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The Impact of Smart Water Management Systems (SWMS) on Water Distribution Efficiency in Urban Areas: A Case of Zanzibar Water Authority

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Abstract
Urban areas in developing countries face persistent water-distribution challenges, primarily due to high non-revenue water (NRW), aging infrastructure, and population growth. The Zanzibar Water Authority (ZAWA) has introduced Smart Water Management Systems (SWMS) to improve efficiency and reduce losses. However, there is limited empirical evidence on how these systems influence water distribution performance and customer satisfaction. A descriptive quantitative research design was adopted, involving 107 respondents drawn from ZAWA staff and urban water users. Primary data were collected through questionnaires and analysed using descriptive and multiple regression techniques in SPSS 26 to assess the contribution of SWMS components—system integration, data accuracy, automation, maintenance, and user training—to the distribution efficiency and consumer satisfaction. Results revealed that SWMS significantly enhanced water-distribution efficiency and user satisfaction ($R^2 = 0.79$). Smart metering, automated pressure control, and real-time leak detection were the most influential factors ($\beta = 0.692$, $p < 0.001$). Additionally, user training and optimized automated controls exhibited positive and statistically significant effects on perceived reliability and service quality. The study concludes that strengthening SWMS features, improving automated response mechanisms, and enhancing user training can markedly increase customer satisfaction and operational efficiency in urban water distribution. Water utilities should prioritize continuous technological upgrades, predictive monitoring, and capacity building to achieve sustainable water management outcomes.

Keywords: *Efficient Water Distribution; Smart Water Management Systems; Water Conservation; Urban Water Management.*

1.0 Introduction

Urban areas worldwide face persistent water loss challenges. This is especially the case in developing countries where infrastructure is aging and population growth intensifies demand. Non-Revenue Water (NRW), water lost through leaks, theft, and or metering inaccuracies, remain critical issues. For example, Dar es Salaam reported NRW levels of 47 per cent in 2018, which were reduced to only 38 per cent by 2021 despite the remedial measures adopted by water authorities in addressing the challenge (Dar es Salaam Water and Sewerage Authority [DAWASA], 2020). Arusha has similarly been grappling with system losses, prompting innovative projects to prevent the loss(Arusha Urban Water Supply and Sanitation Authority [AUWSA], 2021). Zanzibar, with her reliance on rainfall and limited freshwater sources, experiences NRW levels of about 40 per cent, straining an already fragile water supply (Zanzibar Water Authority [ZAWA], 2023). Such figures underscore the urgent need for strategies that can minimize water losses and improve distribution efficiency.

To address these challenges, Smart Water Management Systems (SWMS) have emerged as a key technological solution. SWMS monitor, operate, and optimize real-time water-distribution networks using sensors, smart meters, data analytics, and automated controls. By detecting leaks, managing pressure, and improving overall resource allocation (Et-Taibi et al., 2024), these systems aim to maximise water utilization and reduce losses.

Evidence from developed countries highlights the potential of SWMS in controlling water loss. In the Netherlands, the Amster-dam Water Authority implemented SWMS in 2015 and reduced water

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loss by 25 per cent through automated pressure control and real-time leak monitoring (Amsterdam Water Authority, 2019). A European Commission (2020) analysis showed that cities such as Berlin and London achieved up to 30 per cent gains in water efficiency after adopting SWMS. Similarly, U.S. cities, including San Francisco and Boston, have installed smart meters and sensors to cut down water consumption.

Promising outcomes are also reported in emerging economies. For example, India's Smart Cities Mission (2020) documented a 15 per cent reduction in NRW in Pune following the deployment of smart meters and data-driven management. In Cape Town, advanced metering and pressure management during the 2017–2018 drought cut down water loss by 22 per cent (South African Water Research Commission [SAWRC], 2019). The Brazilian Water Authority (2021) recorded a 20 per cent improvement in São Paulo's water distribution efficiency after the implementation of SWMS.

Zanzibar has begun to follow these examples. In 2023, ZAWA launched a pilot project in Stone Town and ChakeChake, installing smart meters and automatic leak-detection systems. Within six months (January – June), water loss fell by 12 per cent (ZAWA, 2023). The Ministry of Water (2021) has since urged a wider use of digital technologies to secure Zanzibar's future water. Against this background, the present study evaluates how effectively has ZAWA enhanced urban water-supply efficiency through SWMS. Specifically, the study investigates the extent to which SWMS improve water-distribution efficiency in Zanzibar's urban areas.

