International Journal for Quality Research 18(4) 1071–1092
ISSN 1800-6450

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Article info:
Received 20.07.2023.
Accepted 11.01.2024.

UDC – 005.336.3
DOI – 10.24874/IJQR18.04-10

EXPLORING THE IMPLEMENTATION OF ISO 55001 ASSET MANAGEMENT SYSTEM IN SMALL-TO-MEDIUM WATER UTILITIES IN GREECE: STRENGTHS, WEAKNESSES, AND IMPLICATIONS

Abstract: *The purpose of this study is to explore the implementation of ISO 55001 Asset Management System in small-to-medium water supply and sanitation utilities in Greece, with a focus on identifying their strengths and weaknesses in implementing the standard and discussing the managerial and policy implications of these findings. This study used a qualitative strategy in the form of a multiple case study, where eight experienced experts involved in asset management activities from four small-to-medium water utilities were interviewed. The study used the ISO high-level structure as a suitable study framework for the research. The findings provide encouraging evidence that smaller organizations are interested in genuinely substantial implementation of an asset management system, preferably a simple one that better fits their needs and capabilities, in accordance with the ISO 55001 standard. Moreover, the findings show that while smaller organizations face challenges such as lacking resources, bureaucracy, a short-term mentality, and political constraints, they possess key strengths, such as extensive experience, a commitment to asset management best practices, and an adaptive and innovative culture. The study's findings have significant managerial implications for small organizations striving for enhanced asset management practices.*

Keywords: *ISO 55001, asset management system, water utilities, small-to-medium organizations, multiple case study*

1. Introduction

Asset management is a critical discipline in the infrastructure sector, encompassing a wide range of professional and academic domains, mainly under an unexplored and non-quantified nature (Hodkiewicz, 2015; Lima and Costa, 2019; Wijnia, 2016). The effective management of infrastructure assets is essential to ensuring their longevity, optimizing their performance, and minimizing the risk of failure (Bukhsh and Stipanovic, 2020; Frangopol and Liu, 2007). Several guidelines, reports, and practices on asset management were developed in the 2000s, albeit in a scattered and narrow-focused manner (Frolov et al., 2010; Too, 2010). This trend led to efforts to standardize the subject, most notably with the inception of the international standard ISO 55001 in 2014. ISO 55001 sets out requirements for an

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asset management system that can be applied to any type of organization, regardless of size or sector. The standard provides a framework for developing an integrated, systematic approach to asset management that aligns with an organization's objectives and targets (Konstantakos et al., 2019).

However, it is widely acknowledged that contemporary asset management lacks well-grounded theories and empirical evidence, highlighting the need to extend the body of knowledge in this area (da Silva and de Souza, 2021; Gavrikova et al., 2020; Konstantakos et al., 2019). Consequently, many organizations require a deeper understanding of the ISO 55001 standard to effectively manage their assets (Modgil and Sharma, 2016). Moreover, during the development of the ISO 55001 standard, several issues relating to areas open for future research were explicitly identified. One of these issues is the concern about the ability of smaller infrastructure organizations to implement ISO 55001 requirements, primarily due to limited available resources (Hodkiewicz, 2015). Hence, there is a pressing need to investigate and address the challenges and limitations these organizations face to enhance their asset management practices.

Within this context, this study aims to examine the applicability of ISO 55001 for smaller infrastructure organizations, focusing on water utilities in Greece, such as urban water, drainage, and irrigation organizations. Specifically, this study is guided by the following exploratory open-ended research questions:

RQ1: What are the strengths and weaknesses of small-to-medium water infrastructure utilities in implementing ISO 55001?

RQ2: What are the managerial and policy implications of the strengths and weaknesses identified in ISO 55001 implementation for small-to-medium water infrastructure utilities?

The research subject is placed on virtually unexplored ground, requiring a qualitative approach in the form of a multiple case study. For this purpose, primary data were collected from four small-to-medium water infrastructure utilities through in-depth interviews with experienced asset management experts. These experts provided insights into the strengths, weaknesses, and feasibility of ISO 55001 implementation. Participants were selected from several functions of the examined organizations, including operations, technical, accounting, and administration departments, to ensure an interdisciplinary approach to the study.

This paper is organized as follows. Section 2 provides a comprehensive background of infrastructure asset management for water utilities, emphasizing the specific challenges faced by smaller organizations. Section 3 describes the methodology employed in the study. Section 4 presents the analysis of the case studies, highlighting the most important cross-case results. Section 5 addresses the first research question by identifying the strengths and weaknesses of small-to-medium water infrastructure utilities in implementing ISO 55001. Section 6 addresses the second research question by discussing the managerial and policy implications of the findings for improving asset management practices in small-to-medium water infrastructure utilities. Finally, Section 7 concludes the study and provides directions for further research.

2. Challenges and strategies in managing small-to-medium water utilities

Water utilities worldwide have the significant responsibility of managing the common good of water for present and future generations, making them one of the most critical and costly public infrastructures (Haider et al., 2014). The primary components of water utilities' infrastructure include dams and canals (for irrigation and drainage systems),

and treatment plants and pressured pipeline distribution networks (for potable water supply systems). In contrast to industrial production, individual water utility assets may span hundreds or thousands of kilometers (Malano et al., 1999). Given the present study's focus on small-to-medium water utilities, it is crucial to identify their internal attributes concerning asset management in scholarship and highlight their similarities and differences from larger water utilities.

The management approach applied to water supply systems often depends on their size, with smaller utilities being characterized by several distinct factors. These may include limited technical and financial resources, low capital and operational costs, and limited access to recent technologies (Braden and Mankin, 2004; Carrico et al., 2020; Francisque, 2017; Haider et al., 2014). Mismanagement and poor leadership have also been reported to be prevalent in small water utilities (Hamilton et al., 2006). Moreover, such utilities typically rely on part-time personnel and have only a few staff members with the required technical expertise to manage their assets, as well as being responsible for planning, controlling, and implementing infrastructure initiatives. Despite these heavy responsibilities, permanent staff often receive relatively low pay and little recognition (Ford et al., 2005).

