



## Advancing Drinking Water Distribution Systems through Smart Water Applications: Insights, Benefits, and Lessons Learned

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تطوير أنظمة توزيع مياه الشرب من خلال تطبيقات المياه الذكية: رؤى وفوائد ودروس مستفادة

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### Abstract:

The global water sector is increasingly challenged by population growth, urbanization, climate change, and water scarcity. Conventional management practices are proving inadequate to address leakage, inefficiency, and rising demand, underscoring the need for digital and data-driven solutions. This study investigates the role of Smart Water Applications, with particular focus on Smart Water Metering (SWM), in enhancing drinking water distribution systems. Using a multiple case study approach, SWM adoption in the United States, the United Kingdom, Australia, and South Korea is analyzed, highlighting both pilot projects and large-scale deployments. Findings show that national policies, regulatory frameworks, financial support, and institutional readiness shape adoption trajectories. Across contexts, SWM provides wide-ranging benefits, including reduced water losses, enhanced leakage detection, cost savings, and improved customer engagement. Crucially, the study identifies significant gains in asset and maintenance management, such as predictive maintenance, optimized infrastructure monitoring, reduced operational disruptions, and extended asset lifecycles. Despite persistent challenges—most notably high upfront costs and legacy system integration—SWM emerges as a transformative pathway for improving efficiency, resilience, and sustainability in water distribution. The insights presented offer valuable lessons for utilities, policymakers, and stakeholders aiming to advance digital water innovation worldwide.

**Keywords:** Smart Water Metering (SWM); Smart Water Applications; Drinking Water Distribution Systems; Asset Management; Operation and Maintenance Management; Digital Water Transformation; Water Conservation; Sustainability.

### المخلص

يواجه قطاع المياه العالمي تحديات متزايدة نتيجة النمو السكاني، والتوسع الحضري، وتغير المناخ، وندرة المياه. وقد أثبتت ممارسات الإدارة التقليدية عدم كفايتها لمعالجة التسربات، وعدم الكفاءة، والطلب المتزايد، مما يؤكد الحاجة إلى حلول رقمية تعتمد على البيانات. تبحث هذه الدراسة دور تطبيقات المياه الذكية، مع التركيز بشكل خاص على عدادات المياه الذكية، في تحسين أنظمة توزيع مياه الشرب. وباستخدام منهجية دراسة حالات متعددة، تم تحليل تبني عدادات المياه الذكية في الولايات المتحدة، والمملكة المتحدة، وأستراليا، وكوريا الجنوبية، مع تسليط الضوء على كل من المشاريع التجريبية والتطبيقات واسعة النطاق. وتظهر النتائج أن السياسات الوطنية، والأطر التنظيمية، والدعم المالي، والجاهزية المؤسسية تؤثر في مسارات التبني. وفي مختلف السياقات، تُوفر عدادات المياه الذكية فوائد واسعة النطاق، تشمل تقليل فاقد المياه، وتحسين كشف التسربات، وتوفير التكاليف، وتحسين تفاعل العملاء. والأهم من ذلك، تُحدد الدراسة مكاسب كبيرة في إدارة الأصول والصيانة، مثل الصيانة التنبؤية، والمراقبة المحسنة للبنية التحتية، وتقليل الاضطرابات التشغيلية، وإطالة دورة حياة الأصول. على الرغم من التحديات المستمرة، وأبرزها ارتفاع التكاليف الأولية وصعوبة دمج الأنظمة القديمة، تبرز إدارة المياه المستدامة كمسار تحويلي لتحسين الكفاءة والمرونة والاستدامة في توزيع المياه. وتقدم الرؤى المعروضة دروسًا قيمة

لشركات المرافق وصناع السياسات والجهات المعنية التي تسعى إلى تطوير الابتكار الرقمي في مجال المياه على مستوى العالم.

**الكلمات المفتاحية:** عدادات المياه الذكية؛ تطبيقات المياه الذكية؛ أنظمة توزيع مياه الشرب؛ إدارة الأصول؛ إدارة التشغيل والصيانة؛ التحول الرقمي للمياه؛ ترشيد استهلاك المياه؛ الاستدامة.

