managers can take prior actions to optimize the work of the system before problems develop. Such systems may also be implemented together with digital twins that can offer a virtual reflection of the physical water network and can be simulated and optimized in real-time.

5.3. Early Warning Systems and Emergency Management

Among the most important uses of smart water systems in China lie the creation of flood, drought, and water quality incidents early warning systems [81]. Early warning systems use real-time monitoring data, weather predictions, and forecast models to provide warnings to curb the effects of extreme events on communities, infrastructure, and the environment.

In flood management, an example is the use of early warning systems to predict the occurrence of floods in addition to giving early warnings to the authorities and the local population through the use of river gauges, rainfall sensors, and meteorological forecasts [82]. These systems combine hydrological and hydraulic models to model the flood situation under varied rainfall conditions, assisting in determining the possible level of flooding and areas at risk. Such systems have been designed in major rivers in China, such as the Yangtze and Yellow rivers, where floods occur regularly. These systems can offer real-time updates on water levels, precipitation, and potential flood hazards to allow more people to evacuate in time, allocate resources more efficiently to respond to floods, and carry out the flood control process more efficiently. As shown in **Figure 4**, the decision support system architecture integrates real-time monitoring data, predictive models, and optimization algorithms to guide water management decisions. This architecture is crucial for improving water resource allocation, flood control, and infrastructure management.

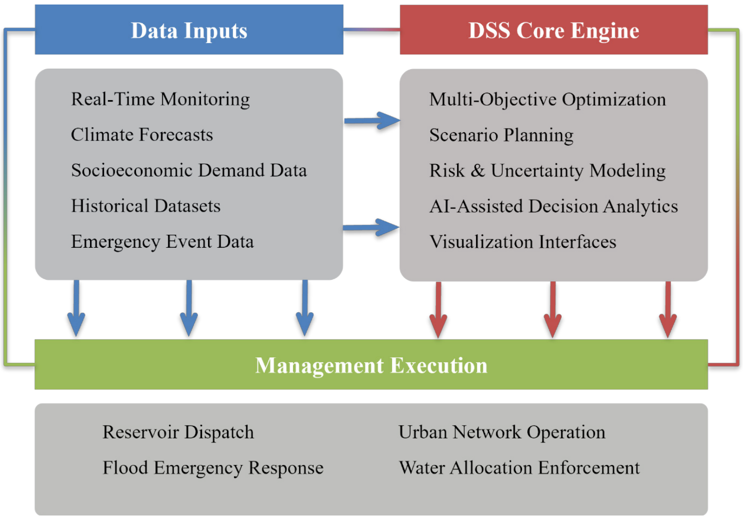

Figure 4. Decision support system architecture for water resource management.

In China, to manage the drought, similar technologies are used in the early warning system that monitors the water scarcity and predicts it [83]. Such systems combine the data on soil moisture, forecasts of precipitations, and the storage level of reservoirs to forecast their possible drought. These systems can allow water managers to be proactive through the provision of early warnings, including the redirection of water, water-saving strategies and water upgrading in the reservoirs. Besides aiding in management of water supply, the drought early warning systems have also important role in safeguarding agricultural production, since they enable the introduction of irrigation timetable, and other methods of safeguarding water.

Another significant feature of early warning systems is water quality control [84]. Water quality may quickly decline in areas that experience a large amount of industrial or agricultural runoff, particularly when there is heavy precipitation or other extreme weather conditions. The primary water quality parameters that the early warning systems keep track of include turbidity, pH, dissolved oxygen, and concentrations of such contaminants as nitrates and heavy metals. These systems can also help to identify possible pollution incidents and give early alerts to the authorities and the local communities by identifying the real-time sensor data and using it to compare with the water quality models. These systems are also being actively implemented to observe pollution rates in rivers, lakes, and reservoirs in China, which allows responding fast to resolve the issue of pollution on the health of the population and ecosystems.

5.4. Decision Support for Flood Risk and Water Infrastructure

The water resource management in China, especially in flood-prone regions like the basin of the Yangtze River, is considered to have flood risk management and water infrastructure planning as key elements of water resource management. Flood risk and infrastructure management decision support systems are based on the intensive use of models, real-time data, and optimization methods to enhance flood preparedness and infrastructure resilience [85].

