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Strategic Digital Water Resources Management: Challenges and Opportunities in the Period of Industrial Transformation and Climate Change

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Abstract

The advancement of industries and the impacts of climate change are among the primary drivers of the critical challenges the world faces today. This paper reflects a profound connection to the lessons of ancient civilizations, emphasizing the importance of sustainable practices. It addresses both the necessity and the barriers to integrating digital technologies into industrial activities. While the task was highly systematic, it was carried out using reputable databases, and this article highlights some of those efforts. Using VOS Viewer software, a total of 700 articles were analyzed, with a specific focus on titles and studies published between 2023 and 2025. Nowadays, the use of Artificial Intelligence (AI) and the Internet of Things (IoT) adds significant value to optimizing water resource management. However, even the most advanced technologies and systems—designed to identify users' water consumption patterns and provide detailed analysis and data—come with their own set of challenges. Key issues such as inadequate technological infrastructure, resistance to change, and financial constraints are critical areas that need to be addressed to improve water management practices. Without a clear strategy and proper preparation—including a thorough understanding of contemporary needs and advanced conditions—efforts to design and outline effective solutions will fall short. Where there is sufficient internal capacity and a robust organizational structure, there is no reason why innovative, non-bureaucratic approaches, such as targeted recommendations, should not be considered to address water-related challenges and engineer sustainable solutions.

Keywords: Digital water industry, Emerging technologies, Industrialization, Internet of things technology, Water crisis.

1. Introduction

Water is the most important natural resource on earth especially for humans. Its importance has now led to it becoming a global issue. The world has started facing water crises while also having issues regarding proper management systems for such a crucial resource. In various parts of the world, a variety of factors such as population growth, industrialization and climate change have led to water shortages. Water is no longer considered a renewable source as nature is unable to replenish water on the same scale that it is being used currently (Ingrao et al. 2023).

Presently, almost a quarter of the world's population suffers from water scarcity and it is predicted that by 2025, 1.8 billion people will no longer have access to clean water (Abou-Shady et al., 2023). The water scarcity problem does not only threaten humanity but it also has profound effects on the social, economic and political development of the world (Shahsavari-Pour et al., 2023). On an international scale, it addresses a plethora of social and economic problems. Shifting the focus on the consequences of this crisis can help manage the consumption of water while providing a solution to the problem at hand. But, unfortunately, certain sections of the world, particularly those that are still developing, find it difficult to cope with their interests being neglected. No one wants to plan for the long term, so the lack of short-sightedness has only worsened the water shortages.

Ignoring the ramifications that high water consuming activities can have and anything industrial related can in the long run initiate an environmental crisis that everyone will have to deal with (Younus et al., 2023). Great planning needs to be put in place in order to cater to the global water crisis we are currently facing. Setting up a management system that is already present is one of the many steps that can be taken. Utilizing campaigns to educate the masses on the issue at hand and investing into technologies that can build up the infrastructure. Controlling the pollution and developing new technologies can help prevent the water resources from running out. New international treaties regarding the issue can encourage everyone to work as a team and allow the water crisis across borders to subside (Shemer et al., 2023).

As recognized, there lies a significant gap water management processes and digital innovations, which warrants urgent attention. Investment in digital technologies has been a crucial component of addressing the bottlenecks faced in the management and distribution of water resources. Under the social, environmental, and even administrative spheres, these technologies enable the processes of management and provision of water services to occur efficiently and sustainably respectively. There is now real-time monitoring, remote data collection and predictive analysis available with technologies such as the Internet of Things (IoT), sensors, advanced measurement, and digital twins (virtual replicas of physical assets), Advanced measurement and IoT. These advancements allow water companies to improve their service and infrastructure management (Pekmez, 2020).

Digital Water is a paradigm where cutting-edge digital technologies and data-driven tools are integrated by utilizing IoT, artificial intelligence, big data analytics to optimize the management, operation, and maintenance of water and infrastructure assets (Kamyab et al., 2023) on the other hand, Akvo embraces the concept of Digital Water as the integration of innovative technologies to optimize water usage. Digital Water is pivotal for monitoring water changes, consumption, water leaks, and enhancing the overall efficiency of distribution systems. Real-time analytics and the application of Geographic Information Systems (GIS) help transform water sector organizations by enhancing their ability to manage water resources. However, among the so frequent water sector transformations that are fueled by digital technologies, there are several centers which remain less developed, among them densely populated areas, or countries with ineffective structures. In the European Union, the trend of growing population and water demand in the last decades has been even more apparent and continues to put enormous pressures to devise creative means and more severe approaches to water management policies (Quaranta et al., 2023).