## Introduction

The global water sector is facing unprecedented challenges due to the combined effects of population growth, economic development, rapid urbanization, and climate change. According to the United Nations World Population Prospects, the world's population is projected to reach 9.8 billion by 2050, and more than 40% of the global population is expected to be under severe water stress [1]. The OECD Environmental Outlook to 2050 further predicts a 55% increase in global water demand compared to 2000 levels, driven primarily by rising urban consumption [2]. These trends are expected to place immense pressure on already stressed water resources, posing significant risks to urban water security, particularly in water-scarce regions.

The global smart water metering market, as shown in Figure 1, is anticipated to expand significantly over the coming decade. Valued at approximately USD 4.67 billion in 2024, it is projected to reach USD 14.06 billion by 2034, reflecting a compound annual growth rate (CAGR) of 11.65% between 2025 and 2034. This growth trajectory is largely driven by the increasing demand for advanced and modern water metering technologies, which are recognized as critical tools for enhancing efficiency, improving resource management, and addressing the challenges of water scarcity and distribution losses [7].



**Figure 1:** Smart Water Metering Market Size 2025 to 2034 (USD Billion).

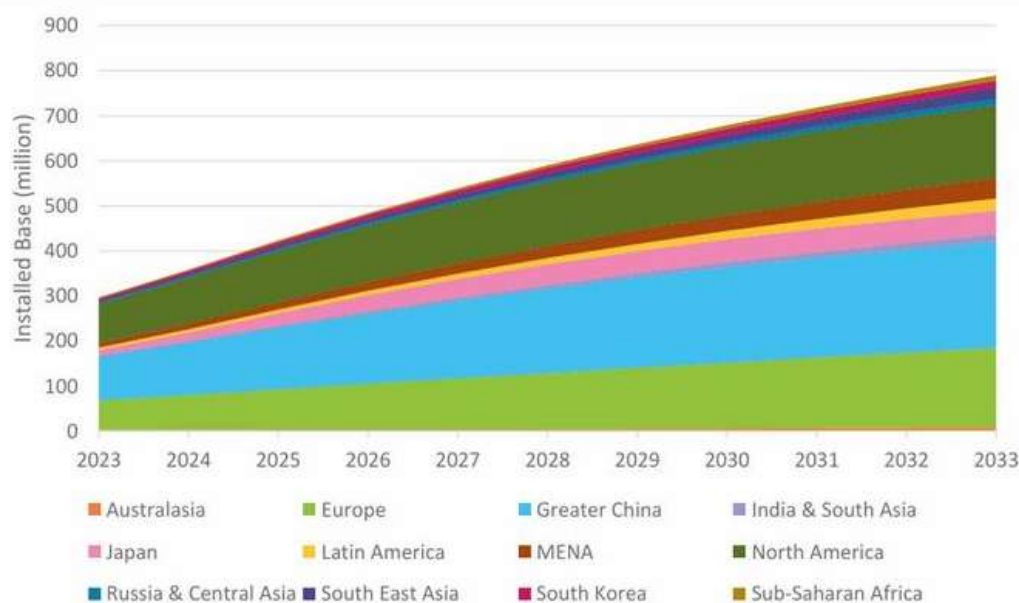
Climate change and urbanization not only challenge utilities' pursuit of water security but also expose a dual responsibility: while water utilities are directly impacted by climate change, their operations themselves contribute to greenhouse gas emissions. This growing awareness has positioned digital technologies as pivotal tools for creating a more sustainable urban water cycle. Recent evidence suggests that digital transformation—including smart metering, real-time monitoring, and advanced data analytics—has proven effective in improving the efficiency and sustainability of utility operations. However, the global progress of digital water transformation remains largely understudied. An international survey involving 64 utilities from 28 countries highlights that water distribution systems are often the entry point for digital adoption across the urban water cycle, with economic benefits acting as the primary driver, followed by government regulation and hydro-climatic pressures. Importantly, further research is needed to better understand how regulation, corporate mindset, and consumer involvement shape the success of digital transformation in the sector [3].

Traditional water management practices, reliant on mechanical meters and infrequent consumption data, are increasingly inadequate in addressing these mounting challenges. Issues such as water scarcity, leakage, and inefficiencies in distribution systems highlight the urgent need for innovative and data-driven solutions.