The primary focus of all water utilities, regardless of their size, is the efficient operation and maintenance of valuable assets, which can be achieved by implementing optimum maintenance, rehabilitation, and renewal strategies, while keeping costs within viable limits (Alegre and Coelho, 2012; Mazumder et al., 2018). However, the size of the assets required for water utility services is significant and reduces the degrees of freedom for rehabilitation and maintenance. While the age and condition of assets are critical in designing a water utility's strategy, the most crucial factor is the availability of monetary or other resources to provide the desired level of service. Larger water utilities may have more resources, a larger budget, and be more efficient compared to smaller ones (Peda et al., 2013; Tsagarakis, 2013). For small water utilities, budgetary constraints typically determine the infrastructure cost and, consequently, the level of service. However, following short-term priorities "to keep the system running" due to insufficient budgets is not ideal (Malano et al., 1999). Instead, an output-driven budgetary approach should be employed that allocates as many resources as needed according to a clear definition of the established service level (Banyard and Bostock, 1998). In any case, the optimal allocation of available resources must comply with the specific requirements of the water utility. As far as renewal strategies are concerned, there has been little attention devoted to small water utilities in the literature. This may be due to the fact that, in developed countries, the vertical (e.g., treatment plants, pumping stations, and storage facilities) and linear (e.g., transmission mains and pressure pipelines) components of most small water utilities have been constructed within the past 50-60 years. Given that physical water infrastructure has a life expectancy of up to 100 years or more (Tscheikner-Gratl et al., 2019), the operational issues related to assets' age are considered non-critical since they do not typically exhibit alarming structural deterioration phenomena (Kirmeyer et al., 1994; USEPA, 2007).

Asset management is an ongoing effort that must be continuously improved to enhance performance. To achieve improvement, it is necessary to identify and understand unutilized potential while also readily assessing the organization's current situation. Therefore, central to infrastructure assessment is performance evaluation (Alketbi et al., 2022; Alsyouf et al., 2021; Rasoulkhani et al., 2019). However, most performance evaluation systems have been developed to assist large water utilities, which are more susceptible to operational vulnerabilities due to their size (Stone et al.,

2002). In contrast, smaller water utilities have received little attention due to their serving fewer people and using fewer infrastructure assets. Consequently, small-to-medium water utilities have typically not undergone performance evaluation in the past, and their service levels have rarely been defined or monitored. When a small water utility has not been previously assessed, an analysis of the status quo should be conducted with the specific requirements of the utility in mind. In most cases, a significant lack of monitoring data is observed, and even basic asset information is not readily available. As a result, most performance assessment systems proposed for smaller water utilities emphasize the need for simplicity and comprehensiveness (Haider et al., 2014).

Like other infrastructure systems, water utilities face global challenges such as climate changes, growing populations, economic crises, and pandemics like the recent COVID-19 outbreak (Van den Berg and Danilenko, 2011; Zechman Berglund et al., 2021). Aging infrastructure and water scarcity are also specific problems they may encounter, which require prioritizing necessary interventions (Ortega-Ballesteros et al., 2021). To achieve optimal solutions in terms of balancing performance, risks, and costs, water utilities can benefit from adopting smart and sustainable asset management tools to enhance the effective service life of all or a subset of individual components in the supply system (Brown, 2004; Cornejo et al., 2019). For example, advanced prediction models such as machine learning and survival-analysis algorithms can help identify when underground water pipes are expected to break (Snider and McBean, 2020). Several new technologies have also been proposed for efficient water utility management, including Big Data tools (Ponce Romero et al., 2017; Rusakova and Inshakova, 2021), Blockchain (Dasaklis et al., 2022), Digital Twins (Conejos Fuertes et al., 2020), and the Internet of Things (Dogo et al., 2019). Although these new tools offer advantages, smaller utilities may lag in adopting sophisticated asset management techniques. Hence, it is essential to prioritize the adoption of these tools, keeping in mind the unique needs of smaller utilities (Winter and Fabry, 2012).

3. Methodology

The exploratory and open-ended nature of the research objective in this study necessitates a qualitative research design, providing a rationale for obtaining in-depth information through a naturalistic approach. An exploratory, instrumental, and multi-case study type was implemented based on the generic and unexplored formation of the main questions aimed at identifying the strengths and weaknesses of small-to-medium water utilities towards ISO 55001 implementation and the practical implications of these findings. The focus was on the comparative analysis of the perceptions of experts in selected water supply organizations, further exploiting the importance of multiple-case studies in providing a rich understanding of parameters that can lead to the identification of patterns (Eisenhardt, 1989; Yin, 2017).

The case selection process was conducted with care to ensure representative cases of small-to-medium water utilities were included. As there is no "one size fits all" sample for multiple-case strategies, the selection process traditionally pertains to non-probability sampling (Saunders et al., 2019). Thus, the most appropriate method for covering ISO 55001 implementation issues is purposive (or judgmental) sampling, allowing researchers to select information-rich cases that best fit the research objectives based on their judgment (Neuman, 2019; Patton, 2014). The selection of cases for this study was based on several explicit criteria. Firstly, all four organizations were small-to-medium-sized local public infrastructure utilities operating in the water sector in Greece. Secondly, they were representative of the country-wide status of small-to-medium water infrastructure utilities. Thirdly, they possessed the necessary human and technical

resources to implement the requirements of ISO 55001 asset management. Fourthly, they were asset-intensive in their operation, with a primary focus on managing water as a physical resource, which is crucial for society's well-being, specifically for reasons of safety, hygiene, protection of property, and enhancement of the domestic product. Finally, the selection process entailed a detailed examination of the organizations' archival data, including their operational procedures and strategic plans, to ensure that they met the criteria for inclusion in the study.