These challenges encompass water within dry regions, industrial and agricultural pollution, and the inadequacy of infrastructural measures, all of which deleteriously affect a population, biological systems, and economies at either the local or global scale (Nwokediegwu et al., 2024). From a strategic perspective, water resource management is inherently long term in nature and includes crafting policies that transcend current climate socio economic conditions and provide a solution for the future (Santos et al., 2023). It is estimated that proper management of water resources within industries will lower variable costs, enhance competitiveness and retain environmental integrity. Various industries, such as manufacturing, agriculture, and mining, are under intense pressure from governments and NGOs to reduce water consumption and prevent pollution. As a result, a large number of organizations are developing a water management strategy that would promote recycling and reuse of water on a broader spectrum (Romano et al., 2017). Content, in terms of strategic management of the digital water value should develop roadmaps and macro policies to improve efficiency, reduce waste, and manage water demand to ensure the sustainability of this valuable digital water resources.

To develop and maintain water, these processes include data analysis, precise evaluation of current and future challenges and the implementation of sustainable strategies. In addition, changes in the world economy associated with the introduction of various new technologies have led to the emergence of fresh ways of delivering sustainable development in the water sector. Innovative production technologies, growth of the share of value-added industries, ensuring a significant share of new technologies in no longer innovatively new, and stimulating the innovative activity of organizations are determined as the main factors that alter the intensity of water consumption (Valaskova et al., 2022). Although water management can result in better production processes and lower operating costs, plenty of challenges exist as well. As an example, the industries still require advanced technologies and tools for measuring and controlling the water consumption. Climate change and the ups and downs in prices of water are also considered for the development of a framework for water management and to constantly revise the same (Allan et al., 2013).

The purpose of this article is to observe and analyze the needs and challenges of the water resource management and the application of digital technologies in the industrial sphere, as well as to consider innovative approaches and a strategic solution in this area. This broad theater of action can become its strategic theater of operations for addressing global water crisis feeding new, cross-organizational collaborations, macro policies, and technological advancements as pathways to broaden the struggle to reach all those who need access to ocean saltwater.

2. Materials and Methods

In this article, to understand the digitalization of water in respect to industries, a systematic synthesis of available works has been done. The authors had delivered an extensive search over Scopus, Web of Science, Science Direct, Google Scholar and the like, as mentioned, carrying keywords 'digital water', 'water industry strategic management', 'water management in industries', and 'smart water technologies'. Twelve series of saved files containing 700 articles were extracted as input data for the VOS Viewer software from the Science Direct database. After applying selection and elimination criteria in the VOS Viewer software, a total of 93 keywords were selected for final analysis.

The selection criteria included articles related to digital water technologies in industrial applications, studies concerning strategic frameworks or management practices, review articles, case studies, and empirical research published in English from the years 2023 to 2025.

3. Results and Discussion

3.1. Water resources management and industries innovation through digitalization

The concept of integration is currently becoming more common for water service providers and customers across the world and it helps companies to digitalize. Organizational restructuring and the implementation of digital means of automation and innovation are required. This is to say that before engaging the process of digitalization, it is critical to first conduct an assessment to know what the problems and needs are. Also, on all levels, it is necessary to instill a digital culture, foster involvement of workers and encourage the adoption and appreciation of change.

Most digital programs require the collection and analysis of large data sets through robust digital hardware and software (Grover et al., 2022). There exists growing concern on whether digital non-digital industries should be digitalized so as to remain competitive and address consumer needs.

It includes the introduction of new technologies and new ways in which the business is done to provide better value to customers, improve their experience, and achieve more creativity. But there are always challenges: old systems, cultures, and even security issues. Organizations should be able to develop effective transformation strategies that are harmonious with business goals, emphasize on human resources development, and are structured in a way that promotes change. To put it another way, if properly controlled, digital conversion presents ample opportunities for growth and innovation in non-digital industries (Onesi-Ozigagun et al., 2024).

In order to enhance the effectiveness of these systems, new lines of research must concentrate on what works utilizing a pragmatic approach. Such systems management has been reviewed but that review revealed the need for approaches that are holistic. Although there are tools for the effective management of these systems, they are infrequently found in practice. For instance, smart water systems tools and distribution optimization tools remain under-utilized or poorly integrated with one other in the industry. However, the lack of compelling use cases for why the new products should be adopted causes problems with the adoption process, which is primarily elective. Grigg (2024) suggests that reforms in this field have the greatest chance of succeeding when they are tested in carefully crafted real-world experiments.