## Smart Water Metering (SWM)

In response to these challenges, Smart Water Technologies (SWT)—and particularly Smart Water Metering (SWM)—have emerged as critical tools for advancing sustainable water management.

According to Transforma Insights, the global shift from traditional meters to smart meters represents a major Internet of Things (IoT) initiative for improving water conservation and hygiene. As presented in figure 2, their analysis projects that by 2033, nearly 789 million smart water meters will be deployed worldwide [4]. The principal driver behind this growth is escalating water scarcity, aggravated by increasing consumption, leakage, and losses. Additional motivations include the capacity of smart meters to monitor and diagnose consumption patterns across domestic, commercial, and industrial sectors, as well as to enhance cost tracking and optimize resource utilization.



**Figure 2:** SWM Connected Devices 2023 to 2033 [Source: Transforma Insights, 2024]

Beyond implementation, scientific research on SWM has expanded rapidly since 2000, reflecting its growing global importance. A recent review highlights that the most active disciplines advancing knowledge in this field are engineering, computer science, and energy, which provide the foundations for technological innovation and system integration. In terms of geographic contributions, the United States, India, and China lead in scientific production, underscoring their commitment to addressing water challenges through research and innovation [5]. The benefits of SWM adoption are well documented. These systems provide real-time, high-resolution consumption data that supports accurate billing, enhances leak detection and fraud prevention, and improves the efficiency of water distribution networks. International experiences demonstrate that SWM adoption can reduce per capita water consumption by up to 24%, generate significant operational savings, and enhance customer satisfaction [6].

Globally, SWM adoption has progressed from pilot and trial projects to large-scale implementations, with residential applications dominating while commercial and industrial deployments also expand. Notable implementations have been reported across North America, Europe, Asia-Pacific, and the Middle East, with adoption patterns shaped by national policies, regulatory environments, and funding mechanisms. However, uptake remains uneven, as utilities continue to face barriers related to high initial investment costs and the challenges of transitioning from legacy systems.

Against this background, this study reviews the status, benefits, and lessons learned from SWM adoption in selected countries (USA, UK, Australia, and South Korea). It explores how water utilities have transitioned from pilot projects to full-scale implementations, the role of regulatory frameworks in shaping adoption, and the measurable benefits realized through these technologies. The objectives of this research are to: (1) assess the diffusion status of SWM implementation in the selected countries; (2) evaluate the impact of water policies on adoption; (3) compare national strategies and regulatory approaches; and (4) analyze historical trends to provide insights into future prospects.

By synthesizing global experiences, market projections, and research outputs, this study contributes to a deeper understanding of the drivers, challenges, and outcomes of smart water metering adoption. The findings provide valuable lessons for policymakers, utilities, and researchers aiming to accelerate SWM deployment and enhance the sustainability, resilience, and efficiency of water management systems worldwide.

## Objectives

The primary objective of this study is to critically examine the adoption, implementation, and outcomes of Smart Water Metering (SWM) and related smart water applications in drinking water distribution systems. Specifically, the research aims to assess the diffusion and implementation status of SWM across selected countries—including the United States, the United Kingdom, Australia, and South Korea—focusing on both pilot projects and full-scale deployments, while evaluating the influence of water policies and regulatory frameworks on adoption.

In addition, the study seeks to compare national strategies, deployment approaches, and funding mechanisms to identify best practices and lessons learned from diverse geographic and institutional contexts. Furthermore, the research analyzes the operational, economic, and environmental benefits of SWM, such as water conservation, leakage reduction, cost savings, and improvements in customer engagement and service quality, while also identifying barriers and enabling factors affecting adoption and scalability. By addressing these aspects, the study provides insights and recommendations for utilities, policymakers, and stakeholders, ultimately contributing to a deeper understanding of how smart water technologies can enhance the sustainability, efficiency, and resilience of urban water distribution systems.

## Methodology

This qualitative study adopts a multiple case study approach to examine the implementation of Smart Water Metering (SWM) and related smart water applications in drinking water distribution systems. Through the detailed analysis of selected real-world projects across different countries, the study investigates how these technologies have been deployed, highlighting both successes and challenges. The research focuses on identifying the operational, economic, and environmental benefits of SWM, as well as lessons learned from practical adoption, particularly in the context of asset management and infrastructure optimization. Moreover, the study emphasizes the strategic importance of integrating smart water technologies into utility operations, maintenance, and asset management, illustrating how various countries are planning and implementing these innovations to enhance system efficiency, improve service delivery, and support sustainable management of water distribution assets.