The four cases examined in this study include an inter-municipality water conjunction utility (referred to as SY), a local irrigation utility (referred to as TOEB), a local drainage utility (referred to as GOEB), and a municipal urban water and sewerage utility (referred to as DEYA). A structured description of each case is presented in Table 1.

Table 1. Description of cases

	Case 1: SY	**Case 2: TOEB**	**Case 3: GOEB**	**Case 4: DEYA**
Legal status	Public agency.	Non-profit mandatory partnership of irrigators (retaining the public agency status).	Public agency.	Public agency.
Main operations	Distill and transfer potable water to local community entities (serving a population of around 100.000).	Provision of irrigation water to a cultivated area of 11.500 acres.	Provision of drainage services for a total area of 100.000 acres.	Provision of potable water and sewerage services (serving a population of around 65.000).
Number of employees	Ten full-time employees and ten part-time technical staff.	Four full-time employees and more than fifty part-time workers during the summer irrigation season.	Ten employees, most of them on a part-time basis.	Forty-five employees, most of them on a full-time basis.
Main assets	A distilling plant, with a capacity of 2.500-3.000 m^3/h, and a pressured pipeline network for transferring water, with a total length of 150 km.	A reservoir of 600.000 m^3 capacity, a canal network, and installed irrigation pumps.	Large drainage pumps.	200 km water network, 100 km sewage network, and a central sewage treatment plant.
Main future priorities	To establish a modern real-time monitoring system for all critical operational activities.	To install an accurate and real-time water consumption surveillance system.	To establish a Geographic Information System (GIS) database to illustrate the areas of jurisdiction clearly.	To consolidate their existing scattered asset monitoring systems under an overarching system.

Although the aforementioned cases represent a homogeneous sample within the research scope at the strategic level, they exhibit heterogeneity and sampling variation at the operational level. This may seem contradictory, but it is argued that this is also

a strength (Patton, 2014). Any patterns that emerge during the research are likely to be of particular interest and value and may represent critical themes in addition to providing research uniqueness (Saunders et al., 2019).

The methodology employed in this study involved the selection of semi-structured and in-depth interviews to explore the perceptions of experts from the selected water supply organizations regarding their organizations' asset management systems. The experts were chosen from the water utilities' operations, technical, accounting, or administration departments based on their background in the management of physical assets, their experience in their respective fields, and their critical roles in the utilities' operation. It is worth noting that involving and committing every member of the organization towards asset management optimality is one of the fundamental principles underlying ISO 55001 implementation. Therefore, at least one interviewee was selected from each core function, as interviewing all employees was beyond the study's scope. The resulting sample consisted of eight participants, with two individuals selected from each organization. For all four organizations, one representative from the technical or operations department with a professional background in engineering was interviewed. A representative from the accounting or administration department participated in three cases, while in the fourth case, an agronomist was interviewed. The reliability and value of using expert judgment when targeting participants from different backgrounds and operational functions are well recognized in the scholarship when it comes to improvement initiatives (Chountalas et al., 2020; Rosqvist et al., 2003).

All interviews were conducted on-site and lasted between one and two hours. The interview guide used is detailed in Section 4.1. Before the interviews, assurances were provided regarding the anonymity of each organization and individual identity, and permission was obtained to audio-record the interviews. After the data analysis, interview participants were asked to review the transcripts and add comments. While not all participants responded due to heavy workloads, those who did confirmed the analysis, providing another source of methodological triangulation for the study (Creswell, 2017).

Complementing primary data with secondary data using mixed sourcing techniques is essential for ensuring research validity (Creswell, 2017; Vitale et al., 2008). To this end, this study conducted desk research to supplement and triangulate the primary data acquired through interviews (Patton, 2014; Yin, 2017). Secondary data were collected by exploring on-site and online references throughout the research to compare and contrast interview results and identify similarities or discrepancies. The data collected from the interviews required only minor adjustments after this procedure, further enhancing the study's validity and reliability.

4. Case study analysis

4.1. Introductory notes

To obtain data, researchers often use a questioning route or discussion guide, which includes a select group of questions or discussion points designed to elicit conversation among participants and guide their commentary towards the most fruitful areas of discussion (Greenbaum, 2000). This research utilized a directional guide (see Table 2 for sample questions) to elicit the most compelling and informative responses from participants while maintaining focus on the core subjects required by ISO 55001.

Discussion guides are often used in academic literature as the basis for subsequent written reports (Krueger and Casey, 2014). Given the exploratory nature of this study and the need to replicate questions directly associated with the conceptual framework, the interview

guide was structured based on the ISO 55001 framework, which follows the high-level structure for management system standards outlined in ISO/IEC (2014). Overall, there appears to be a uniformity of opinion among participants in response to most questions, with only minor differences. Therefore, a cross-case analysis of the findings is provided directly rather than examining the cases in detail, as Malterud (2012) recommended for multivocal synthesis. Any discrepancies are explored where they exist.

The preceding arguments are reinforced by the fact that, despite their operational differences, all organizations are dependent on the performance of the same type of critical assets, such as pumps, long-spanning networks of canals and underground pipelines, water processing plants, etc., and their service continuity is essential for society. From a broader perspective, these organizations are responsible for managing the natural resource of water, albeit in different processing states, such as potable water, irrigation water, and sewage.