Management strategies for water in smart cities are evaluated using the MCDM method that applies a range of parameters including ‘community involvement’ and ‘technical effectiveness and risks control’ among others. The findings showed that greater-value strategies such as ‘technological development for smart irrigation systems and efficient water management techniques’ were prioritized. This research addresses the complexities of urban water resource management and provides a comprehensive approach for making sustainable decisions in water management (Bouramdane, 2023).

The research endeavors such as Zaman et al. (2024) have examined aspects such as energy efficient technologies used in the operations of the mining industry with a great consideration towards sustainability. One such advance was a system to sort ores that didn’t require much water, and new techniques to selectively leach were also introduced for the efficient processing of low-grade complex minerals. Such technologies along with the use of tunneling machinery and incorporating non-explosive techniques are great for increasing mineral recovery. It has also been determined that the characteristics of the ore, scalpel and socio-economic factors play a great role in developing new technologies that are resource efficient.

To be able to effectively and efficiently manage water resources, a new coordinated approach is required that is all-encompassing and addresses existing problems as well as the advantages presented by these new systems. The study evaluates smart water solutions in Africa and the US, where, among other things, development, implementation, effects, and actual problems are addressed. It also identifies relevant technologies that include the Internet of Things, artificial intelligence, and remote sensing, which are crucial to the development and implementation of these systems.

Such systems have a range of environmental, social, and economic benefits, above all water savings and better supply of potable water, which are discussed. Moreover, the systemic barriers such as technical, financial and regulatory aspects that have been faced during the development and implementation of these systems are discussed. There is a call for further research, saying that the global water crises require fuller exploitation of these systems. As Tsukerman notes, this should be done through integration of technology, policy, and sociocultural factors in smart water systems’ functionality (Olatunde et al., 2024).

The relationship between IoT and industry has been presented in figure 1. In the mentioned graphical representation, the greatest value is held by the “Internet of Things (IoT)” and ”Industry 4.0”, which includes numerous other components such as digital technologies (blockchain, big data, data analytics, machine learning, digital twins, and blockchain digitization), sustainability (SD, energy efficiency, carbon emissions, water scarcity, water footprint, climate change), emerging industries (emerging strategic industries, inclusive finance with digital means, remote sensing, digital water), infrastructures and systems (water management, water infrastructure, networks, security, sensors), business and management (asset management, optimization, SWOT).

According to 1, the Internet of Things (IoT), among other advanced technologies, has the potential to improve productivity and lower operational expenses in the sector by applying digital technologies, resource management, and security integration. Real-time data capture and analysis leading to quicker and better business decisions are facilitated by IoT.

All those processes, besides efficiency improvement, are expected to lower costs of operations and raise their profitability (Eigner and Stary 2023).

Resilience, in the context of a city, is the capacity of the urban setting to adapt to climate change and other adversities. Advanced technologies such as sensors and smart metering systems, which are incorporated into smart water networks, are indicated as tools for achieving better management of water resources and for improving urban resilience. Furthermore, the experts covered the water networks for urban climate resilience advocacy areas and reported this technology as a further research area. A study investigates the theoretical and practical aspects of the aforementioned networks in strengthening urban resilience in the context of achieving sustainable goals from the social, economic and governance perspectives. Also, they identify some of the unexplored areas within the scope of the available research and proffer ways into the future concerning comparative and multidisciplinary research approaches (Adelani et al., 2024).

The application of robotics, or dual modeling into systems such as plumbing, aided by the use of AI alongside assistance of remote sensors for more precise irrigation protocols, all contribute to advancements in technology. However, such advancements bring risks including cybersecurity problems, technological abuse, and overdependence on automation. Water as a resource is not an area of Sekully's interest and shouldn't be. Exploring Mars isn't either. In this practical section, applications of advanced technologies within various sectors (auto industry – self driving Tesla cars; aerospace industry – Boeing 737 MAX) are discussed with an emphasis on the necessity of avoiding use of failure strategies acting through a 'learn and implement' principle. For successful automation, the location of their installation and their scopes should consider the maximum number of potential operating staff to be involved in the system to increase efficiency. These are minimal manual options for the task, and it also requires people to be educated about the technology, Locate and manually stop the technology if it fails (Corman, 2023).

