CHAPTER 26

Integrated Smart Water Infrastructure Planning for PCMC

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ABSTRACT

Climate change and rapid urbanization are exerting unprecedented stress on urban water infrastructure in emerging cities. This study investigates the challenges in the water supply system of the Pimpri-Chinchwad Municipal Corporation (PCMC), Maharashtra, India, and proposes an Integrated Smart Water Infrastructure (ISWI) framework to enhance system efficiency, sustainability, and resilience. Using a mixed-method approach that combines a systematic review of global best practices with insights from an interview with a PCMC Sub City Engineer, the research identifies key issues such as high non-revenue water (NRW), pipeline leakages, irregular supply, and inadequate real-time monitoring. The literature review emphasizes the potential of technologies like SCADA, IoT sensors, Advanced Metering Infrastructure (AMI), and Digital Twins for predictive maintenance and leak detection. Although PCMC has initiated smart metering and SCADA in select zones, challenges such as outdated infrastructure, water scarcity, and financial constraints hinder full-scale adoption. The study recommends phased implementation of smart technologies with robust cybersecurity and data analytics to achieve continuous water supply and long-term water security.

Keywords: Smart Water Infrastructure, Urban Water Management, PCMC, SCADA, Sustainable Cities.

1.0 Introduction

The purpose of this study is to analyze the current water supply and management system used in the Pimpri-Chinchwad Municipal Corporation (PCMC) and to come up with an integrated smart water infrastructure planning model that can help to increase efficiency, minimize wastages of water and improve the reliability of the services.

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Water is among the most important resources that support urban life, economy, and health of people. The stress on the available water supply systems is accumulated as urban areas grow and a more substantial population is known to be in place. Most urban water systems were developed decades ago with lower populations and less demand patterns, which is seen in the older water distribution systems of such cities as Mumbai, Chennai, Kolkata and Delhi which had originally been planned with much smaller urban populations and less per capita demand. Such systems are nowadays finding it hard to handle the escalating consumption, ageing infrastructure, and climatic change, as well as rising demands of reliable and fair service delivery. Consequently, the problem of water leakages, wastage, uneven distribution and interruption in supply has become a common problem in the urban local authorities.

The prevailing system of water supply was traditionally based on manual control of water supply systems, regular inspection of supply systems, and reactive maintenance. Although such ways were satisfactory several years ago, nowadays they are insufficient in the crowded urban setting. The manifestation of high non-revenue water, and inefficient use of available resources were caused by delays in leak detection, poor visibility in real-time consumption as well as the lack of integrated decision-making. Current water management in urban areas needs to be transitioned to proactive and non-reactive systems that are able to forecast issues and aid effective planning.

As a way of addressing these issues, the idea of smart water infrastructure has become very popular across the globe. Smart water systems combine digital technologies because they include sensors, automated control, real-time data platform and analysis tools to monitor a water network around. By enabling utilities to monitor flow and pressure, identifying irregularities in advance, predicting demand, and enhancing operational efficiency, these systems enable utilities to monitor their systems. In addition to its efficiency, smart water infrastructure contributes to the long-term sustainability of the water infrastructure due to its minimization of water loss, increased reliability of services, and resilience to disruptions.

Tecnological developments in India have worsened the water stress conditions in numerous urban centers whereby population growth, growing industries, and a lack of locally available water resources have exerted strain and strain on pre-existing water supply networks causing chronic water shortages and scarcity, particularly in the summer seasons. Municipal corporations are prone to seasonal shortages, reliance on scarce water resources on the surface, and losses in infrastructure. The use of smart technologies to enhance urban services, such as water supply and management, is under the focus of government initiatives as the Smart Cities Mission. Nevertheless, to make smart water systems successful, special planning of the systems would be necessary that should take into consideration the local circumstances, institutional resources, financial viability, and stakeholder alignment.

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The Pimpri-Chinchwad Municipal Corporation (PCMC) is a fast developing urban and industrial area, where management of water has taken a new dimension. As the population increases, residential developments expand and the industrial demand also increases the water supply system at PCMC is having difficulties in terms of leakage losses, non-revenue water, seasonal scarcity and unfair distribution. Though there are the first steps in the digital monitoring and automation, the necessity to have a uniformed approach to the planning of smart water infrastructure is still present.

The study being targeted at the designing of a comprehensive smart water infrastructure planning model of PCMC. The research question is to review the current water management, detect the gaps in the systems, and evaluate how smart technologies and data-based solutions could be used to enhance efficiency, reliability, and sustainability. Through the interconnection of the knowledge obtained in research around the world and realities of operation in the country, the study aims at making practical recommendations that can help PCMC transform into a smarter and more resilient urban water system.