## Implementation of Smart Water Metering (SWM)

### (A) United States of America (USA)

In the United States, a total of 41 Smart Water Metering (SWM) projects were reviewed, encompassing both pilot initiatives and full-scale implementations. As shown in Figure 1a, several cities—including Columbia, Kansas City, and San Francisco—have achieved complete deployment, applying diverse implementation strategies. The figure further indicates that installations in other cities remain ongoing.

California provides a notable case, where the severe drought between 2012 and 2016 prompted significant investment in water efficiency technologies. From 2015 onward, numerous SWM projects were initiated, supported through grants issued jointly by the Bureau of Reclamation and the State of California. These grants enabled municipalities to accelerate adoption and safeguard scarce resources.

Beyond California, deployment has expanded across other metropolitan regions. Kansas City, for example, implemented an SWM system serving approximately 167,000 customers across 318 square miles. The city sought to reduce the substantial costs of manual meter reading, and SWM adoption resulted in significant reductions in field visits, labor expenditures, and customer service demands. Similarly, San Francisco installed 180,000 smart meters, enabling customers to monitor water consumption in real time. Adoption has also extended to a wide spectrum of urban contexts, from rural towns with fewer than 1,000 connections to major metropolitan areas such as New York, Boston, Cincinnati, Philadelphia, and Chicago, where utilities serve more than one million customers.

Despite these advancements, Figure 1 illustrates that several cities report lower completion rates. This slower progress is often attributed to the absence of federal regulatory mandates and limited government support for large-scale implementation. Nevertheless, the recognized advantages of SWM—including reduced water losses, real-time consumption monitoring, accurate billing, and improved operational efficiency—have driven steady uptake. Although adoption has occurred without federal compulsion, the increasing engagement of utilities, state governments, and stakeholders suggests a positive trajectory for nationwide implementation.

### (B) United Kingdom (UK)

In Europe, the diffusion of Smart Water Metering (SWM) has been slower than that of smart metering in the electricity and gas sectors, largely due to regulatory constraints under the European Union. In the United Kingdom, SWM adoption is progressing, though at a gradual pace. Thames Water, for instance, has initiated one of the largest deployment programs across England and Wales, with In South Korea, the transition from conventional water meters to Smart Water Metering (SWM) began around 2000, coinciding with the integration of water management and information and communication technology (ICT). The government initiated approximately 137 pilot and trial projects across multiple cities, reflecting a strong national commitment to digital transformation in

water utilities. These projects provided a testing ground for evaluating technical performance and operational feasibility before broader implementation.

A critical factor shaping the UK's trajectory is the regulatory framework. The Water Industry Act of 1991 does not mandate universal smart meter installation, leaving customers under no legal obligation to adopt SWM technologies. Consequently, water companies cannot enforce compulsory adoption. Instead, the government allows selected utilities—such as Affinity Water, Anglian Water, Essex and Suffolk Water, South East Water, Southern Water, Sutton and East Surrey Water, and Thames Water—to promote installation on a voluntary basis, particularly in regions classified as water-stressed. This regulatory context has slowed diffusion but enabled targeted adoption in areas of greatest need.

### **(C) Australia**

Australia has witnessed significant experimentation and implementation of SWM, with 43 projects reviewed in detail. Several early initiatives, completed by 2015, were pioneering in scope. Notable examples include the Kalgoorlie Smart Metering Trial in Queensland, TasWater (formerly Southern Water) in Tasmania, and City West Water in Victoria, all of which subsequently informed nationwide adoption strategies.

Between 2010 and 2012, the Kalgoorlie project installed 13,800 smart meters at a cost of approximately AUD 4 million. The outcomes were substantial: annual operating cost savings of AUD 4.5 million, a 13% decline in overall consumption, and significant improvements in leak detection and management. This initiative remains one of the most influential early success stories in Australia's SWM history.

TasWater launched a similarly large-scale program, investing AUD 36 million to install 46,000 smart meters in southern residential areas. Completed in 2014, the project yielded a 37% reduction in water supply costs and a 10% decline in consumption. Complemented by a strong media and public engagement campaign, the project achieved high levels of customer acceptance and reduced complaints compared with conventional meter usage.