Table 2. Sample interview questions

ISO 55001 clause	Questions
4.3	Are there documented and clear maps of the organization's asset portfolio available?
5.3	Is there a clear definition of the individuals who have authority and responsibility for crucial asset management practices within the organization?
6.2	Does the organization have a contingency plan in place in the event of critical assets being out of service or a catastrophic event occurring?
7.5	Do you possess thorough, timely, and valid knowledge of your organization's asset system performance, including the network, plant, and service level?
9.1	Is there a measuring system in place that provides continuous feedback on the current situation and the effectiveness of critical assets?

Section 4.2 presents the cross-case results of the interviews, which follows the structure of the interview guide based on the ISO high-level structure. Following this, Section 5 presents the strengths and weaknesses of small-to-medium utilities in implementing ISO 55001, while Section 6 discusses the managerial and policy implications of these findings.

4.2. Cross-case results

Following the interview guide, all clauses of ISO 55001 were explored throughout the interviews, with an open-ended and semi-structured questioning approach that facilitated fruitful discussions with the interviewees, who were all interested in the research subject. Answering patterns throughout the research exhibited significant commonalities, providing evidence of reliability in the primary data acquired and achieving a high level of qualitative "saturation". The minor differences identified only concerned the intensity of interest in some sections, such as the documentation clause where the organizations' maturity levels were not equal, without affecting the overall response patterns. The research participants' perceptions led to the identification of several themes within each ISO 55001 clause, with collaborative and open discussions allowing new topics to emerge.

To improve readability and due to space limitations, a detailed cross-case analysis is omitted, and a summary of the research results is presented in Table 3, which provides the sum of the replicating response patterns organized by thematic area based on the ISO high-level structure. This presentation style facilitates comparisons between the results and literature, as recommended by Eisenhardt (1989) and Baxter and Jack (2008).

Table 3. Cross-case results

ISO 55001 Clauses	Response patterns
4 - Context of the organization	
4.1 Understanding the organization and its context	The organizations exhibit a confident knowledge of internal and external contexts while acknowledging improvement opportunities. The relevant legislation is outdated, and there is a lack of best practice guidelines on asset management. The economic crisis has resulted in a limited availability of human and techno-economic resources, but it has also triggered an innovative and adaptive culture to overcome difficulties. Operations are dominated by budgetary constraints, leading to short-term thinking to cover service level demand temporarily. Under the current situation, none of the organizations can develop a reliable long-term strategic plan since significant improvements can only be financed through state subsidization. Political constraints often result in non-rational decisions from a business perspective.
4.2 Understanding the needs and expectations of stakeholders	Organizations are governed by locally elected officials who possess a good understanding of external stakeholders' expectations. Before making significant investments, detailed cost/benefit analysis must be publicly presented to dispel the widespread misconception over the value of a public good. Pricing must be guided directly by central government acts. Adequate resources should be available to monitor stakeholders' needs, particularly concerning water demand forecasting. The reduction of administrative bureaucracy is a significant concern for employees, except for DEYA, which operates under a quasi-private legal status with less bureaucratic burdens. There is a trend towards part-time employment that does not provide the necessary time and motivation to delve deeper into critical operations, endangering service continuity. Full-time employment should be made available for all personnel.
4.3 Determining the scope of the asset management system	Mapping and documenting critical assets are crucial for service continuity and developing best practices.
4.4 Asset management system (development of SAMP)	Compliance with the quality management standard (ISO 9001) has been limited to bureaucratic and paperwork-based procedures due to its solely extrinsic motivation. The interviewees were hesitant to advocate for a full-scale asset management system for their small-to-medium organizations. Instead, they deemed a partial adaptation of an overarching asset decision-making framework to be more appropriate and beneficial, gradually incorporating best practices in infrastructure asset operations such as documentation, auditing, and continual improvement. A full-scale asset management system may be more valuable for larger organizations with complex processes, as acknowledged by the interviewees.
5 - Leadership	
5.1 Leadership and commitment	Top management's strong commitment and accountability are essential for smooth operations and continual long-term improvement. Consultation between top management and employees is typically more direct in small organizations. In the context of "managing the moment," there is often little opportunity for consultation on setting long-term goals. Some interviewees emphasized that consultation might be used as a pretext to transfer responsibilities downwards if a project fails.

5.2 Policy	The regulatory and technical background is outdated and requires urgent changes, mainly towards the homogenization of practices and decision-making criteria. Most interviewees prefer a more centralized administrative approach for water utilities, aiming at a semi-governmental status to avoid local political biases. Full-time hiring is regarded as the most cost-effective human resources strategy, considering the required quality in operations and the need to prevent monopolistic phenomena due to knowledge dependence by contractors.
5.3 Organizational roles, responsibilities, and authorities	The lack of human resources is a significant impediment to the performance of water utilities. Small-to-medium utilities face the challenge of not only optimizing their organizational structure but also determining how to manage their limited workforce, which must cope with a diverse range of tasks. Due to the lack of resources, employees are often required to operate as generalists to address a wide range of needs, which differs significantly from the practice of large international utilities that tend to specialize in well-defined responsibilities. However, general responsibilities may promote innovation and adaptive capabilities within organizations. Participants acknowledged the importance of well-defined roles and delegation of authority to experienced and competent staff to avoid conflicts.
6 – Planning	
6.1 Actions to address risks and opportunities for the asset management system	Currently, the organizations do not have any formal procedures or documentation to incorporate risk. Risk concerns are primarily addressed through the intuition of experienced staff. Risk assessment is crucial, but it is also a challenging field due to the large volumes of infrastructure. It is recommended to prioritize risk and focus primarily on critical assets. Best practice guidelines for risk assessment should be provided by the government. The participants expressed concerns about the practicality of risk assessment methods and recommended a simple format that best suits their organizations' needs.
6.2 Asset management objectives and planning to achieve them	For costly infrastructure, the benefits of long-term planning should outweigh the substantial costs involved. An ex-ante decision-making framework is only beneficial when implementing a partial adoption for selected activities susceptible to standardization, such as risk assessment, documentation, performance evaluation, and auditing procedures, to avoid duplicating efforts. The decision-making framework should be implemented incrementally due to the scarcity of resources. A simple written guide is needed without too much sophistication, as this could increase bureaucracy. The practical experience developed over the years is more important than the decision-making guide. For emergencies, general guidelines are a better fit than detailed contingency plans (note that this opinion goes against reported international practice).
7 – Support	
7.1 Resources	The shortage of human and techno-economic resources is severe, making it impossible to plan for the long term with own resources. Resource prioritization is limited to cover urgent ongoing maintenance needs. Extensive mapping of technical resources, especially core assets and services, is necessary in a readily available, digitized, and standardized manner to surpass old documentation barriers (paper archives). Participants expressed the need for similar water utilities to merge into larger entities to create a sufficient depth of resources in both human and technical capabilities and benefit from increased scales of operations and economies. This suggestion is surprising given the autonomous way these organizations have been operating up-to-date.