2.0 Literature Review

Increased population growth, climate uncertainty, and the old structure have led to a significant interest in urban water management as an academic and policy-oriented topic of research. A number of researches point out that traditional water supply systems that heavily rely on manual monitoring and regular repairs are no longer suitable in the modern urban settings. These concerns are identified by a number of scholars on the international and local levels. To illustrate, Mankad and Arolkar highlight that, traditional water systems lack good leakage control, effective monitoring, and real-time data which restricts effective decision-making in Indian cities, whereas Parkhe demonstrates that urban and Tier II cities in India have a severe issue of water wastage, ineffective monitoring and a ineffective distribution as a result of old-fashioned and manually managed systems.

Researchers claim that, in most cases, these traditional systems lead towards high non-revenue water, slow response to water wastage, and poor transparency in operations. To counter the effect of these outbreaks, smart water systems have been advanced as a promising solution, the digital technologies that are incorporated include real-time sensors, automated control systems, and central data platforms. According to existing literature, these systems can enhance visibility throughout the water network in a major way, as well as help utilities to transition to practices based on reactive maintenance to proactive and preventive management.

The other valuable topic in the literature is associated with robustness and stability of smart water infrastructure. In the article by Mankad and Arolkar, titled Smart Water

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Metering Implementation, the authors note that even though IoT-based water systems can enhance monitoring and control, such systems also present security issues when it comes to the system and communication reliability as well as data management in large urban and heterogeneous networks. In the same manner, in their review article, Zapata-Sierra et al. (2024) identified the communication, cybersecurity, and system integration as a significant research topic in the field of smart water, which demonstrates a rise in interest towards operational and cyber threats in intelligent infrastructures.

Resilience of smart water studies also posit that an appropriate method of implementation must be balanced embracing physical infrastructure, decision system, information systems, and stakeholder involvement. The usage of technologies like SCADA, constant internet control, and innovative metering infrastructure is extensively addressed as facilities that help in making decisions in real-time and responding promptly to the situation not only in the normal functioning process but also in emergency cases. Nevertheless, researchers warn these systems may not be resistant to technical breakdowns and malicious cyber actions without the proper level of redundancy, system risk analysis, and interagency response mechanisms. This literature provides a clear elucidation of the need to incorporate resilience planning and technological improvements on urban water systems.

According to the recent researches, smart metering, predictive analytics, and digital twin technologies play a vital role in enhancing the performance of the water management system and the water demand. Smart meters can minimize the use of water because timely and clear feedback to the users is given, however, long-term effect is maintained because of the constant interaction. On the utility level, digital twins contribute to the increased accuracy in demand forecasting and the possibility to identify the problems early on and eliminate leakage and pressure loss, among others. Nevertheless, some situations concerning the data quality, integration of the systems, and high cost of implementation remain to be troublesome, particularly in the prospering city centers.

Overall, the literature emphasizes that successful smart water infrastructure requires adaptation to local contexts, supported by strong governance and capacity building.

3.0 Research Methodology

This research study focuses on smart water infrastructure planning and scope and applicability using a qualitative and exploratory method in the context of Pimpri-Chinchwad Municipal Corporation (PCMC). The methodology aims to build on the understanding of smart water systems, resilience and digital water management presented in the existing literature and to anchor the analysis by the context of the local urban area. A systematic review of peer-reviewed journal articles, government publications, municipal reports and

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policy documents was conducted to learn about global best practices and technological trends in smart water management. Particular emphasis was placed on those studies that address real time monitoring, demand management, system resilience, and predictive maintenance as these themes are directly pertinent to the challenges faced by PCMC.

To ensure that the findings from around the world fit to our local context, the research uses secondary data relating to PCMC's water supply system, including official reports from the municipality, any statistics made available to use, and efforts documented to do with water sourcing, treatment, and distribution. Moreover, interviews with the representatives of the water department in PCMC provided secondary insights that help to gain a practical picture of operation challenges, the current system of limitations related to infrastructure, and the current digital programs. These interactions helped bridge the gap between existing theoretical frameworks that were discussed in the literature as against the practical reality of municipal water management in a rapidly growing urban region like Pimbri-Chinchwad.

The data collected had been analyzed using thematic approach to identify the key gaps between existing water management practices in PCMC and the capabilities provided by smart water infrastructure. Themes such as non revenue water, leakage detection, demand variability, limitations in monitoring and institutional readiness were examined with respect to smart technologies highlighted in the literature. This strategy made it possible to establish a unified view in planning which would take into account technological achievability and local government limitations. The methodology guarantees that recommendations of the study are context specific, practical and consistent with the long-term goal of PCMC to develop a more efficient, resilient and sustainable urban water supply system.