In the face of myriad challenges like legacy systems, security questions and even cultural hiccups, they aim to enhance innovation, digitize technologies and ensure effective business processes which altogether improve customer experience. All of this however requires strong management as well support to ensure successful transformation because to them, digitalization is the future that non tech thereby creating a booming opportunity for growth and innovation in industries that were perhaps never thought to be capable of. Correspondingly, one would need to create strategies that target long term goals such as identifying human resource skills while fostering a change orientated culture to ensure sustained success with regards to individual organizations, it is imperative for them to become competitive in the ever-changing market so that they can effectively address their client's needs, to achieve this, they go through a process of transformation that involves re-evaluating their processes.

VOSViewer illustrates the relationships between concepts in a particular field through a diagram, in this case, a vision. In this diagram, each concept is represented by a circle, and the size of the circle indicates the importance of the concept within the dataset. The lines between the circles further explain the relationships, with the thickness of the lines indicating the strength of the connection.

The figure 2a depicts keywords that have been collated in multiple review and research articles where 700 articles from 2023 to 2025 have been used and out of the 1586 keywords highlighted 93 were marked as important and frequently referenced in the articles. The suggested keywords encompass digital water and its resource management along with water crisis, strategic water and resource management, IoT technology, big data analysis, emerging technologies and industry, that were suggested based on the importance of the topics in the Direct Science database.

Sustainability and digitalization are intertwined as per Figure 2b with the help of concepts like 'sustainable development' and 'climate change' directly pointing to the aforementioned topics. Sustainability is at the core of the matter with regard to the research. The other two criteria with regard to the graph are climate change and the water crisis and are both interlinked. There are various tools that have been developed as a result of industrialization and resource management such as big data and artificial intelligence.