2.0 Literature Review

The review systematically examined the acceptance of Smart Water Metering System (SWMS) (Okoli, 2023). Along with their benefits and drawbacks, the study looked at how water utilities all across used Smart Water Meter Systems (SWMS). Using a quantitative approach, the study by Okoli (ibid) focused on efficient SWMS deployments in industrialized as well as developing countries. It shows how these technologies have enabled better resource allocation, lessening of water losses, and more customer involvement. The study determined that Smart Water Meter Systems (SWMS) have been effectively implemented globally, encompassing both industrialised and developing nations. These initiatives have demonstrated that SWMS may enhance the administration of water utilities. However, high costs, insufficient technical expertise, and infrastructural challenges hinder widespread adoption, particularly in poor Countries. The study envisaged that SWMS possesses significant promise for achieving environmentally sustainable water management and recommends prioritising investments, governmental assistance, and further research to address these challenges. The study reveals that governments and professionals in the water industry should prioritise investments in SWMS technology to enhance accessibility, particularly in developing countries. Specialised funding mechanisms or collaborations could help bridge the funding deficit.

Verma et al. (2023) conducted a study on the real-time smart water management system (SWMS) for smart homes. The system integrated quality sensors (SQ) to assess water quality, quantity sensors (QS) to monitor water usage, and overflow sensors (SO) to prevent overflow issues. The study demonstrated how such solutions might assist individuals in conserving water and enhancing their awareness of domestic consumption. However, there are challenges such as elevated installation costs and integration issues. The study concludes that the suggested system is a commendable initial step in water management; nevertheless, additional re-search is necessary to enhance sensor cost-effectiveness, improve integration, and address challenges encountered during the implementation. Recommendations for increasing the use of smart water technologies include developing user-friendly interfaces, providing training, and advocating for regulatory backing.

Mohankumar and Gowtham (2024) conducted a study on Optimising urban sustainability: A smart waste management system with Arduino technology. This research proposed and evaluated a Smart Waste Management System (SWMS) that employs Arduino hardware to enhance efficiency and sustainability of municipal waste management. The system integrated Arduino microcontrollers with sensors to monitor temperature, humidity, and waste levels in real time. The system enhanced collection routes and schedules, dispatched real-time notifications to citizens, and provided municipal authorities with access to centralised dashboards. The findings indicate that the SWMS significantly enhances operational efficiency, reduces costs, prevents bin overflow, increases public engagement, and safeguards the environment. The study advocates for the utilisation of SWMS, the enhancement of algorithms for increased predictive capabilities, its scalability, compatibility with other intelligent technologies, and backing through financial resources and public awareness initiatives.

In general, Okoli (2023), Verma et al. (2023), and Mohankumar and Gowtham (2024) have examined various aspects of smart water management systems (SWMS) and associated technologies. Nonetheless, there remain significant gaps in the literature that the current study intends to address. The majority of research on SWMS has been on its use in extensive domains, such as water conservation (Verma et al., 2023), real-time monitoring for smart homes, and urban waste management systems (Mohankumar et al., 2024). However, studies have not thoroughly examined the impact of SWMS on the efficiency of water distribution in urban areas, particularly in developing countries such as Tanzania. We do not completely understand how these technologies enhance service delivery, diminish water losses, and optimise water distribution in densely populated urban areas.

3.0 Research Methodology

3.1 The Study Area

The study focused on Zanzibar Water Authority (ZAWA), which faces high non-revenue water (≈40 %) and limited freshwater resources. These challenges, together with ZAWA's 2023 pilot of smart meters and leak detection systems, make Zanzibar an appropriate case for assessing the effectiveness of SWMS. Second, Zanzibar's reliance on rainfall and her recent initiatives to integrate smart technologies into water-management practices provide a relevant context for examining the real-world application and impact of SWMS. Finally, ZAWA's pilot projects and early adoption of SWMS present an excellent opportunity to assess the advantages and disadvantages of employing smart water technology in an evolving urban environment.