4.0 Data Analysis

The analysis of the data shows that at present PCMC provides about 600 MLD of water, which is the potential demand of the water of about 650 MLD that is short by an estimated 50 MLD. To a large extent this supply-demand gap is coped by emergency means like water tanker mobilization, redistribution on a temporary basis in areas with high supply, and augmented reliance on deep-drilled borewells in high summer. Nonetheless, these emergency measures add to the operational expenses and cause access inequalities because the supply of tankers is uneven and is often prioritized or strictly impacted by circumstance. Almost 35 percent levels of non-revenue water and a 25 percent level of leakage losses also exacerbate this shortage, whereby a considerable amount of treated water is squandered. Also, PCMC does not have real-time visibility of flows and losses because it has approximately 40 percent connections metered and little over 30 percent of the network covered by SCADA. The present gap-management practice reveals that existing gap-management strategies are

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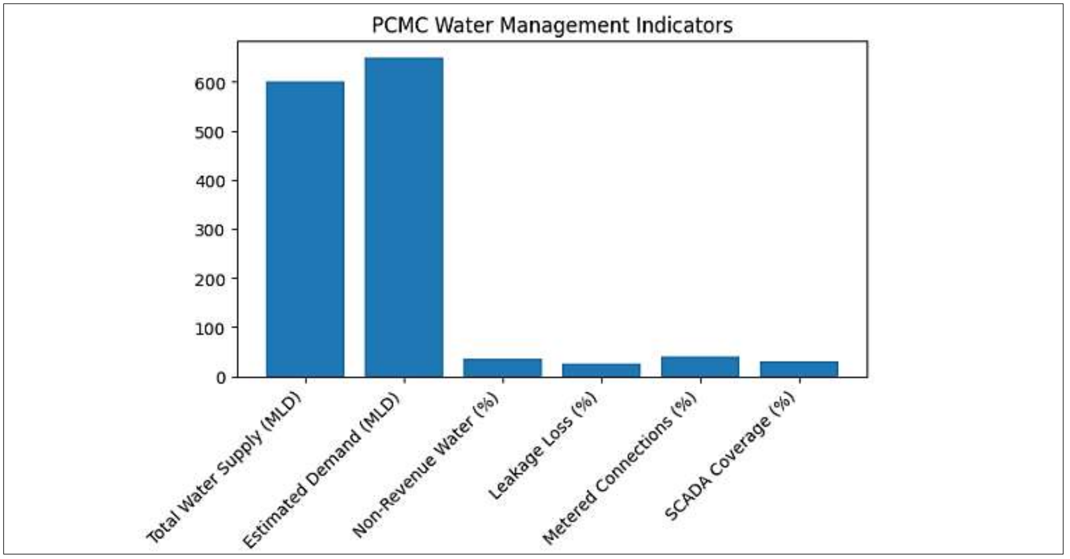
reactive and inefficient hence substantial interest in an integrated smart water infrastructure approach capable of reduce losses, build up a better monitoring facility, and a more resourceful approach to demand.

Figure 1: Key Water Management Performance Indicators of PCMC



Source: Created by authors

Table 1: Key Water Management Indicators – PCMC

Parameter	**Value**
Total Water Supply (MLD)	600
Estimated Water Demand (MLD)	650
Non-Revenue Water (%)	35
Leakage Loss (%)	25
Metered Connections (%)	40
SCADA Coverage (%)	30

Source: Created by authors

5.0 Findings/Results

The results presented in this paper are obtained through the research of secondary data on the system of water supply in PCMC with references to the information obtained with the help of municipal reports and talking to the authorities. The findings are given in a manner that demonstrates major operational loopholes, existing states of utilizing smart technology,

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and where smart water technology infrastructure can enhance enormous performance of the systems. The results are explained in accordance with the aims of research and themes that were observed in the literature review.

5.1 Water supply–demand gap and system efficiency

According to the analysis, PCMC is now delivering about 600 MLD of water, and the estimated amount of required water is about 650 MLD per day meaning that there is an ongoing gap between supply and demand. This deficit is aggravated in summer seasons subjecting the distribution system to more stress thus resulting to intermittent supply in some regions. The existence of such a gap proves previous literature statements that urban water stress cannot be attributed only to lack of water availability but also to distribution inefficiencies and limitations in the management of demand.