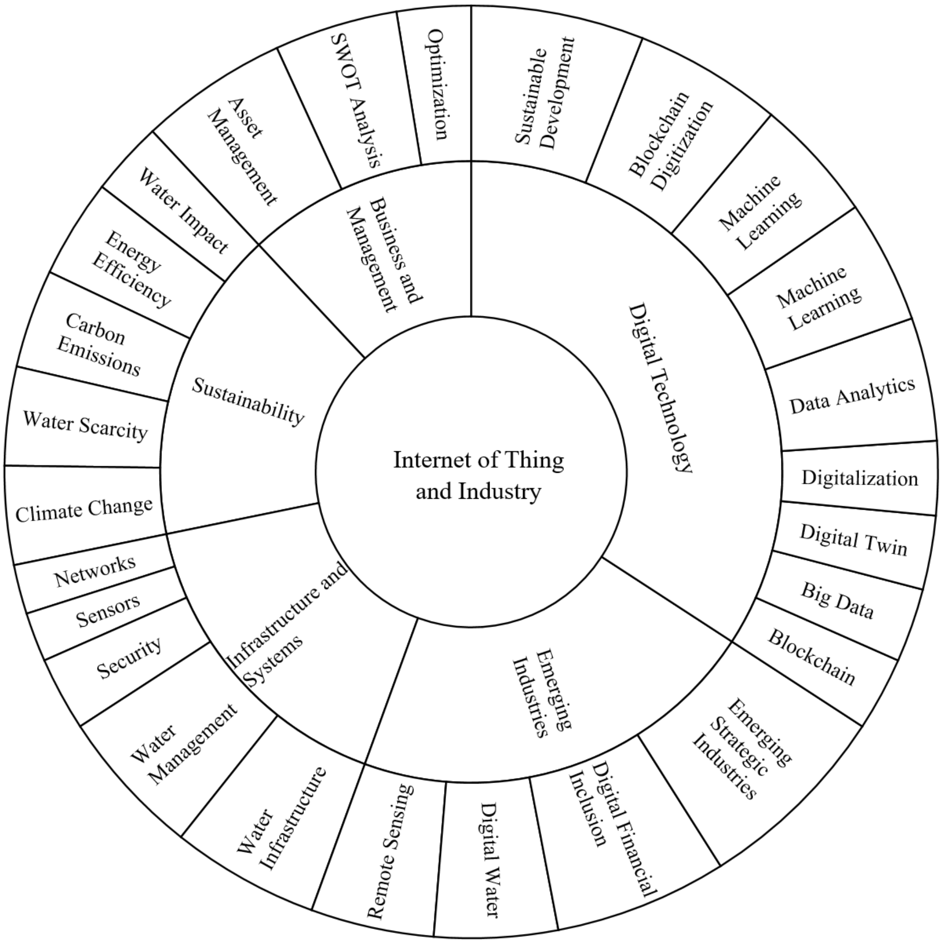

Fig. 1. The relationship between IoT and industrial transformation

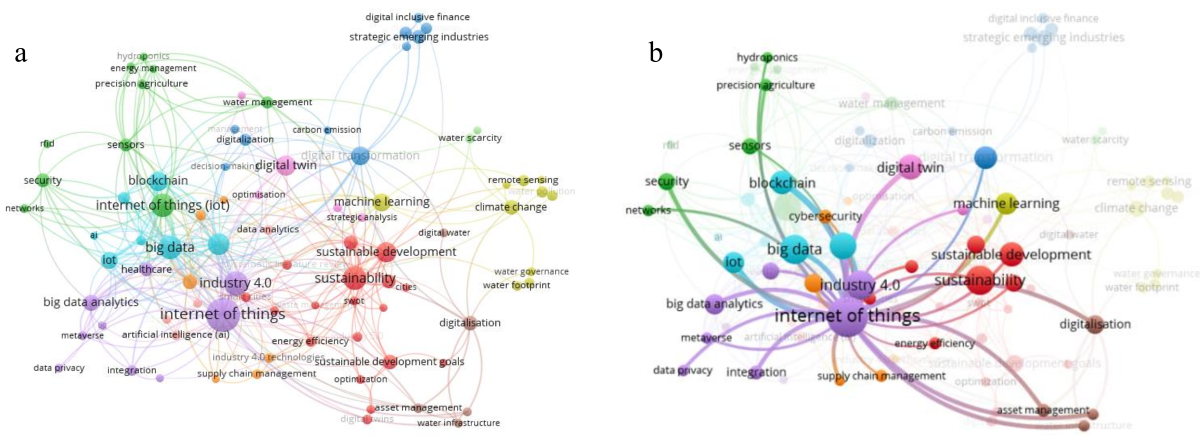

Fig. 2. Visualization of the relationship and overlap of the studied keywords

But water management still remains a sore spot given the depletion of water resources which has led to climate change. Achieving energy sustainability is pivotal for the future and can be only achieved if we use new innovative technologies. Thus, the chart displays that tools like AI and IoT could be used to target issues like the water crisis and global warming and thus to achieve global sustainability (Turek et al., 2023).

3.2. Digital water resources management strategies in industries

3.2.1. Development of new technologies

Digital transformation in water maintenance and distribution services focuses on leveraging data to improve efficiency. In this context, digital transformation encompasses fundamental and technological changes that are geared towards better consumer service due to optimization of water resource management. The implementation of digital models, including digital twins, utilized in the management of Water Distribution Networks (WDN) has improved the quality of decision-making and productivity (Ramos et al., 2023). This technology is proven to work as an innovative tool in the management of WDN. It has the capability of designing and management of infrastructure systems efficiently, as well as making technical management decisions based on hydraulic models and artificial intelligence. The research reported in this paper suggest that this technology can be cost effective, and can increase the efficacy of water systems management (Ciliberti et al., 2023).

Sensors that are embedded into the water supply networks make it possible to assess both the water quality and the quantity that is dispersed. These sensors can monitor temperature, pressure, and water quality and report the data to a control center as it becomes available (Yin et al., 2023). Unsurprisingly, Artificial Intelligence (AI) uses algorithms to analyze historical telemetry and accurately predict future water demand, which enables more efficient resource planning (Rane et al., 2023). Blockchain technologies are an example of such systems that enable secure, decentralized recording, storing and transferring of information.

By applying big data technique, which is a collection of massive data that cannot be touched manually, managers are able to understand more detailed information regarding the current situation of water resources and history and trends of climate changes. This information facilitates in deciding how to achieve more effective management in resource allocation Kamyab et al., 2023. Apart from perceptions and members' pooled knowledge, new technologies tend to greatly improve the complex function of forecasting models and aid in the distribution of water resources or the optimal allocation.

The use of these technologies, that include data analytics, artificial intelligence and machine learning algorithms, enable optimization and decision-making improvement in this area. These challenges however, provide room for optimization of water resources and enhancement of service quality through innovation and further research. Having large amounts of information means more processes such as water sensors, meteorological data and drinking history can be used which results in a more precise risk prediction. Such risks can be water leaks, water shortage and pollution of water resources (Gohil et al., 2021).