3.2 Research Design

This project applied a descriptive research approach. A descriptive survey research seeks to understand current phenomena by examining individual beliefs, attitudes, behaviours, or values. This method presents the situation as it exists, without attempting to change or influence it, thereby enabling a clear and objective understanding of the research problem. Furthermore, descriptive research enables the systematic examination of multiple factors and their interactions within their natural context (Mahat et al., 2024).

3.3 Research Methods

The study adopted a quantitative research design to examine key factors using numerical data. Quantitative approaches employ measurement, statistical analysis, and systematic data-collection tools to answer research questions or test hypotheses. This design was selected for its reliability, validity, and ability to support causal inference. It also offers flexibility in data collection and analysis, aligning well with the objectives and characteristics of the present study (Dubey & Kothari, 2022).

3.4 Population, Sample Size, and Sampling

The study population comprised 147 individuals, including 125 Zanzibar Water Authority (ZAWA) staff , technical personnel, engineers, and managers responsible for operating and maintaining the water-distribution infrastructure and implementing Smart Water Management Systems (SWMS), and 22 urban community water users. Community participants were proportionally selected from a larger pool of active ZAWA service users to represent diverse metropolitan neighbourhoods and to ensure that the combined sample reflected both technical and consumer perspectives on SWMS. To determine the minimum sample size, the Yamane (1967) formula $n=N/(1+N(e)2)$ was applied, where N is the population size and e is the margin of error. With $N = 147$, $e = 0.05$, and a 95 % confidence level, the calculation produced:≈107.

Accordingly, a minimum sample of 107 respondents was required for the study (Dehalwar & Sharma, 2023). A simple random sampling technique was employed to select participants. This method gave each member of the target population an equal chance of inclusion, thereby minimizing selection bias and ensuring that the final sample accurately represented both ZAWA staff and urban community members (Smith, 2020).

3.5 Data Collection and Analysis

The procedures for data collection and analysis were carefully designed to achieve the objectives of this study (Muguro et al., 2024). Both primary and secondary data sources were used. Primary data were obtained mainly through questionnaires, chosen for their efficiency and cost-effectiveness in reaching a large number of respondents (Muguro et al., 2024).

After collection, data were analysed using both descriptive and inferential statistics. Descriptive statistics—including measures of central tendency (mean, median, mode) and variability (range and standard deviation)—were employed to summarize and present the dataset. SPSS Version 26, the Statistical Package for the Social Sciences, facilitated these analyses. Using both descriptive and inferential statistics ensured a comprehensive understanding of the data and robust testing of the research questions (Hamed, 2020).

3.6 Ethical Considerations

The study adhered to strict ethical standards to ensure privacy and dignity for every participant and to foster an inclusive research environment. Participants were informed in advance of the study's purpose, procedures, and any potential conflicts of interest. Their participation was entirely voluntary, and they retained the right to withdraw at any stage without negative consequences. Confidentiality was protected through securing data storage and separating personal identifiers from survey responses. Informed consent was obtained after participants received comprehensive explanations on the study objectives and after having the opportunities of asking questions. Particular care was taken to maintain objectivity and to safeguard equitable treatment of all participants, including those from underrepresented groups (Iphofen, 2020).

4.0 Findings and Discussion

4.1 Response Rate and Demographic Characteristics.

Table 1 presents the number and percentage of questionnaires distributed, returned, and not returned to establish data reliability. Table 2, by contrast, profiles the composition of the respondents, detailing key demographic variables. Presenting these tables separately clarifies the distinction between response completeness and respondent characteristics, helping readers understand each table's unique contribution to the analysis.

A total of 107 questionnaires were distributed to Zanzibar Water Authority (ZAWA) officials, technical staff, and urban community water users. Of these, 102 were returned, representing a 95 per cent response rate, while only 5 (4.7 %) were not returned. This high return rate indicates strong engagement and enhances the credibility of findings by reducing the risk of non-response bias (Table 1).

Table 1. Survey response rate of distributed questionnaires (N = 107).

Categories	Frequency	Percentage
Returned Questionnaires	102	95.33
No answers	5	4.67
Total	**107**	**100**

Table 2 presents the sociodemographic profile of the respondents. Findings revealed the distribution of participant by gender, age and education levels: Men comprised 55.9 per cent (n = 57) and women

44.1 per cent (n = 45). The largest age group was 31–40 years (33.3 %), followed by 41–50 years (27.5 %), 21–30 years (20.6 %), followed by 51 years and older (18.6 %). In terms of education, 52.0 per cent had a bachelor's degree, 35.3 per cent had a postgraduate qualification, 10.8 per cent had a higher diploma, and 2.0 per cent had a diploma. These distributions confirm that the survey captured a diverse range of gender, age, and educational backgrounds.