7.2 Competence	Competence is typically expected from full-time employees. The lack of key personnel creates significant risks for maintaining institutional memory within the organizations. Career development programs should prioritize a homogeneity of skills among trainees. Participation in industry conferences is also recommended to facilitate knowledge-sharing among employees with similar interests and experiences.
7.3 Awareness	Communication and coordination between different functions and operations is strong, due to the narrow span of control and the limited area of operations.
7.4 Communication	A coordinated communication plan with external stakeholders has been neglected up to now, which could potentially hinder the organizations' ability to effectively engage with the public and respond to their needs and concerns. Despite the monopolistic status of the provided services, participants stress the importance of public communication and emphasize the need to promote it through all available means, including social media, to increase transparency and build trust with the community.
7.5 Information requirements	Detailed asset registries are rare in small-to-medium organizations. Typically, only elementary asset taxonomies are contained in accounting registries to fulfill financial legislation requirements. Information requirements should include much more than a simple balance sheet entry, such as performance indicators, geographical locations (GIS), and technical properties of assets. Past information is entirely stored in paper repositories, highlighting the need for digitization and modernization. The overwhelming choices for data collection require establishing priorities for critical assets and processes. Timeliness and accuracy of data are critical for emergencies, where quick decisions must be made.
7.6 Documented information	To keep information readily available and imperishable, digitized environments should be a top investment priority for water utilities.
8 - Operation	
8.1 Operational planning and control	The primary objective of water utilities is to ensure service continuity. Emergencies often require quick decisions to be made on-site, as they do not follow usual or easily predictable patterns. These decisions are based on the experience and capabilities of personnel. Operational plans can be particularly useful for complex asset systems, as they can aid in the implementation of corrective and preventive actions.
8.2 Management of change	Participants expressed a willingness to explore and adopt new ideas and approaches, indicating a general openness to change. Organizations demonstrated adaptability in response to a significant lack of resources.
8.3 Outsourcing	The inadequacy of specialized personnel to oversee contractors is evident. Outsourcing operational activities is a viable option. Critical assets and strategic activities management should be kept within the organizations. The ownership of infrastructure should remain in the public sector. Further research and government initiatives are necessary to address the practicalities of outsourcing.
9 - Performance Evaluation	
9.1 Monitoring, measurement, analysis, and evaluation	Real-time and continuous feedback ensures the assurance of asset performance and service continuity. Timeliness and readiness of data are crucial for water utilities. The selection of appropriate KPIs should be the responsibility of a governmental body to provide benchmarking opportunities. Linking accounting records and asset archives facilitates decision-making for asset renewal.

9.2 Internal audit	Formal internal audits play a significant role in ensuring continuous improvement for larger organizations. Due to the narrow span of control and criticality of service triggering staff participation, smaller water supply organizations conduct continuous informal performance evaluations. Direct supervision from public water regulating bodies is necessary to ensure the objectivity of external auditors. While self-assessments are a common practice in small organizations, their effectiveness is questionable due to potential political expediency of top management.
9.3 Management review	Management reviews serve as effective tools to foster staff participation in larger water utilities. Smaller water utilities face challenges in achieving the same level of effectiveness with management reviews due to political constraints and limited resources.
10 – Improvement	
10.1 Nonconformity and corrective action	Water utilities prioritize emergencies as their top concern. Corrective actions are often undertaken to maintain operations in the short-term, rather than for long-term planning. Documentation of past actions is problematic due to scattered and paper-based local archives. A centralized back-office information system is needed to facilitate access to past corrective actions and support decision-making in water utilities.
10.2 Preventive action	Preventive actions are of utmost importance, but they are typically scheduled only for individual assets. For entire asset systems, the objective is to transition to a predictive approach, utilizing scientific justification for root causes (such as statistical analysis, risk assessments, etc.).
10.3 Continual improvement	Water utilities are, in essence, technology organizations, and as such, the concept of continuous improvement is a natural necessity.

5. Strengths and weaknesses of small-to-medium utilities

This section presents the classification of small-to-medium water utilities' main strengths and weaknesses towards ISO 55001 implementation. These classifications have been deduced from the cross-case analysis conducted in the study.

5.1. Strengths

- **Deep understanding of their environment**

After conducting the interviews, it was confirmed that the organizations being investigated possess a deep understanding of their internal and external environment, which can be attributed to their small area of operations, flat organizational structures, and the fact that the top management is usually comprised of locally elected officials who possess substantial knowledge of the community's needs and interests. However, due to insufficient resources and inadequate legislation, these organizations are unable to develop long-term plans and build further benefits from this contextual knowledge. It is worth noting that all participants recognize the present situation is not ideal, thus providing an opportunity for new and different ways of thinking, techniques, and processes for improvement initiatives.