3.2.2. Water resources management with the help of smart systems

The smart management of water resources has proven to be necessary for sustainable development and environmental conservation. Their systems based on state-of-the-art tools such as big data analysis and Internet-connected sensors promote more efficient water use across sectors. An important aspect of water resource management is its optimization in consumption. Water consumption patterns are determined smartly by the systems based on collected and analyzed data, thus making it easier for the users to make use of effective recommendations. These systems can inform users automatically and provide information regarding the levels of consumption, leaks from pipes, and better performances of pumps. By facilitating this monitoring and control by managers which then enables the managers to respond swiftly to changes in the environment.

With the most cutting-edge technologies monitoring processes; the amounts of water and its quality can be assessed instantly (Singh & Ahmed, 2021). Such information embraces such parameters as pH, temperature and different pollution rates and gives managers the right tools to address the problems as they arise. In the management of water resources, devices that connect to the internet and transmit water resources over the web are emerging as a crucial resource. These sensors can collect reliable information about the conditions of water sources and send it to system software for analysis in real time (Owen, 2018). This information helps managers make timely decisions and prevent crises. The availability of comprehensive and up-to-date information facilitates quick responses to issues and challenges (Kamyab et al., 2023).

By analyzing data, corrective actions can be taken at the right time, thereby reducing costs and water resource waste. As a result, the use of smart systems assists water managers in effectively managing their resources and moving towards more sustainable development (Krishnan et al., 2022).

3.3. Challenges and obstacles to digital transformation in water resources

Smart water management systems do have their benefits but also face several challenges. The main issues confronted in implementing these systems include high start-up investments, the requirement for necessary technology infrastructure, and development of the requisite legal frameworks. However, at the same time, there are significant opportunities. For instance, Gupta and colleagues (2020) suggest that technological development and enhancement of awareness of environmental issues may promote development and adoption of such systems and infrastructure.

3.3.1. Technology infrastructure weakness

The easiest of the technological challenges to identify in regard to water resource sustainability for digital transformation is technology infrastructure weakness. This situation has a knock-on effect on the efficiency or effectiveness of these processes especially in developing nations where there are regions that are deprived of proper access to IT infrastructure with adequate services. The lack of smart technologies coupled with poor connections to wide-band internet networks in rural regions creates a barrier to effective management and regulation of water resources. This kind of lack of infrastructure inhibits not only the accurate and timely collection of data but also the use of this data for effective decision making.

Additionally, the absence of dependable technical infrastructure can result in users developing skepticism towards new systems, technologies, and tools. Such developments pose a major challenge without investments in developing infrastructure to support information and communication technology (ICT).

Such investments involve building high-speed internet networks, deploying modern technologies, and providing local employees with appropriate supervision to help them develop the necessary skills to utilize the technologies. There should be partnership between governments, the private sector, and local communities aimed at working together towards enhancing and developing technological infrastructure to better manage water resources and improve the effectiveness of digital systems. In summary, all these efforts can contribute to the enabling environment that will in turn foster the effective advancement that will lead to optimal usage of water resources (Yakovenko and Shaptala, 2024).

3.3.2. Resistance to change

Change aversion acts as a significant barrier in the process of digital transformation and may affect the development of a particular organization negatively. Both organizations and its employees might be unwilling to change their practices, and adopt newer methods and technologies. Such aversion can arise from change anxiety, lack of knowledge or awareness, or lack of competency in using new applications. For instance, employees who have used older technology for several years may fear that new technology will be cumbersome and difficult to learn. Moreover, lack of proper training and assistance from management can also worsen the negative perception.

For such negative perceptions and attitudes to change, companies should emphasize the organizing of training sessions and practical workshops aimed at lowering employee skills and altering the social dynamics of the organization in a way encouraging innovative thinking and adoption of changes. Also, adequate and good communication on the pros of the new technologies and their ability to enhance the organizational output can solve the issues. In summary, providing an environment where workers feel secure and safe from the turbulence and can adjust to the new order is essential in the course of digital changes (Polyanskiy et al., 2022)

3.3.3. Financial constraints

Water organizations are confronted with a range of financial constraints that impede the investment in their new technological models. These constraints can stem from lack of budget availability, diverse financial priorities, and economic forces at local and global levels.

The costs that these organizations incur in constructing new infrastructure and training their human resources are far beyond their financial resources thereby limiting the widespread use of intelligent systems and data use in the management of water resources. This financial constraint does not only limit the capacity of upgrading obsolete systems but also hinders creativity and creates a lack of educational opportunities for the staff members.