Flood risk management DSS involves the use of predictive models to model flood scenarios and determine which regions are under high risk. Such systems consider topography, intensity of rainfall, flow of rivers, and land use, among others, to create detailed flood risk maps [86]. Those systems assist in prioritizing the flood prevention efforts, like building a levee, a dam, and a drainage system, by supplying the decision-makers with the latest data on the risks of floods. Flood risk models could also be incorporated with an early warning system to make available the information of the likely flood events in time so that the authorities could decide to take preventive measures, such as closing flood gates, reinforcing embankments, and evacuating the people residing in the at-risk areas.

The DSS in water infrastructure is vital in the management of the operation and maintenance of important infrastructure like dams, pipelines, and treatment plants [87]. These systems assist in keeping track of the state of infrastructure, foresee possible failure, and maximize the maintenance cycle to prolong the existence of assets and significantly decrease the possibilities of system breakdowns. Predictive maintenance models utilize sensor-readings on infrastructure to track conditions of wear and tear, corrosion, and pressure changes, and give early notifications of possible failure and more focused maintenance.

The adoption of decision support systems into smart water management systems is changing the allocation, monitoring, and management of water resources in China [88]. When DSS are used in conjunction with real-time monitoring, complex modeling and optimization algorithms, water managers can make more informed decisions that are more adaptive to improve the efficiency of a system, cost reduction, and better resilience of the water infrastructure. The presence of early warning mechanisms, real-time control, and flood risk management tools can play a significant role in assisting China in dealing with the issues of extreme weather conditions, urbanization, and water shortage. Nonetheless, there are still problems with the expansion of such systems across geographical areas, the integration of data over the platforms, and issues regarding the predictive model reliability. Ongoing improvement on technology and integration of data will play a crucial role in achieving the maximum potential of the decision support system in water management practice in China.

6. Challenges and Barriers to Scaling Smart Water Systems

6.1. Technological and Data Interoperability Issues

Technological interoperability is one of the main problems of the widespread use of smart water systems in China [89]. The water management infrastructure in China has been historically disjointed, with various regions and sectors having several different technologies and systems, which in many cases are not compatible with each other. Consequently, it has been hard to integrate information collected using various sources, such as sensor networks, remote sensing technologies, and historical data, in order to come up with a unified and working system.

Data integration is hindered by the inability to have standardized data formats and communication protocols across various platforms [90]. The proprietary systems that are used by water management agencies and other players are normally not easily interfaced with other systems. As an instance, sensor networks installed in urban water utilities might be based on disparate communication protocols from those implemented in remote monitoring systems of river basins, and it might be difficult to integrate data into one and the same platform. Likewise, water treatment plants, wastewater treatment plants, and flood control systems can all be based on various software platforms, with each having its own data format and structure.

As a way of addressing these hurdles, the Chinese government and the private sector are now striving to come up with standard data protocols as well as integration structures that can enable the interoperability of smart water technologies [6]. Nevertheless, it has been moving at a very slow pace, and the incorporation of data has been an important barrier. The inability to work intraoperatively restricts the effectiveness of the water management systems and also the creation of decision support tools, which demand the availability of data across different sources in real time.

6.2. Operational and Maintenance Challenges

In China, although there has been increased deployment of smart water systems, the operation and maintenance (O&M) of the smart water systems is a challenge. Smart water technologies need maintenance which includes the sensors, monitoring equipment, and data processing systems, which need regular maintenance to make sure they are accurate and reliable. The availability of skilled staff, technical skills, and access to spare parts is also an issue for the sustainability of the smart water systems in the long run in many areas, especially in rural and remote areas [8].

Indicatively, sensors can drift as time goes by in certain areas, hence giving false data. Monitoring sensors should be calibrated frequently in order to achieve the credibility of the information obtained in monitoring systems. Nevertheless, these sensors have to be calibrated and maintained by special knowledge, and these smaller municipalities or rural areas frequently lack such. Local governments and water utilities are also subject to a financial burden in the cost of maintaining the high-level sensor networks that might require the replacement of components or upgrading technology as time goes by [91].