- **Alignment and commitment**

The narrow span of control in small-to-medium water utilities facilitates alignment between different organizational functions and overarching asset management objectives. The criticality of the service provided to the community's welfare prioritizes every action towards maintaining an acceptable level of service. Based on this foundation, strong commitment is exhibited

at all organizational levels to implement best management practices for the involved infrastructure assets, which participants consider a critical success factor for further asset management improvement initiatives. Alignment and commitment are major priorities, particularly when dealing with more complex interrelations of authorities and responsibilities.

- **Experience, consultation, and state of infrastructure**

Based on the extensive experience of the skilled and solution-oriented workforce, there is strong confidence in their own judgment to deal with everyday activities and even with nonconformities when they occur. Despite resource inefficiencies, the narrow size of small-to-medium water utilities and the need to keep the systems running in the short run has facilitated a culture of vocal consultation inside the organizations when tackling incidents. This may seem sufficient from a short-term perspective involving quick fixes and temporal maintenance. However, in the long run, systematic planning is the preferred strategy to ensure that all conflicts and disputes are properly confronted, as unexpected trends, pattern failures, and other unforeseen challenges can always arise. In that context, an overarching asset management system is beneficial to be in place. A significant strength of these organizations for ISO 55001 implementation also lies in the relatively new state of the infrastructure itself. Most of the organizations' assets were constructed 35-40 years ago, a time that is not considered critical in terms of operational difficulties related to asset age. In that sense, the utilities do not have to focus on asset renewals but on managing the existing infrastructure optimally, which aligns with the core objective of ISO 55001.

- **Adaptive and innovative culture**

The significant lack of human and economic resources in small-to-medium Greek utilities has forced personnel to operate as generalists to cope with various operational needs within the organizations. Additionally, the nature of the service requires a fast response, high-level performance, and a high-risk decision-making environment. As a result, mainly full-time employees have been given the opportunity to gain a more thorough understanding of the whole picture of asset management by delving deeper into the organizational needs, promoting an adaptive and innovative culture towards a holistic management approach. Although this practice is marginally sufficient for the current strained economic environments, organizations will need specialization in the near future to achieve optimal asset management processes. The acquired abilities of generalists can become a foundation for leading specialized staff towards successful asset management improvements.

- **Willingness to change**

During the interviews, the participants demonstrated a remarkable openness to change, which is crucial for the success of any management improvement initiative. Although this positive attitude is not always observed in the ISO management systems implementation literature, where resistance to change is often reported, the saturation achieved among the participants provides strong evidence of validity. This result can be attributed to the fact that the examined organizations operate within rapidly changing environments and are currently in a state of flux. Thus, the employees are more accustomed and, therefore, more willing to adopt changes. However, the participants also recognized that any new initiative must depend on favorable conditions within the organizations, especially with regard to adequate resources availability.

5.2. Weaknesses

- **Lack of resources**

During the interviews, the lack of resources was considered the primary barrier to implementing ISO 55001. This shortage is

not limited to economic and technical resources, as expected due to the ongoing economic crisis, but further extends to significant gaps in personnel at all levels and functions, including key individuals involved in asset management activities. Resources are so scarce that the organizations' main concern is avoiding a severe collapse of operations in emergencies and keeping the system running in the short term. Under the current circumstances, it was acknowledged that any long-term planning is simply not feasible. Surprisingly, all participants recommended that water utilities merge into larger entities to establish critical resource depth, both in human and technical terms, as a possible solution to this problem. This depth was acknowledged as a crucial prerequisite for any attempt to advance in the long run, including developing a complete strategic asset management plan. Instead, the current lack of resources renders only a partial implementation of ISO 55001 feasible.

- **Bureaucracy**

In addition to resource inefficiencies, the large amount of bureaucratic paperwork required for all operations of these organizations discourages employees from focusing on improvements. While these organizations are mainly public-oriented and some bureaucracy may be necessary to justify the rational spending of taxpayers' money, the administrative model imposed is outdated and reflects an older era of technology and practice obsolescence. Therefore, it is not surprising that participants see the ISO 55001 framework as another source of excessive paperwork load.

- **Inadequate documentation**

Documentation is crucial for providing direction, making informed decisions, and driving organizational improvements. Everyone involved must understand that collecting information should be done not just as a typical responsibility but as a means of promoting a culture of standardization and continual improvement. Proper documentation certainly requires considerable time and effort, and thankfully all participants agreed on that, also acknowledging the importance of having an accurate and reliable information repository. Nevertheless, it was admitted that the current level of documentation is not sufficient, particularly given the inadequate quality of past paperwork archives. This shortage creates a tendency for decision-making to rely on assumptions and shortcuts rather than evidence-based documentation. Additionally, when time and resources are limited, it is often the case that decisions are based solely on the experience and insight of one person.

- **Short-termism**

In times of economic strain, organizations tend to focus on cost-cutting and stall investments to avoid exceeding their reduced yearly budgets. The participants acknowledged that short-termism is the prevailing mindset in current operations, mainly due to the dramatic reduction in available resources and the narrow time window of publicly-elected top management to provide evidence of good governance to their voters. However, instead of spending less and being unprepared for future improvements, organizations should focus on more targeted spending with a long-term perspective. Participants also acknowledged that the asset management framework of ISO 55001 could significantly contribute to such a process, providing a background for reasoned decisions and facilitating the identification and evaluation of future threats and opportunities. The participants consider the inadequacy, or even absence, of a documented decision-making chart, with checklists and requirements, as a barrier to deriving optimal decisions and confronting short-termism.