To address these barriers, organizations can look for tapping on foreign resources, use affordable technology, enhance intra-organizational partnership, and apply easily accessible teaching facilities. Liberating these financial barriers is crucial in enhancing the management of water resources and optimizing working of the digital systems (Candelieri and Archetti, 2014).

3.3.4. Lack of data

Collected based on Standard Parameters: Rarely, the data used in water resources management is collected from sources fitted with appropriate quality parameters. This variety of data may also distort the analysis and consequently impair decision making. Lack of harmonization in data standards can lead to poor data collection and usage, further compromising the efficiency of any digital program designed to manage water resources. It is critical to uniform these data standards if the quality and accuracy of the decision-making process is to improve.

Such standards can comprise acceptable practices for collecting data, standard templates for information storage and dissemination, and acceptable analytical methods related to handling the data. Organizations will therefore be able to improve the credibility of the data collected and then benefit from enhanced analyses done in the case of management of water resources. In addition, water resources management benefits from data standardization in that it allows for co-operation between various such organizations and enhances information flow within countries and across borders.

This is particularly useful in the context of the growing pressures on water resources since it can aid in fostering better decision making which is more holistic and sustainable for the resources (Xiang et al., 2021).

3.3.5. Cybersecurity Challenges

The increasing incorporation of digital technologies and the growing application of smart systems and IoTs makes cybersecurity an issue of paramount importance. The use of smart devices has its downsides as well; malicious cyberattacks can compromise critical information and infrastructure and allow for dire situations such as water crises to emerge. This worrying trend has already enabled water services to be corrupt, disrupted, and even stolen by malicious attackers, all of which can have negative consequences for society and the environment as a whole. Because of such growing concerns, safeguarding and preserving information now has topmost priority in the agenda of water management organizations. To combat these nefarious challenges, organizations have to be prepared to take transformative and reinventing actions.

For starters, creating strong security measures to safeguard and secure infrastructure and data from malicious activities is of the utmost importance. Informing staff of the current risks and threats and phishing prevention should go hand in hand to combat cyber warfare. Furthermore, regular assessments of both systems and infrastructures aid in addressing potential security threats and weaknesses. Integrating water management and cybersecurity services can also help improve the organizational systems and strategies to stay on the safe side in the face of potential threats and attacks. Throughout history, water has been of utmost political importance and hence, with the narrative of water being finite, it becomes utmost paramount for organizations to not only strengthen but also enhance their information governance and security systems (Hassanzadeh et al., 2020).

3.3.6. Climate change

The unpredictable changes that climate change could bring about in the water supply, as well as the new patterns of weather that it could reorganize, makes the provision of new resources challenging. That said, the use of more sophisticated algorithms for predictive and management purposes needs to be employed if the water resource management is to be adequately transformed digitally. Pattern recognition that involves data related to climate change and water resources can be effectively achieved through the employment of artificial intelligence and machine learning technologies.

In addition, co-operation between different agencies and the sharing of information between different organizations is crucial for good water management in response to climate change. All in all, we may be able to mitigate climate change's negative consequences by improving the forecasting and management of water resources using these technologies and tools (Kijak, 2021).

3.4. International digital water resources management and transboundary cooperation

3.4.1. The importance of international cooperation

Global collaboration in water resource management is essential to mitigate international water crises. More concretely, international water issues require nations to work together to avert sharing information and best practices. In this regard, digital technologies comprising Geographic Information Systems (GIS) and big data are invaluable. These technologies can improve transparency and intergovernmental coordination in enabling decision-making based on detailed analysis of the shared water resource data (Hietala et al., 2021).

3.4.2. Successful examples at the global level

However, some of the dynamic solutions in digital technology for water resource management appear to be shaped by certain advanced countries and even some leading global cities. For example, Australia is utilizing the digital water management systems to optimize the efficient use of water while minimizing the waste during the course of irrigation and other activities. Moreover, the use of more advanced models, including data-based predictive models, have been shown to assist in the city of Barcelona to predict water metering in the future (Volpe et al., 2022).

Another study assessed the roles of DWS–Digital Water Services in leakage management stages in a real-world network in southern Italy. In those services, DWS integrated validation of topological data, calibration of hydraulic models, designing District Metered Areas and planning of the pipes to be rehabilitated. Water Distribution Network (WDNetXL) platform is used to create a digital clone of the water distribution network, which assists the optimal activity planning in terms of costs and leaks management (Laucelli et al., 2023).