The second important issue in operation is to make sure that data communication networks operate continuously. Most of the intelligent water systems are based on real-time data transfer; however, in certain areas, the lack of an effective internet or cell connection can interrupt the information flow. The issue is especially common in remote locations when the system of efficient communications is not well-developed. Delays in data transmission in such cases may result in an inability to make decisions in time and make water management systems more effective [92].

To help solve these operational and maintenance issues, the government of China is putting investment in training local water management personnel and also devising ways to make sensor networks reliable and cost-effective [10]. Nevertheless, these initiatives will have to be increased to make sure that smart water systems can be successful in the long term.

6.3. Cybersecurity and Data Privacy Concerns

With the adoption of digital technologies in smart water systems, which will be used more often as the main monitoring, control, and decision-making tools, cybersecurity and data privacy have become central issues [93]. The introduction of Internet of Things (IoT) devices, cloud computing, and big data analytics in water management systems introduces a new vulnerability that may be used in cyberattacks. Specifically, when water systems are automated via digital infrastructure, it becomes vulnerable to hacking or other malicious interferences, which would disrupt the supply of water, destroy infrastructure, or diminish the quality of water.

In China, national security is highly concerned with the protection of critical infrastructures such as water systems. Nonetheless, there are many challenges associated with ensuring the cybersecurity of the smart water systems. These networks have massive interconnections of devices and systems that raise the volume of attacks. Also, most of the systems employed in water management, particularly old systems, might not have been provided with stringent cybersecurity measures. This exposes them to cyber-attacks such as denial-of-service (DoS) attacks, data attacks, and system attacks [94].

The privacy of data regarding the use of smart meters and other types of monitoring technology that help to track how people use water also become an issue of concern when it becomes commonplace use. Urban smart meters are able to supply more specific data about the patterns of water consumption, and this may raise some concerns about the utilization of this data and its accessibility. The issues are the concerns that the information about personal consumption may be used commercially, or that the misuse of sensitive information may lead to the invasion of privacy [95].

China is enhancing its regulatory environment in connection with data protection and cybersecurity to resolve these cybersecurity and privacy issues [6]. The nation has unveiled various laws and policies that regulate cybersecurity in relation to critical infrastructure, and these are the Cybersecurity Law of the People's Republic of China and the Data Security Law that offer guidelines on data protection, network security, and countering cyberattacks. Nevertheless, due to the increasing number of interconnected devices in smart water systems, there will be a need to persist in creating and deploying effective cybersecurity protocols to ensure the integrity and security of water infrastructure.

6.4. Institutional and Social Barriers

Besides technological and operational conditions, institutional and social obstacles are also a strong factor in hindering the introduction of smart water systems in China. The fragmentation of the water management responsibility by various government agencies, sectors, and geographical areas is one of the problems of high priority. In China, water governance has been marked by a separation of roles between the national, provincial, and local governments, as well as a lack of coordination among the agencies involved in water governance, water quality, water supply, flood management, and protection of the environment. Such absence of coordination may cause inefficiencies and slow down implementation of smart water systems, since agencies may not be willing to share information, resources, or decision-making authority [96].

In addition to that, though in China, cities are becoming more and more smart in their use of water technologies, rural regions and those that are less developed have more barriers to such use [97]. The expense of installing and maintaining smart water systems is too prohibitive in terms of the financial resources of some small municipalities and rural communities with small budgets. Also, the introduction of innovative technologies implies the need to have a highly qualified staff, able to use and maintain them. In the rural regions where opportunities to access education and training facilities are not always available, the ability to operate and maintain smart water systems is frequently lacking.

The level of awareness and acceptance of smart water technologies by the population is also a significant factor that affects the usage of these technologies. In other places, the deployment of smart water systems may be met with resistance because of the privacy of data and surveillance, or even the loss of jobs as more jobs are automated. To overcome such social barriers, it will be necessary to interact with the local communities, be transparent with the usage of data, and educate people about the advantages of smart water technologies to the environment and the health of the population [98].