- **Political constraints and antiquated legislation**

The examined organizations do not prioritize leadership skills to the extent that they should. Due to the inflexible administrative model

imposed by legislation, key individuals with experience, skills, and solution-oriented mindsets are not always recognized as essential. Furthermore, there needs to be a motivational framework that enables key individuals to concentrate on training and motivating employees, preparing asset management objectives and plans, and raising awareness and promoting cross-functional collaboration. Past instances of haphazard decision-making due to political pressures have occurred since most directors are publicly elected officials. For top management, there is a need to focus on the business perspective of the organizations. Therefore, most interviewees suggested that their organizations could benefit from closer supervision by centralized state or regional authorities to ensure more efficient long-term planning. Participants also widely reported that the background legislation is obsolete, with the legislation for irrigation utilities dating back to the 1950s and that for water utilities dating back to the 1980s. During the research, it was determined that significant changes are needed, mainly towards the standardization of practices and decision-making criteria.

6. Managerial and policy implications

As the insights into the strengths and weaknesses of small-to-medium water infrastructure utilities in implementing ISO 55001 were obtained from experts actively involved in asset management, they hold substantial managerial implications for small organizations seeking to improve their asset management practices.

Small-to-medium utilities must first recognize and capitalize on their strengths to implement an effective asset management system according to ISO 55001 requirements. One such strength is their extensive experience in the industry, which enables them to have an in-depth understanding of their environment and the challenges they face. They can leverage this experience to create effective asset management strategies that are tailored to their unique circumstances. In addition, these organizations should align their organizational functions with overarching asset management objectives. By breaking down silos and fostering collaboration between different departments within the utility, such as operations, maintenance, and finance, they can create a unified approach to asset management that is more effective and efficient. Furthermore, small-to-medium utilities should foster a strong commitment to asset management best practices. This involves promoting a culture of continuous improvement, where employees are encouraged to identify areas for improvement and suggest new approaches to asset management. Such an approach can help ensure that the utility is always striving to improve its asset management practices and avoid complacency. Moreover, they should embrace an adaptive and innovative culture and a strong willingness-to-change attitude. This involves being open to new processes and working methods, even if they may disrupt established routines. By being willing to change, small-to-medium water utilities can create a culture that is focused on continuous improvement and is able to adapt to the changing needs of the industry.

Second, it is crucial to address the identified weaknesses in small-to-medium water utilities towards implementing ISO 55001 for improving asset management practices. These weaknesses, such as lack of resources, bureaucracy, inadequate documentation, short-term mentality, and dealing with political constraints and antiquated legislation, can hinder the implementation of an effective asset management system. To overcome these weaknesses, water utilities may streamline bureaucratic processes to minimize red tape and expedite decision-making. Investing in better documentation and data management systems can ensure that reliable and accurate data serve as the foundation of effective decision-making, leading to successful asset management

practices. Adopting a long-term perspective in decision-making can promote a more sustainable approach to asset management, leading to cost savings throughout an asset's lifecycle. Lobbying for legislative changes to support more effective asset management practices can also be instrumental in overcoming political constraints and antiquated legislation. By addressing these weaknesses, small-to-medium water utilities can better position themselves to implement an effective asset management system, thereby improving their asset management practices and realizing cost savings throughout their entire lifecycle.

Third, it is essential to implement a structured approach to asset management that involves a comprehensive and continuous effort integrated into the organizational culture of small-to-medium water utilities. This requires identifying priorities based on reliable and accurate data, which can be achieved through regular audits of asset management practices. By conducting regular audits, water utilities can track their progress towards meeting ISO 55001 requirements and addressing any deficiencies, ensuring consistent adherence to best practices. To establish a structured asset management approach, water utilities must involve people in the process, recognizing that asset management is an internal process that involves the entire organization. Therefore, regardless of position, every employee must be aware of the importance of asset management practices and how their actions can impact the overall system's performance. To achieve this, utilities can conduct regular training sessions to ensure that all employees understand their role in asset management and have the necessary skills to support the organization's objectives. Implementing an asset management system requires a long-term perspective, recognizing that achieving optimization targets will take time and effort. Therefore, water utilities must be patient and persistent in their efforts, continually evaluating their progress and making adjustments as necessary. They must also consider the lack of resources when identifying priorities and ensure that they use data-driven decision-making to maximize the impact of their efforts.

Fourth, outsourcing the overarching asset decision-making system can be a tempting option for small-to-medium water utilities due to the lack of resources or expertise in asset management practices. However, it is crucial for the utility to resist this temptation and maintain control over its asset management practices to ensure that they are aligned with the organization's overall objectives and values. Although external consultants can provide valuable technical aid on infrastructural alternatives, the utility must ensure that the decision-making system remains under its direct authority. This can help to ensure that the utility maintains an internal process of infrastructure asset management that is tailored to its specific needs and objectives. As highlighted in the study, water utilities of all types and classes have many similarities and common difficulties at an overarching strategic level, providing sufficient grounds for standardizing strategic management initiatives. To establish an effective asset management system, water utilities should evaluate the existing efficiencies of all components of an asset-intensive infrastructure organization using a suitable appraisal framework. This evaluation can help identify areas that need improvement and establish a structured, fact-based decision-making system. Having such a system is particularly important for small-to-medium water utilities as they generally lack the resources to make costly mistakes. Therefore, by resisting the temptation to outsource the overarching asset decision-making system, water utilities can ensure that their asset management practices are tailored to their specific needs and goals, leading to a more efficient and effective use of their resources.