3.5. Future and strategic perspective of digital water resources management

3.5.1. Sustainable development and long-term strategies

The development schemes and policies which are to cover water resources adequately and appropriately in the context of climate change within the social and economic context should be designed to cover a longer time. It is paramount that these policies be accompanied by the adoption new technologies in order to enhance resource use efficiency. To illustrate, the use of artificial intelligence predictive models can aid in the more efficient management of water resources within constantly altering environments (Syed et al., 2024).

3.5.2. Opportunities for economic transformation by utilizing new technologies

The enhanced technologies that the digital economy provides can create more efficiency in water resources management and infrastructure costs however it will need the use of IoT and accurate data. The sensors and tools would greatly lower the cost needed in managing water, aggregating cost on water management (Chintada et al., 2023). Siemens and ABB have noted that there is expected to be a decrease between 15 to 25 percent when it comes to expenses, this expectation is aided by Siemens Digital Industries. The ROI on digital water management is expected to be seen in 2 to 4 years, the cost on getting digital management is almost always recouped under the time frame. In fifty different countries already, by both government and non-govt organizations have already commenced in developing a water sector strategy that encourages the usage of digital technologies.

Of the articles that have been reviewed two thirds were found to focus on monitoring tools, this coupled with IoT's sensors allowed industries to minimize non reversible water wastage by approximately 25 percent, the remaining one third focused on investment in demand management. About forty percent of the research undertaken estimated the use of AI in doing forecasting around water consumption and pressure to minimize water prevention. A multitude of studies noted that costs would act as a barrier in Asia Pacific Region, consider estimates ranging from $50,000- $500,000 would be needed depending on the size on the project.

According to case studies, the introduction of digital water management tools led to reduction in water consumption by 20-40% across sectors. This information was further structured according to thematic areas with a view to spotting trends, identifying gaps and defining challenges. The data were collated in order to shed light on present practices in the industry, opportunities for strategy for the use of digital technologies, effects of policies and regulation, and techniques for future research.

The analysis showed that both chemical and petrochemical sectors incorporated smart technologies that reduced water-related energy use by about 30% as well. European and North American countries' policies at the national or the regional levels prescribe more than 70% of the industries to incorporate real time monitoring technologies by the year 2024.

They also predict that the size of the global market for the digital water technologies will go up to twenty billion dollars by the year 2027, revealing a CAGR growth rate of about thirteen percent. Various industries and regions were compared with each other to bring out the evidence of context and to look for trends in globalization.

It has been estimated that deploying ICT in the water supply industry nevertheless has the potential for cost saving of around 30 billion cubic effective cubic meters annually. According to the World Bank, the financial return on deployment of digital water system technologies is about five times higher than their first installation costs. The World Economic Forum records that 80% of industries are using simple digital water systems in developed countries.

3.5.3. Industrial Transformations and Their Relation to Water Management

As already stated, for the purposes of this paper, Industrial Transformation encompasses a number of elements but is primarily characterized by industrialization and globalization patterns. To elaborate on the effects of such patterns, these dynamics introduce a new dimension to the already critical issue of water resource management and governance by creating additional demand. With the increased demand for water comes an even greater industrial transformation in the global market. This creates a paradox: while green technologies are intended to mitigate the rise in water demand, they may inadvertently exacerbate the issue by consuming the already shrinking supply, potentially accelerating industrial transformation further.

Grasping how industrial changes are related to the administration of water resources especially in regard to climate change and limits in water resources provides the basis for formulating appropriate strategies. There is a need to make use of new technologies as instruments for productivity expansion and sustainability embedding into production processes managers (Hamdy et al., 2023).

4. Conclusion

According to experts and institutions, sustainable management of water resources is the way of the future and it requires management using reserves alongside technological improvements. Water resource management is particularly necessary for challenges such as climate change as well as high evaporation rates that are caused by high population growth. On the other hand, new technologies if misused, such as big data, artificial intelligence, and social networks, can interfere greatly in the delivery of services.

Furthermore, there are concerns such as basic technological infrastructural issues, lack of willingness to change and limited financial capability to be tackled before these technologies are widely adopted. Water managers need to integrate collaboration and ideas from all parts of the globe for the change to be feasible in the long run. In conclusion, while aiding in the digital transformation, it helps in the optimization of processes and the saving of cost, it has more positive effects on the management of water resources.

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6. Conflict of Interest

No potential conflict of interest was reported by the authors.

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