6.5. Financial Constraints

Costs of installation and operation of smart water systems are also an important hindrance to the proliferation of the systems in China [7]. Even though big cities and economically developed territories can afford to invest in smart water technologies, smaller cities and rural communities cannot simply afford such systems, not due to a lack of them, but because they do not have the funds to install and maintain them. The price of buying and installing sensors, creating the software platforms, and educating the staff members may be excessively high. **Table 4** is a summary of the major challenges to scaling smart water systems in China that include technological interoperability, operations, and financial barriers. It also gives suggested solutions that would facilitate the surmounting of these barriers, like the formulation of data standards and more collaboration between the government and the industry.

Table 4. Barriers to scaling smart water systems in China and proposed solutions.

Barrier	Description	Proposed Solution
Technological Interoperability	Difficulty in integrating systems and data across regions and agencies	Development of standardized data protocols and integration frameworks
Operational and Maintenance Costs	High costs associated with sensor calibration, maintenance, and system upgrades	Increased government subsidies and public-private partnerships (PPP)
Cybersecurity Risks	Vulnerability of smart water systems to cyberattacks and data breaches	Strengthened cybersecurity protocols, real-time monitoring, and encryption
Financial Constraints	Lack of funding for deployment and maintenance in underfunded regions	Introduction of low-interest loans, grants, and targeted investment in rural areas

Public-private partnerships (PPP) have, in most situations, been applied in sharing the financial load on the smart water projects, as the technology and skills required to install such systems are supplied by private businesses [32]. The use of the involvement of the private sector, however, brings the issue of the lock-in of the vendors, as municipalities could become reliant on one vendor as both a technology provider and a maintenance service provider. This can bottle out competition and increase costs in the long run.

To deal with these financial limitations, China has been considering different funding options, such as government subsidies, grants, and low-interest loans to assist the application of smart water systems in regions that are underfunded [99]. Also, water utilities are seeking to cut down on operational expenses and enhance efficiency, which would pay off against the initial investment of smart water technologies.

There are many barriers to the scaling of smart water systems in China that include technological and data interoperability problems, operational, cybersecurity, and financial limitations. Although tremendous gains have been achieved in the field of adoption of smart water technologies, the barriers will have to be overcome to achieve the maximum potential of such systems. The attempts by the Chinese government to develop data integration standards, enhance cybersecurity, and use the public-private partnership to solve financial limitations are in the right direction. There, however, will be a need to continue investing in infrastructure, training, and policy development to make sure that the success and scalability of smart water systems in the country will be successful in the long-term [100].

7. Conclusions

The potential of smart water systems to revolutionize water resource management right in China will allow practicing water resource management more efficiently, sustainably, and resiliently to the growing water scarcity, pollution, and climate variability. The adoption of modern technologies like sensors, real-time monitoring, machine learning, digital twins, and decision support systems into the water management systems is already transforming the process of managing the water resources in China. These systems help improve water allocation, the effectiveness of infrastructure, and have better forecasts of floods, droughts, and water quality by offering great benefits to both urban and rural regions.

Nevertheless, even though the process of smart water system adoption has advanced dramatically, there are still several challenges involved. The scalability of these systems is still hindered by technological interoperability problems, ineffective data governance, cybersecurity threats, and limitations of operation. Moreover, the cost implication of implementing and supporting smart water technologies is another obstacle that is present among small cities and rural areas because they lack access to funding and expertise. Social acceptance of these technologies, especially the issues of data privacy and employment displacement are also a challenge to the universal adoption.

To address these issues, China needs to keep investing in the creation of standardized data protocols and enhance the governmental coordination between the state, provincial, and local governmental agencies. It will also be necessary to scale these systems effectively by improving the ability of the local water managers by training them, encouraging the use of public- private partnerships, and ensuring that the use of the data is transparent and accountable. Moreover, it will be essential to consider the issue of finances by developing new funding schemes and offering incentives to local governments to implement smart water infrastructure to eliminate the disparity in access to such technologies on the regional level.

The further prosperity of the smart water systems in China will not only help to achieve better water security in China, but it will also provide significant lessons to other countries, which also struggle with the problems of water management. With China making positive strides towards the realization of sustainable water management by using digital solutions, its case studies and advancements will be a template for other countries to work towards ameliorating the increasing water crisis. The future of smart water systems in China is bright, yet the successful realization of the full potential of the system will be realized through the continued partnership between the government, industries, and communities to not only overcome the challenges but also realize the benefits of this revolutionary technology.

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