Fifth, smaller water utilities may benefit from merging into larger entities to acquire sufficient resources and enable economies of scale and long-term planning. Such mergers

could involve the combination of assets and resources across different utilities or the formation of regional or statewide networks that can pool resources and expertise to develop more effective asset management practices. The benefits of merging into larger entities include access to more resources, better financial stability, and the ability to leverage economies of scale to implement more effective asset management practices. Merging could also enable smaller utilities to address common difficulties in implementing ISO 55001 requirements, such as a lack of resources, inadequate documentation, and short-term thinking. However, merging also has potential drawbacks, including a loss of autonomy and increased bureaucracy. In addition, it's crucial to assess the impact of merging on service delivery, customer satisfaction, and the overall sustainability of the water sector. The study's participants also expressed a need for a more centralized administrative model under closer supervision by governmental agencies. This would promote the homogenization of asset management practices and decision-making criteria across utilities. While this could lead to more consistency and standardization in asset management practices, it could also lead to a loss of autonomy and increased bureaucracy. Therefore, careful consideration and evaluation of such a model is necessary to ensure that the benefits outweigh the drawbacks.

Finally, the study found that full compliance with ISO 55001 requirements may not be necessary for small-to-medium water utilities due to the associated costs. Participants perceived that the significant costs required for full compliance are more justified for larger organizations or when vital and very costly assets are involved. For smaller organizations, such as the water utilities examined in the study, a light and flexible implementation approach, aided by simple documented guidelines, may be more appropriate. This approach could involve avoiding complex processes and heavy documentation, instead focusing on the most critical aspects of the asset management system that align with the organizations' objectives and values. This finding has practical implications for small-to-medium water utilities that may hesitate to adopt ISO 55001 due to perceived high costs of compliance. These utilities can adopt a more tailored approach to asset management that focuses on their specific needs and capabilities. This approach could involve implementing a simplified asset management system aligned with the organization's overall objectives and values rather than attempting to fully comply with ISO 55001 requirements. By adopting a more flexible approach, small-to-medium water utilities can still improve their asset management practices and achieve greater efficiencies while avoiding unnecessary costs and complexity.

Turning to the policy implications of the study's findings, it is clear that policymakers can take various measures to promote effective asset management practices in small-to-medium water utilities. They can develop and implement regulations that require utilities to adopt a structured approach to asset management aligned with ISO 55001 and encourage utilities to report on their asset management practices regularly and undergo external audits to ensure compliance. Policymakers can also establish funding mechanisms, such as grants or low-interest loans, to support utilities in implementing and maintaining an effective asset management system. Additionally, they can provide technical assistance to smaller utilities in developing and implementing an effective asset management system and encourage collaboration among utilities by establishing regional or statewide networks that allow utilities to share best practices and resources. Furthermore, policymakers can develop simplified and streamlined guidelines for smaller utilities to adopt in implementing ISO 55001 requirements. These policies can help small-to-medium water utilities overcome the challenges they face in adopting ISO 55001, leading to a more sustainable and efficient use

of infrastructure assets.

7. Conclusion

This study aimed to examine the applicability of ISO 55001 asset management system in smaller organizations, with a focus on identifying their strengths and weaknesses in implementing the standard and discussing the managerial and policy implications of these findings. The research was conducted using a qualitative strategy in the form of a multiple case study, which is suitable for exploring generic and unexplored subjects. Eight experienced experts involved in asset management activities from four representative small-to-medium water utilities (i.e., potable water, irrigation, and drainage) were interviewed. The ISO high-level structure, as followed by ISO 55001, was considered a suitable study framework for the research. Through the interviews, the study participants provided valuable insight into several issues, indicating that even smaller organizations are interested in genuinely substantial implementation of an asset management system according to ISO 55001 requirements to direct, coordinate, and control their asset management activities.

The research findings indicate that while there are several challenges faced by small-to-medium water infrastructure utilities that may hinder the immediate benefits of implementing ISO 55001 for managing their assets, there are circumstances under which it can indeed be beneficial. Challenges such as limited resources, outdated legislation and technical background, and budgetary constraints require immediate short-term thinking to cover service-level demands. Moreover, risk concerns are primarily addressed through the intuition of experienced staff. Despite these challenges, participants acknowledged the importance of incorporating best practices in infrastructure asset operations, such as documentation, auditing, and continual improvement. While some interviewees expressed reservations about advocating for a full-scale asset management system, they suggested implementing a partial adoption of an overarching asset decision-making framework to gradually incorporate best practices, with a focus on selected activities susceptible to standardization, such as risk assessment, documentation, performance evaluation, and auditing procedures. Additionally, the findings highlight the need for extensive mapping of technical resources, a coordinated communication plan with external stakeholders, and the digitization and modernization of information requirements. Under these circumstances, a tailored and holistic approach to asset management for small-to-medium water infrastructure utilities can be beneficial. Therefore, while there may be challenges that require a cautious approach, the implementation of ISO 55001 can be beneficial when implemented incrementally and with a focus on selected activities that align with the organizations' objectives and targets.

The findings of this study ultimately indicate that small-to-medium water utilities must prioritize asset management practices to optimize the efficiency of their infrastructure assets while minimizing costs over their entire lifecycle. The study's limitations include the small sample size and the focus on a specific geographical location. Further exploration of similar cases is recommended to gain additional insights into asset management practices and their potential for improvement in the water and other infrastructure sectors. The identified weaknesses of small-to-medium water utilities in implementing ISO 55001 provide fertile ground for further qualitative research and legislative initiatives. Future research could also address the potential benefits and drawbacks of imposing a more centralized administrative model on smaller water utilities or merging them into larger entities, using Transaction Cost Theory as a framework for exploration. Additionally, a quantitative survey involving larger research samples could be undertaken to enhance the robustness of this study's findings regarding

the strengths and weaknesses of small-to-medium utilities in implementing ISO 55001. This research could also examine, through the prism of Public Choice Theory, the public's attitudes towards political decisions on key asset management options, such as the degree of outsourcing or privatization for water utilities. In conclusion, this study highlights the critical role of effective asset management practices in ensuring the long-term sustainability of infrastructure assets and calls for continued efforts to improve asset management practices and policies in the water and infrastructure sectors through further research and legislative initiatives.

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