From a regulatory standpoint, Australia does not mandate SWM adoption. Utilities are required to comply with the AS4747 standards, which permit continued reliance on mechanical meters alongside smart technologies. Consequently, many utilities have self-financed projects, though government grants have provided critical support. High upfront capital costs remain a persistent barrier, often compelling utilities to defer or abandon proposed projects in favor of other infrastructure priorities, particularly water and wastewater treatment.

A comprehensive review indicates that while early projects demonstrated strong technical and economic benefits, momentum slowed after 2015. This deceleration reflects regulatory flexibility, high costs, and competing infrastructure demands, which collectively shape the country's SWM trajectory.

### **(D) South Korea**

In South Korea, the transition from conventional water meters to Smart Water Metering (SWM) began around 2000, coinciding with the integration of water management and information and communication technology (ICT). The government initiated approximately 137 pilot and trial projects across multiple cities, reflecting a strong national commitment to digital transformation in water utilities. These projects provided a testing ground for evaluating technical performance and operational feasibility before broader implementation.

To date, South Korea has undertaken 146 SWM projects, including 137 pilot/trial initiatives and nine full implementations. Notable examples include Gochang City, Taean City, and Damyang City, all of which achieved near-complete deployment. Smaller populations and lower service densities in these areas facilitated rapid implementation and measurable success.

One particularly influential initiative was the Seosan Smart City project, launched in 2016 as part of a drought response strategy. This project combined SWM with wireless transmission and integrated decision-making systems to address high leakage rates and improve overall efficiency. The program installed 1,550 smart meters, 30 base stations, nine sub-district metering areas, and a real-time monitoring platform. With an investment of approximately USD 0.4 million, jointly financed by Seosan City and the national government, the project achieved multiple benefits, including reduced leakage, improved monitoring accuracy, and enhanced customer satisfaction. Given the demonstrated successes of existing projects and strong national policy support, SWM adoption in South Korea is expected to accelerate further. Both government agencies and utilities continue to articulate ambitious objectives, signaling an expanding role for SWM in the country's future water management strategies.

### **Conclusion**

This study has reviewed and examined the global adoption and implementation of Smart Water Metering (SWM), highlighting experiences from the United States, the United Kingdom, Australia, and South Korea. In addition to review article papers related to SWM applications. The analysis demonstrates that while the pace and scale of deployment vary across regions, the overall trajectory indicates a growing integration of SWM into water management strategies worldwide.

In the United States, local and state-level initiatives, particularly in response to drought conditions in California, have driven substantial progress. Pilot projects have evolved into full-scale implementations, achieving

measurable benefits including reductions in water losses, labor costs, and operational inefficiencies. In addition, Australia's early SWM projects demonstrated significant technical and economic benefits, with successful programs in Kalgoorlie and Tasmania leading to reduced water consumption, cost savings, and improved leak detection. However, high initial investment costs and competing infrastructure priorities Constrains the expansion of smart management adoption Constrains the expansion of smart management adoption.

The United Kingdom provides a contrasting example, where regulatory constraints and voluntary adoption policies have resulted in a gradual uptake. Targeted deployment in water-stressed areas demonstrates that SWM can still advance under a flexible policy environment, though widespread implementation remains constrained by the absence of mandatory legislation. In South Korea, strong national policy support and the integration of information and communication technologies have facilitated both pilot and full-scale projects. The SWM project of Seosan Smart City exemplify the potential of combining SWM with real-time monitoring and decision-support systems to improve efficiency, reduce leakage, and enhance customer satisfaction.

As a conclusion, the findings suggest that SWM adoption is shaped by a combination of regulatory frameworks, financial support mechanisms, technological readiness, and stakeholder engagement. While challenges such as high initial costs and legacy system integration persist, the demonstrated operational, economic, and environmental benefits of SWM present a persuasive basis for continued investment. Future adoption is expected to accelerate globally as utilities, governments, and stakeholders increasingly recognize SWM's role in addressing water scarcity, improving distribution efficiency, and supporting sustainable urban water management.

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### Compliance with ethical standards

#### *Disclosure of conflict of interest*

The authors declare that they have no conflict of interest.

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