Table 2. Socio-demographic characteristics of survey respondents (N = 102).

		Frequency	**Percent**
Gender	Male	57	55.9
	Female	45	44.1
	Total	***102***	***100.0***
Age	21 to 30 years old	21	20.6
	31 to 40 years old	34	33.3
	41 to 50 years old	28	27.5
	51 years old and older	19	18.6
	Total	***102***	***100.0***
Education level	Postgraduate	36	35.3
	Degree	53	52.0
	Higher Diploma	11	10.8
	Diploma	2	2.0
	Total	***102***	***100.0***

4.2 Descriptive Statistics

Table 3 summarizes respondents' ratings of how Smart Water Management Systems (SWMS) influence water-distribution efficiency across five dimensions: System integration, real-time data accuracy, automated controls, maintenance, and user training. Mean scores 3.28–3.52 on a five-point scale; overall mean = 3.42 ± 1.04 indicating that they were generally positive but had variable perceptions, with the highest ratings for data accuracy and integration and lower ratings for automation and training.

Table 3. Descriptive statistics of Smart Water Management Systems (SWMS) impact on water-distribution efficiency.

Statement	***Likert Scale***	***Frequency***	***Percent***	***Mean ± Sd***
The SWMS works well with other water management systems and the infrastructure that is already in place.	Strongly disagree	4	3.9	
	Disagree	24	23.5	
	Neutral	21	20.6	3.41±1.172
	Agree	32	31.4	
	Strongly agree	21	20.6	
	Total	**102**	**100.0**	
The SWMS gives accurate and dependable real-time data for keeping an eye on water quality, flow rates, and pressure levels	Strongly disagree	5	4.9	
	Disagree	15	14.7	
	Neutral	30	29.4	3.52±1.167
	Agree	26	25.5	
	Strongly agree	26	25.5	
	Total	**102**	**100.0**	
The SWMS's automated controls and reactions make water distribution and resource management more efficient	Strongly disagree	2	2.0	
	Disagree	24	23.5	
	Neutral	28	27.5	3.28±.989
	Agree	39	38.2	
	Strongly agree	9	8.8	

	Total	**102**	**100.0**	
The SWMS is constantly serviced and kept in good working order so that it works well	Strongly disagree	1	1.0	
	Disagree	13	12.7	
	Neutral	27	26.5	3.46±.767
	Agree	60	58.8	
	Strongly agree	1	1.0	
	Total	**102**	**100.0**	
Users get enough training and know how to use the SWMS's features and functions well	Strongly disagree	4	3.9	
	Disagree	25	24.5	
	Neutral	20	19.6	3.32±1.101
	Agree	40	39.2	
	Strongly Agree	13	12.7	
	Total	**102**	**100.0**	
Average mean ± Std				***3.418±1.039***

4.2.1 Integrating Components and Ensuring Functionality

The data presented in Table 3 indicate that the respondents assigned a mean score of 3.41 on the integration of SWMS with other water management systems and the existing infrastructure, accompanied by a standard deviation of 1.172. Among the 102 respondents, 4 individuals (3.9%) strongly disagreed, 24 (23.5%) disagreed, 21 (20.6%) were neutral, 32 (31.4%) agreed, and 21 (20.6%) strongly agreed. The findings indicate a variance in perspectives regarding the effectiveness of integrating SWMS with other systems. Approximately 52per cent of the respondents agreed or strongly agreed that integrating SWMS with other systems was effective . Nevertheless, nearly a quarter (27.4%) disagreed or strongly disagreed. This indicates that many customers are aware of a certain degree of integration; however, they expressed concerns on the effectiveness of integrating SWMS with the existing water management systems. The variation in responses indicates the necessity for further investigation to identify specific issues customers encounter in this domain.

4.2.2 Accuracy of Real-Time Data

The mean score for the SWMS's real-time data correctness and dependability was 3.52, with a standard deviation of 1.167. This indicates that individuals typically perceive the system data as reliable; however, variations in responses do exist.