5.2 Sources of non-revenue water

When the breakdown of NRW is further considered, leakage losses occur as the biggest element, and is over two-thirds of the total NRW. Coding and the consumption of unauthorised advertising and measurements add a smaller, though significant, amount. This distribution brings out the structural nature of the losses as opposed to behavioural/billing related issues. Leakage losses are the leading causes of water loss according to the domination; therefore, this implies that aged pipelines and delayed detection systems are among the major causes of water loss. This observation complements the literature that argues out the significance of real-time monitoring and proactive maintenance as a means of minimizing physical losses in the water networks.

5.3 Status of smart technology adoption

The results further show that there is partial and unbalanced adoption of smart technology in PCMC. Only an approximate 40 percent of the connections are metered and SCADA has a coverage of approximately 30 percent of the distribution system. Along with the fact that these initiatives are good moves towards digitalization, they are limited in terms of scale which limits the capacity of the system to offer real time visibility and coordinated control. As it was emphasized in the literature review, the entire effect of smart water systems is weakened and the effectiveness on the resilience and operational efficiency of water systems is restricted due to fragmented implementation.

On the whole, the findings indicate that PCMC experiences the problem characteristic of fast urbanization cities such as high NRW, infrastructure depreciation, and poor digitalization. The results support the idea that an all-encompassing smart water

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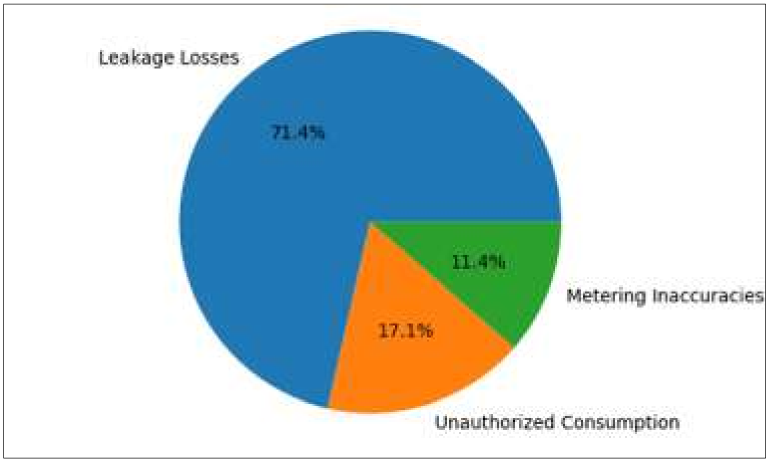
infrastructure strategy is necessary that can integrate the aspects of network-wide monitoring, data-informed decision-making, and the local phased efforts strategies.

Figure 2: Composition of Non-Revenue Water in PCMC



Source: Created by authors

6.0 Conclusion

The study will answer the question and relevance of the need to have an integrated smart water infrastructure planning plan in the Pimpri-Chinchwad Municipal Corporation that considers the increasing stress on urban water, the deterioration of the infrastructures, and the escalating demands. The evaluation highlights that PCMC also experiences unremitting supply demand imbalance, excessive non-revenue water and excessive leakages-all contributing factors to reduction of efficiency and reliability of the current system of water supply. In addition to that, the real-time monitoring and informed decision-making are further impeded by partial metering coverage and partially implemented SCADA.

These results reinforce the support that the existing predicaments regarding the water management in PCMC are not just influenced by the accessibility of water, but are predominately brought about by the lack of effectiveness in distribution, latency in leak identification, and fragmented digital application. Despite the first steps provided in the smart water management, no fully integrated and network-based approach will allow making the use of such technologies to be beneficial. This strengthens the importance of a proper planning framework that brings together technological upgrades, institutional coordination, data integration and capacity building.

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This paper claims that the smart water infrastructure is more than a pure technological solution to a problem but rather a component that will form the foundation of proactive management, demand forecasting and safeguarding against seasonal and operational uncertainties. This way, the gradual approach of implementation, adapted to the local environment and aided by the competent governance, could help PCMC in the gradual reduction of non-revenue water, enhancement of service stability and efficiency, as well as optimization of resource utilization.

This study brings the contextual aspect as it aims at the circumstances of the particular area of the Pimpri-Chinchwad Municipal Corporation that is marked by a rapid population increase, a rise in industrial water requirements, seasonal crises, the deterioration of infrastructure, and incomplete digitalization. Instead of using generalized smart water models, the research establishes smart infrastructure planning as specific to the institutional and financial capabilities and the operational issues of PCMC.

The results show that the best practices of the world (real-time monitoring, advanced metering infrastructure, predictive maintenance, and data-driven decision-making) can be successfully adjusted to local realities when followed in a gradual and adaptive fashion. This combination approach, through its alignment of international smart water strategies with the ground-level conditions of PCMC, provides a convenient reference framework concept in other urban local agencies, intending to transition to more efficient, resilient, and sustainable urban water supply systems.

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