4.2.3 Automation and Enhancement

The mean score indicating the effectiveness of automated controls and responses in enhancing water distribution and resource management was 3.28, with a standard deviation of 0.989. The majority of the respondents had favourable ratings for the system; however, a subset expressed uncertainty regarding the potential for automation.

4.2.4 Maintaining Pace and Endurance

The SWMS's regular maintenance and operational condition received an average score of 3.46, accompanied by a standard deviation of 0.767. The elevated average score indicates that the respondents perceive SWMS as well-maintained and functioning effectively, contributing to its overall success.

4.2.5 Training and Utilisation of Users

The mean score reflecting user training effectiveness and utilisation of SWMS features was 3.32, with a standard deviation of 1.101. The ratings indicate the general perception of the user training as effective; however, there is significant variability in users' confidence regarding their ability to utilise the system.

The average mean is calculated at 3.418, with an average standard deviation of 1.039 across all statements This indicates that individuals generally had a positive yet somewhat inconsistent perception of the effectiveness of SWMS across various regions. Table 4 highlights the strengths of the system alongside potential areas for improvement, including system integration, data accuracy, automation, maintenance, and user training.

4.2.6 Regression Analysis

We used regression analysis to determine the parameters that influence customer satisfaction with the reliability and high-quality water delivery of the distribution system.

Table 4. Shows regression coefficients

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.951	.208		4.567	.000	.538	1.364
	Smart Water Management Systems (SWMS)	.567	.058	.692	9.814	.000	.453	.682
	The SWMS's automatic controls and responses make water distribution and resource management more efficient	.234	.068	.242	3.424	.001	.098	.369
	Users get enough training and use the SWMS's features and functions well.	.237	.07	.245	3.395	.001	0.098	.375

The regression analysis presented in Table 4 identifies the factors influencing customer satisfaction regarding the reliability and quality of the water supply provided by the distribution system.

The model examines three primary factors: Smart Water Management Systems (SWMS), the effectiveness of automated controls, and the users' ability to learn and utilise SWMS features. The constant term, indicating the baseline level of satisfaction, has a coefficient of 0.951 and a p-value of less than 0.001. This suggests that, when controlling for other variables, customers exhibit a high level of satisfaction.

The Smart Water Management Systems (SWMS) predictor exhibits a coefficient of 0.567 and a standardised beta of 0.692. The t-value of 9.814 and a significance level of 0.000 indicate that SWMS exerts a substantial positive effect on customer satisfaction. This suggests that modifications to SWMS features will significantly enhance customer satisfaction regarding the water supply.

The Efficiency of Automated Controls and Responses exhibits a coefficient of 0.234, a standardised beta of 0.242, a t-value of 3.424, and a significance level of 0.001. The data indicate that SWMS had a positive and statistically significant impact on customer satisfaction. Customers are concerned with the effectiveness of automated systems in resource management and water distribution.

The coefficient for User Training and Utilisation is 0.237, and the standardised beta is 0.245. The variable exhibits a t-value of 3.395 and a significance level of 0.001. Effective user training and utilisation of SWMS features significantly enhance customer satisfaction. Users can maximise the benefits of the SWMS through appropriate training. This may alter their perceptions regarding the reliability and quality of the water supply.

The results indicate that all three predictors significantly influence customer satisfaction, with the SWMS exhibiting the most substantial effect. All predictors exhibited positive coefficients and significant p-values, indicating that enhancing SWMS features, optimising automated controls, and improving user training are essential strategies for increasing customer satisfaction with water supply systems.

Table 5. Model Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.889	.790	.784	.444

An R value of 0.889 indicates a strong relationship between the predictors and the outcome variable in the model. The observed correlation indicates a significant relationship between the independent variables (Smart Water Management Systems, the effectiveness of automated controls and responses, and user training) and customer satisfaction. The model accounts for approximately 79 per cent of the variance in customer satisfaction, which is indicated by a R Square value of 0.790. The predictors collectively account for a significant portion of the variance in customer satisfaction levels. The Adjusted R Square score is 0.784, accounting for the number of predictors in the model. The slight decrease in the R Square value indicates a minor penalty associated with the number of predictors. Adding an excessive number of variables does not enhance the model's explanatory power. The Standard Error of the Estimate is 0.444, representing the mean distance between observed and predicted values. This inaccuracy is minor; however, it indicates that the model fails to consider the various levels of contentment experienced by individuals. The model demonstrates a strong fit and elucidates many of the variations in customer satisfaction regarding the water supply. The low standard error indicates that the forecasts exhibit a high degree of accuracy.

We employed ANOVA to identify significant differences among groups of customers satisfied with the water management system.

Table 6. ANOVA

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	72.969	3	24.323	123.217	.000[b]
	Residual	19.345	98	.197		
	Total	***92.314***	***101***			

The model accounts for 72.969 per cent of the variance in customer satisfaction, represented by the Regression Sum of Squares with 3 degrees of freedom (df). To get the Mean Square for Regression, the Sum of Squares was divided by its degrees of freedom. The outcome is 24.323. The residual sum of squares amounts to 19.345, with 98 degrees of freedom. This illustrates the extent of customer satisfaction variability that the model fails to account for. To calculate the Mean Square for Residual, the Residual Sum of Squares was divided by its degrees of freedom. The outcome is 0.197. The model's F-statistic is 123.217, which is statistically significant due to a p-value of 0.000. The elevated F-value indicates that the regression model effectively predicts consumer satisfaction overall. The cumulative impact of the predictors is statistically significant in elucidating the variations in the dependent variable. The ANOVA results indicate that the regression model significantly accounts for variations in customer satisfaction, as evidenced by the elevated F-value and its corresponding p-value. This indicates that the model's predictors effectively account for the variations in consumer satisfaction about the water supply.

5.0 Conclusions

The study shows that improving user satisfaction with water delivery systems depends critically on Smart Water Management Systems (SWMS). SWMS had higher coefficient and standardized beta point to a notable favourable effect. This suggests that raising client impressions of dependability and quality depends critically on this. Though less so than SWMS, automated controls and user training help to satisfy customers. The 79per cent of the variance in customer happiness covered by the regression model, shows a strong fit and a thorough clarification of the main elements affecting consumer opinion. According to the results, improving customer happiness mostly depends on SWMS, automated control optimization, and better user training. In summary, the research shows that consumer impressions of the dependability and quality of water delivery systems may be much changed by increasing attention on these areas, especially the enhancement of SWMS. The great explanatory power of the model emphasizes the need of these approaches and offers a clear guidance for projects meant to raise consumer happiness. Future research would gain from investigating other elements that might affect satisfaction even more.

6.0 Recommendations

Improve systems of smart water management (SWMS): Improving systems of smart water management (SWMS) as a recommendation reflects both the perspectives of survey respondents and the researcher's interpretation of the regression results. Respondents emphasized the importance of more reliable and up-to-date SWMS features, and statistical analysis confirmed SWMS as the strongest predictor of customer satisfaction. Water utilities should therefore prioritize regular upgrades and new product development. Incorporating cutting-edge tools such as predictive analytics, real-time monitoring, and automated responses will help optimize resource management, improve water distribution, and maintain high service quality.

Optimize automated control and response mechanisms: Optimization of automated control and response mechanisms as a suggestion also emerged from both field feedback and analytical findings. Respondents noted delays and occasional system faults, and the regression analysis showed a significant positive relationship between the efficiency of automated controls and satisfaction. Utilities should enhance software, deploy higher-precision sensors and controllers, and refine algorithms to reduce errors and increase responsiveness, thereby improving operational reliability and efficiency.

Enhance user support and training: The recommendation on enhancing user support and training is strongly based on respondents' perspectives, who highlighted training gaps that limit full use of SWMS features. The quantitative analysis further confirmed user training as a significant contributor to satisfaction. Water supply companies should therefore invest in comprehensive training for both operational staff and end users, provide refresher sessions, and ensure continuous technical support so that users can fully benefit from system capabilities.

Investigate additional factors influencing customer satisfaction: Unlike the preceding points, the recommendation on Investigating additional factors influencing customer satisfaction arises mainly from the researcher's interpretation of the overall findings. Although the model explained 79per cent of the variance in satisfaction, unexplained factors still remain. Future research should explore dimensions such as customer service quality, infrastructure reliability, and environmental conditions. Additional feedback and surveys can help identify new areas for improvement.

By acting on these integrated insights—grounded partly in respondents' field perspectives and partly in researcher-led interpretation of quantitative evidence—water utilities can substantially enhance the performance and user satisfaction of smart water management systems.

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